Letícia Fernanda Haas

PRECISÃO DA TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO PARA AVALIAÇÃO DE DEFEITOS ÓSSEOS PERIODONTAIS

Tese submetida ao Programa de Pós-Graduação da Universidade Federal de Santa Catarina para a obtenção do Grau de Doutor em Diagnóstico Bucal.
Orientador: Prof. Dr. Márcio Corrêa

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Esta Tese foi julgada adequada para obtenção do Título de "Doutora em Diagnóstico Bucal" e aprovada em sua forma final pelo Programa de Pós-Graduação em Odontologia.

Florianópolis, 1 de novembro de 2017.

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A mente que se abre a uma nova idéia jamais retornará ao seu tamanho original.
(Albert Einstein)

RESUMO

A periodontite é uma doença infecciosa causada pelo biofilme bacteriano na superfície do dente, e caracteriza-se pela inflamação gengival, formação de bolsa periodontal, perda de inserção e reabsorção óssea alveolar. A correta avaliação da condição óssea é fundamental para o diagnóstico, planejamento do tratamento e prognóstico da periodontite. As radiografias mais comumente utilizadas para o diagnóstico periodontal são as radiografias periapicais, interproximais e panorâmica. No entanto, as radiografias apresentam limitações inerentes à bidimensionalidade destes exames, o que torna o seu uso limitado. Recentemente, a tomografia computadorizada de feixe cônico (TCFC) é utilizada quando o exame radiográfico não fornece as informações necessárias para o tratamento periodontal. O objetivo deste estudo foi realizar uma revisão sistemática e meta-análise para avaliar a precisão da TCFC na medição de defeitos ósseos periodontais quando comparado ao padrão de referência (medição *in situ*). Nesta revisão sistemática foram selecionados os estudos em que o objetivo principal foi avaliar a precisão da TCFC na medição de defeitos ósseos periodontais quando comparados com o padrão de referência. A busca foi realizada em quatro bancos de dados, e os estudos foram selecionados por dois revisores independentes. A metodologia dos estudos selecionados foi avaliada usando a ferramenta de avaliação de qualidade de 14 itens para estudos de acurácia diagnóstica (QUADAS-2). A qualidade da evidência e a força da recomendação foram avaliadas pelo sistema GRADE (*The Grading of Recommendations Assessment Tool, Development and Evaluation*). A seleção dos estudos foi realizada em duas fases, onde foram identificados 16 artigos, e em sete estudos a meta-análise foi realizada. Os resultados da meta-análise demonstraram que não há diferença estatística entre as medidas da TCFC e as medidas *in situ* para a perda óssea alveolar, além disto, demonstrou uma concordância de 82,82% entre a TCFC e a medição *in situ* para a classificação do grau de envolvimento de furca. Com base em um nível de evidência moderado, pode-se concluir que a TCFC é especialmente útil nos casos de envolvimento de furca, contudo, só deve ser utilizada nos casos em que a avaliação clínica e as imagens radiográficas convencionais não fornecem as informações necessárias para o diagnóstico e planejamento adequado do tratamento periodontal.

Palavras-chave: Tomografia computadorizada de feixe cônico. Periodontite. Defeitos da furca.

ABSTRACT

Periodontitis is an infectious disease caused by bacterial biofilm on the tooth surface, and it is characterized by gingival inflammation, periodontal pocket formation, attachment loss and alveolar bone resorption. The correct assessment of the bone condition is critical to the diagnosis, treatment planning and prognosis of periodontitis. The most used radiographs for periodontal diagnosis are periapical, bitewing and panoramic radiographs. However, the radiographs present limitations to the bi-dimensionality of these exams, which make their use limited. Recently, cone beam computed tomography (CBCT) has been used when the radiographic examination does not provide the requerid information for periodontal treatment. The objective of this study was to perform a systematic review and meta-analysis to evaluate the precision of the CBCT in the measurement of periodontal bone defects when compared to the reference standard (*in situ* measurement). In this systematic review were selected the studies which the main objective was to evaluate the precision of the CBCT in the measurement of periodontal bone defects when compared the reference standard. The search was performed in four databases, and the studies were selected by two independent reviewers. The methodology of the selected studies was evaluated using the 14-item quality assessment tool for diagnostic accuracy studies (QUADAS-2). The quality of evidence and the strength of recommendation was assessed by GRADE (The Grading of Recommendations Assessment Tool, Development and Evaluation). The selection of the studies was performed in two phases. 16 articles were identified, and in seven studies the meta-analysis were performed. The results of the meta-analysis showed no statistical difference between the measurements of CBCT and *in situ* measurements for alveolar bone loss. In addition, it demonstrated a concordance of 82.82% between CBCT and *in situ* for the classification of the degree of furcation involvement. Based on a moderate level of evidence, it can be concluded that CBCT is especially useful in cases of furcation involvement, however, it only should be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning.

Keywords: Cone beam computed tomography. Periodontal bone loss. Furcation defects.

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LISTA DE ABREVIATURAS E SIGLAS

3D - 3 dimensões;
ALARA – As Low As Reasonably Achievable;
CBCT – Cone Beam Computed Tomography;
FOV – Field of view;
GRADE – The Grading of Recommendations Assessment Tool, Development and Evaluation;
KVp – Quilovoltagem pico;
mA – Miliamperes;
mm – Milímetros;
QUADAS – Quality Assessment Tool for Diagnostic Accuracy Studies;
DP – Desvio padrão;
TCFC – Tomografia Computadorizada de Feixe Cônico;
Voxel – Volum elemento.

LISTA DE SÍMBOLOS

% por cento
> maior que
± mais ou menos

SUMÁRIO

1 INTRODUÇÃO

A periodontite é uma doença infecciosa, causada pela presença de biofilme bacteriano na superfície dos dentes (PIHLSTROM; MICHELOWCIZ; JOHNSON, 2005; PAPAPANOU et al., 2007). Além do biofilme bacteriano, existem outros fatores que podem estar relacionados à etiologia e à gravidade da periodontite, tais como: doenças sistêmicas como diabetes mellitus, hábito como tabagismo, e em alguns casos, a predisposição genética (LINDHE, 2005; PIHLSTROM; MICHELOWCIZ; JOHNSON, 2005; WHITE; PHAROAH, 2007).

A periodontite pode causar a destruição do tecido ósseo alveolar, perda de inserção óssea e consequente mobilidade e/ou perda dentária (FEIJO et al., 2012). Em pacientes adultos essa mobilidade dentária patológica pode ocasionar sérios problemas funcionais e estéticos (MA et al., 2015). Em função disto, a correta avaliação da condição óssea é fundamental para o diagnóstico, planejamento do tratamento e prognóstico da doença (LANGEN et al., 1995).

As características clínicas dos tecidos gengivais associadas com as informações obtidas por meio das radiografias permitem a avaliação da altura óssea, bem como demonstram as alterações morfológicas e patológicas causadas pela periodontite (LANGEN et al., 1995; DE FARIAS VASCONCELOS et al., 2012).

As radiografias mais comumente utilizadas para complementar o diagnóstico periodontal são as radiografias periapicais, interproximais e panorâmica (LANGEN et al., 1995; JEFFCOAT, 1994; BAGIS et al., 2015, TABA et al., 2005; ELEY; COX, 1998). No entanto, algumas características inerentes das radiografias convencionais podem limitar o uso destes exames na terapia periodontal.

A primeira limitação a ser considerada é que as radiografias convencionais só demonstram a perda óssea quando há a destruição de 30 a 50% de osso mineral (JEFFCOAT, 1992). Desta forma, as lesões ósseas incipientes que causam destruição moderada não provocam alterações suficientes na densidade do tecido ósseo para serem detectadas radiograficamente (WHITE; PHAROAH, 2007), o que consequetemente faz com que ocorra uma subestimação das medidas dos defeitos ósseos periodontais (EICKHOLZ et al., 1998).

Outro fator restritivo do uso das radiografias é a bidimensionalidade da imagem. As radiografias oferecem uma imagem bidimensional de estruturas tridimensionais, causando a sobreposição de estruturas anatômicas (JEFFCOAT, 1992; NOUJEIM et al., 2009; WHITE; PHAORAH, 2007).

Além disso, há uma dificuldade de padronização nos exames radiográficos (REDDY, 1992; JEFFCOAT, 1994; EICHKHOLZ et al., 1998; MOL, 2004; MISCH; YI; SARMENT, 2006), o que pode mascarar mudanças sutis nas condições periodontais durante o acompanhamento do tratamento. Os erros de angulações verticais e horizontais nas imagens radiográficas podem aparentemente “aumentar” o osso alveolar independente de qualquer mudança real no suporte ósseo alveolar (JEFFCOAT, 1992; JEFFCOAT, 1995).

Aliado a estes fatores, ainda existem as variações de contraste e densidade das radiografias, causadas pelo processamento dos filmes e as variações de quilovoltagem (KVp), miliamperagem (mA) ou tempo de exposição, que podem causar o efeito *burn out* na crista óssea alveolar, dando a impressão de reabsorção da crista óssea mesmo sem qualquer alteração no osso alveolar (JEFFCOAT, 1992).

Desta forma, as radiografias convencionais são imagens que apresentam limitações, podendo portanto, mostrar um quadro incompleto do estado do periodonto, e sendo difícil para o clínico detectar pequenas mudanças ósseas (WHITE; PHARAOH, 2007).

Atualmente, a tomografia computadorizada de feixe cônico (TCFC) tem sido amplamente utilizada na Odontologia. Na periodontia, as imagens tridimensionais geralmente são usadas quando o exame radiográfico convencional não fornece as informações necessárias para a diagnóstico periodontal (SCARFE; FARMAN; SUKOVIC, 2006; HASHIMOTO et al., 2003).

A TCFC não possui sobreposição geométrica das estruturas anatômicas, é relativamente acessível e sua dose de radiação é menor quando comparada com dose de radiação da tomografia computadorizada médica (LUDLOW et al., 2003; SCHULZE et al., 2004; SCARFE; FARMAN; SUKOVIC, 2006; CARRAFIELO et al., 2010; DAVIES; JOHSON; DRAGE, 2012; AL-OKSHI et al., 2015; VELDHOEN, et al., 2017).

A dose efetiva de radiação da TCFC varia de acordo com a marca e os parâmetros de exposição selecionados durante a aquisição da imagem, como tamanho do campo de visão (FOV) e voxel, tempo de exposição, KVp e mA (KATSUMATA et al., 2009; PAUWELS et al., 2012; SEZGIN et al., 2012; ROTTKE et al., 2013). Quando comparada à radiografia convencional, a dose de radiação da TCFC é equivalente a um levantamento periapical completo, e aproximadamente três a sete vezes a dose de uma radiografia panorâmica, dependendo da configuração utilizada (LUDLOW et al., 2006).

Diferentes estudos que compararam o uso da TCFC com as imagens bidimensionais em defeitos ósseos criados artificialmente, demonstraram que a TCFC possui uma sensibilidade entre 80 e 100% para a detecção de defeitos ósseos, enquanto que as radiografias intra-orais apresentaram uma sensibilidade entre 63 e 67% (FUHRMANN et al., 1995; MISCH; YE; SARMENT, 2006; VANDERBERGHE; JACOBS; YANG, 2007).

No entanto, não há consenso entre os estudos quanto à comparação das medidas de perda óssea alveolar realizadas por meio da TCFC com as medidas *in situ*. Alguns estudos relataram que não há diferença estatística entre as medidas da TCFC e *in situ* (MISCH; YE; SARMENT, 2006; GRIMARD et al., 2009; RAICHUR et al., 2012; FEIJO et al., 2012; FLEINER et al., 2013; TAKESHITA et al., 2014), já outros demonstraram que há diferença estatisticamente significativa entre as medidas da TCFC e *in situ* (GRIMARD et al., 2009; LEUNG et al., 2010; LI; JIA; OUYANG, 2015).

Em 2006, Misch, Ye e Sarment, realizaram uma pesquisa para avaliar a acurácia da TCFC na mensuração de defeitos periodontais. Para isso, foram criados defeitos periodontais em duas mandíbulas de crânios secos, nas paredes vestibular, lingual e interproximais nas regiões dos molares e pré-molares, com largura e altura variáveis. Os defeitos ósseos criados artificialmente foram medidos com um especímetro digital, e foram realizadas as radiografias periapicais e a TCFC destas regiões. Comparando os resultados das medidas *in situ* com as medidas da TCFC, os autores concluíram que na mensuração dos defeitos ósseos para todos os sítios combinados, a diferença média foi de 0,93 mm (± 0,65 DP) e 1 mm (± 0,67 DP) para as medidas *in situ* e TCFC, respectivamente. Já para as medidas nas faces vestibular e lingual a diferença média foi 0,53 mm (± 0,51 DP) para as medidas *in situ* e 0,7 mm (± 0,68 DP) para as medidas da TCFC. Esses resultados não foram estatisticamente diferentes (P > 0,09).

Vandenberghe, Jacobs e Yang (2008) relataram que a TCFC identificou 100% dos defeitos ósseos e classificou de forma correta 91% dos casos de crateras e 100% dos casos de envolvimento de furca. Em 2013, Fleiner et al., demonstraram que a TCFC apresentou mensurações precisas do nível de osso alveolar circunferencial em comparação com as mensurações *in situ* e ainda diagnosticou todos os casos de envolvimento de furca.

Feijo et al. (2012) não encontraram diferenças estatísticas entre as mensurações realizadas por meio da TCFC e por meio das mensurações cirúrgicas nas faces mesial e distal de molares superiores. Já nas faces vestibular e palatal os autores relataram que houve diferença estatística entre as medidas. Em outro estudo realizado por Li, Jia e Ouyang (2015) a TCFC apresentou mensurações similares às medidas cirúrgicas de perda óssea nas faces mesial/distal e vestibular/lingual. No entanto, as mensurações da TCFC para a medida correspondente da junção cemento-esmalte até a base do defeito foram significativamente subestimadas, em comparação com as medidas cirúrgicas.

De acordo com os autores, uma hipótese que poderia justificar estes resultados de sub e superestimação da TCFC para as mensurações de defeitos ósseos periodontais, seria o grau variável de desmineralização presente na base do defeito ósseo, que pode ser visualizado pela imagem da TCFC, mas em muitos casos é eliminado na cirurgia por meio do debridamento. Outra condição que poderia contribuir para essa diferença seria a consistência esponjosa da base do defeito ósseo, onde nestes casos a sonda periodontal poderia penetrar mais facilmente (LI; JIA; OUYANG, 2015).

Banodkar et al. (2015) relataram que a TCFC diagnosticou em 100% dos casos o tipo de defeito ósseo periodontal, contudo, quando a correlação entre os defeitos horizontais e verticais foi realizada, a correlação dos defeitos horizontais foi maior do que nos defeitos verticais. Segundo os autores, esta diferença seria pelo fato de que nos casos de defeitos ósseos horizontais foi medida a distância da junção cemento-esmalte até a crista óssea alveolar, e a crista óssea alveolar era corticalizada, o que facilitou a definição da imagem e consequentemente na mensuração. Diferentemente, nos casos dos defeitos ósseos verticais, a base do defeito era composta por tecido ósseo esponjoso, diminuindo assim a sensibilidade de demarcação e mensuração na TCFC.

No entanto, quando se compara as medidas *in situ* com as radiográficas, uma discrepância em torno de 0,5 a 1 mm entre o nível ósseo real e o nível ósseo radiográfico é admitida e considerada clinicamente aceitável (OSBORN et al., 1992; VANDENBERGHE; JACOBS; YANG, 2007; VANDERBERGHE; JACOBS; YANG, 2008; FLEINER et al., 2013), além disso, algumas variáveis devem ser observadas em relação as medidas *in situ*, pois podem contribuir para a alteração destas medidas, como por exemplo: força de sondagem (VANDERBERGHE; JACOBS; YANG, 2008), diâmetro da sonda, presença de tecido de granulação na base do defeito (LI; JIA;

OUYANG, 2015), e o acesso e a visualização, que em muitos casos são difíceis na avaliação clínica (QIAO et al., 2014).

Esses fatores que podem causar viés ao realizar as medições *in situ*, não ocorrem quando utilizam-se as imagens tridimensionais, assim como não há dificuldade de acesso e a visualização na análise das imagens. Além disso, a medição não depende da força exercida pelo operador. Em uma reconstrução 3D, o ponto de referência fixo até a base de defeito pode ser demarcado consistentemente. Ainda, a TCFC permite a visualização de todos os ângulos sem distorções geométricas, ou seja, a imagem é representada em seu tamanho real (EICKHOLZ et al., 1998).

Em 2010, Walter, Weiger e Zitzmann, realizaram uma pesquisa comparando a acurácia da TCFC nas mensurações da perda óssea alveolar com as mensurações *in situ*. Os autores selecionaram 25 molares superiores de 14 pacientes com periodontite crônica avançada generalizada. Em 84% dos casos as medidas realizadas na TCFC foram confirmadas pelas medidas cirúrgicas. Já em 14,7% dos casos a TCFC subestimou as medidas de perda óssea, e somente em 1,3% dos casos a TCFC superestimou as medidas, quando comparadas com as medidas cirúrgicas. Ainda, os autores concluíram que a TCFC demonstrou uma alta precisão na avaliação da perda óssea periodontal e na classificação do grau de envovolvimento de furca nos molares superiores.

Em 2014, Qiao et al., investigaram a acurácia da TCFC quando comparada a mensuração *in situ* (cirúrgica) em 20 molares superiores, de 15 pacientes com periodontite crônica. As medidas da TCFC foram confirmadas em 82,4% das medidas cirúrgicas, indicando um alto grau de precisão. Em 11,8% dos casos de envolvimento de furca as medidas da TCFC foram subestimadas, e em 5,9% dos casos foram superestimadas, quando comparadas com as medidas cirúrgicas.

Apesar desses dados de sub e superestimação da TCFC na classificação do grau de envolvimento de furca, deve-se ponderar que, em muitos casos uma análise clínica precisa não é viável, devido ao acesso limitado à furca e as variações morfológicas existentes (QIAO et al., 2014). Contudo, a correta classificação do grau de envolvimento de furca é fundamental, pois está diretamente relacionada com o sucesso do tratamento. Isto se torna mais relevante nos casos de envolvimento de furca de grau II onde os tratamentos, principalmente as terapias regenerativas, demonstram taxas maiores de sucesso do que no envolvimento de furca de grau III (AVILA-ORTIZ et al., 2015).

Qiao et al. (2014) referiram ainda que a TCFC oferece elementos adicionais importantes quanto a forma da bifurcação assim como a gravidade das lesões, informações estas que não podem atualmente serem obtidas a partir de avaliações clínicas convencionais.

Apesar das vantagens do uso da TCFC, a indicação deste exame deve ser cuidadosamente justificada e a dose de radiação deve ser considerada. Outro fator que deve ser analisado antes de indicar a TCFC é a presença de retentores metálicos, restaurações metálicas e implantes dentários na cavidade oral. Os materiais metálicos causam artefatos que reduzem a qualidade da imagem e prejudicam a interpretação (SCHULZE et al., 2011).

Diante do exposto, o presente estudo teve como objetivo realizar uma revisão sistemática e meta-análise para avaliar a precisão da TCFC na medição de defeitos ósseos periodontais quando comparado ao padrão de referência (medição *in situ*).

1.1 JUSTIFICATIVA

A perda óssea alveolar é uma das consequências da periodontite e pode ocorrer no sentido mésio-distal e vestíbulo-lingual, ou seja, a perda óssea acontece de forma tridimensional. A bidimensionalidade das radiografias não permite a avaliação da altura e da espessura vestíbulo-lingual do defeito ósseo, que são informações importantes para o diagnóstico, planejamento do tratamento e prognóstico da doença periodontal.

A TCFC é uma modalidade de exame que oferece imagens tridimensionais, sem sobreposição das estruturas anatômicas e sem distorções geométricas, o que a princípio parece ser ideal para análise periodontal. Este exame tridimensional tem sido amplamente utilizado na Odontologia, e, portanto, desta maneira, faz-se necessário avaliar a precisão diagnóstica da TCFC em mensurar a perda óssea alveolar.

1.2 OBJETIVOS

1.2.1 Objetivo geral

Realizar uma revisão sistemática e meta-análise sobre a precisão da TCFC na avaliação de defeitos ósseos periodontais.

1.2.2 Objetivos específicos

Realizar uma revisão sistemática e meta-análise sobre a precisão da TCFC em mensurar a perda óssea alveolar horizontal e vertical, assim como no envolvimento de furca, em comparação com as mensurações *in situ* e/ou cirúrgicas que são consideradas como padrão de referência.

2 ARTIGO

Artigo formatado conforme normas da revista *DentoMaxilloFacial Radiology*.

TITLE

Precision of cone beam CT to assess periodontal bone defects: a systematic review and meta-analysis.

ABSTRACT

Objective: Evaluate the precision of cone beam computed tomography in measuring periodontal bone defects when compared to the reference standard (*in situ* measurement). Methods: Studies in which the main objective was to evaluate the diagnostic validity of cone beam computed tomography in measuring periodontal bone defects when compared to the reference standard were selected. Four databases were searched. The studies were selected by two independently reviewers. The methodology of selected studies was assessed using the 14-item Quality Assessment Tool for Diagnostic Accuracy Studies. The quality of evidence and strength of recommendation was assessed by The Grading of Recommendations Assessment Tool, Development and Evaluation. Results: Using a selection process in two phases, 16 studies were identified and, in seven articles meta-analysis was performed. The results from these meta-analyses showed that no difference between the measurements of CBCT and *in situ* for alveolar bone loss, and demonstrated a concordance of 82.82% between CBCT and *in situ* for the classification of the degree of furcation involvement. Conclusions: Based on a moderate level of evidence, CBCT could be useful for furcation involvement periodontal cases, but it should only be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning.

INTRODUCTION

Periodontitis is an infectious disease caused by bacterial biofilm on the tooth surface. [1, 2] This pathology is very common in the adult population, 10-15% approximately, [3] and it is characterized by a combination of gingival inflammation, periodontal pocket formation, attachment loss and alveolar bone resorption. [4, 5]

A correct assessment of the bone condition is critical to the diagnosis, treatment planning and prognosis of periodontitis. The clinical characteristics of gingival tissues associated with the information obtained through radiographs allow for the evaluation of bone height, as well as morphological and pathological changes caused by the disease. [6-8]

The most used radiographs to complement periodontal diagnosis are periapical, bitewing and panoramic radiographs. [6, 7, 9-11] However, conventional radiographs only demonstrate loss of alveolar bone when 30 to 50% of bone mineral in a specific area is destroyed. [12] In addition, these types of radiographs have limitations such as overlapping of anatomical structures [12-16], difficulty of standardization. [7, 17-20] and underestimation of periodontal bone defects measurements. [20] Such characteristics contest the use of conventional radiographs for the diagnosis of periodontitis.

Recently, cone beam computed tomography (CBCT) has been used when conventional radiographic examination does not provide the required information for periodontal therapy. [21, 22] CBCT has no geometric overlapping of anatomical structures, it is relatively accessible and its radiation dose is lower as compared to medical computed tomography. [21, 23-28] When compared to conventional radiography, CBCT radiation dose is equivalent to a full-mouth series and approximately three to seven times the dose of a panoramic radiograph, depending on the setting used. [29] Furthermore, the ability to view the alveolar bone in three dimensions and to make measurements at any location could significantly improve periodontal diagnosis. [30]

Additionally, different studies [19, 31, 32] comparing the use of CBCT vs. conventional two-dimensional imaging in artificial bone defects have shown that CBCT has a sensitivity between 80 and 100% for the detection of bone defects, while intra-oral radiographs have a sensitivity between 63 and 67%. [19, 31, 32] When comparing CBCT with periapical and panoramic radiography the former showed no distortion, no overlapping images, and real size compatibility. [15, 19, 31, 32] However, despite the inherent advantages of CBCT, according to the Sedentexct, 2012 guidelines [33] this exam is not indicated as a routine method for the diagnosis of alveolar bone loss.

In view of the abovementioned aspects and the absence of a systematic review that compares *in situ* direct periodontal measurements with measurements from CBCT reconstructions, this review aimed to: evaluate the diagnostic validity of 3D CBCT generated measurements in the evaluation of periodontal bone defects comparing them to the current reference standard (*in situ* measurement).

METHODS

This systematic review was written in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. [34]

Protocol registration

The systematic review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under number CRD42016037087. [35]

Eligibility criteria

Inclusion criteria:

- Studies in which the objective was to evaluate the validity of CBCT in measuring periodontal defects in humans (*in vivo*, cadavers or dry skulls).
- All studies must have an *in situ* measurement regarded as reference standard for assessment of periodontal bone defects and furcation involvement (FI) [36, 37].
- Regarding periodontal bone defects studies evaluating horizontal and vertical bone loss were considered. Only studies that classified FI according to the system proposed by Hamp *et al* (1975) [38] were included.
- Studies published in any language were considered.

Exclusion criteria:

- Reviews, case reports, retrospective studies, letters and personal opinions.
- Studies that only evaluated other methods such as intra-oral radiographs, panoramic radiograph, fan beam computed tomography or micro-CT.
- Studies that did not compare the measurements from CBCT reconstruction to the reference standard.

Information sources and search

Detailed individual search strategies for each of the following electronic databases were performed: LILACS, PubMed, Scopus, and Web of Science. A gray literature search on Open Grey, ProQuest, Google Scholar, and the reference lists of selected articles were reviewed to add any references that could have been missed during the electronic database searches. The database search was updated until January 23 rd, 2017. EndNote Basic ® (Thomson Reuters New York, NY, USA) software was used to remove duplicates.

Appropriate truncation and word combinations were selected with the support of a Health Sciences librarian and were adapted to each database search (Appendix 1).

Study selection

The selection of articles was carried out in two phases. In phase 1, two authors, one experienced in oral radiology (LFH) and the other experienced in periodontics (GZ) independently reviewed the titles and abstracts of all references. All studies that did not meet the inclusion criteria were excluded. In phase 2, full texts were read independently by the same authors, and the studies that fulfilled all inclusion criteria were selected. When mutual agreement between the two reviewers was not reached, a third author with expertise in oral radiology (MC) was involved to make a final decision.

Data collection process and Data items

The following study characteristics were recorded for all included studies: study characteristics (authors, year of publication, country), sample characteristics (size, type, defect and dental group), observer's characteristics (number, type and calibration), characteristics of assessment methods (instrument used for *in situ* measurement and CBCT image acquisition protocol), statistical analysis and main results. An author (LFH) extracted the data required from the selected studies. A second author (GZ) crosschecked all the retrieved information. Again, the discrepancies between both reviewers were discussed and a third author (MC) made a final decision.

The authors of the articles that did not show all data to perform the meta-analysis were contacted by e-mail three times with an interval of one week.

Quality assessment

The methodological quality of the selected studies was evaluated using QUADAS-2 which is a revised tool for quality assessment of diagnostic accuracy studies. [39] Two authors (LFH, GZ) scored independently each data item as "yes", "no", "unclear", "low" or "high". The third author (MC) was in charge of deciding any disagreement between the authors. The QUADAS-2 tool scoring was made using Review Manager® (RevMan) 5.2.

Synthesis of Results

Two proportion meta-analysis were performed. The first analysis verified the mean difference between CBCT reconstructions and *in situ* assessment of alveolar bone loss measurements using the software Review Manager® (RevMan) 5.2. The second analysis examined the level of agreement between CBCT reconstruction and *in situ* assessment of the degree of furcation involvement using the software MedCalc (MedCalc Software, Ostend, Belgium). The significance level was 5%.

Grading the "body of evidence"

The Grading of Recommendations Assessment, Development and Evaluation (GRADE)[40] system, was used to evaluate the quality of evidence. Two authors (LFH, GZ) rated the quality of the evidence as well as the strength of the recommendations according to the following aspects: risk of bias, inconsistency, indirectness, imprecision, publication bias, large effect, plausible confounding and dose response gradient.

The option involving intervention/treatment studies was used in the GRADE tool since it is the only one that allows to assess the results based on outcomes. Despite being a diagnostic study, it is not possible to use the diagnosis specific option since measurement of only diagnostic validity data does not generate the other required diagnostic data such as sensitivity and specificity, positive predictive value (PPV) and negative predictive value (NPV).

RESULTS

Study selection

In phase 1, 922 articles were selected from four electronic databases. After removal of duplicates, 543 different citations remained. Following a detailed evaluation of abstracts, only 23 articles were selected for phase 2. The limited search performed on Open Grey resulted in 1 study, 2 on ProQuest and 5 studies on Google Scholar. Additionally, 1 study was identified from the reference list.

Therefore, 29 articles were retrieved for full-text reading. Thirteen of them were later excluded. Reasons for the exclusion can be found in Appendix 2. Thus, only 16 studies fulfilled the eligibility criteria and were finally included. A flowchart of the complete selection process is shown in Figure 1.

Study characteristics

The amount of evaluated periodontal areas ranged from 28 [41] to 8,964. [42] Most studies evaluated the periodontal bone defects in patients [4, 36, 41, 43-46], others in dry skulls [19, 30, 32, 47-49] and only one in a macerated mandible. [50] Only one study was published in Chinese. [42] A summary of the descriptive characteristics of included articles is provided in Table 1.

Quality assessment

Although the included studies were methodologically homogeneous and had high methodological quality, none of the studies fulfilled all of the QUADAS-2 methodological quality criteria. More information about the risk of bias assessment can be found in Appendix 3 and Figure 2.

Synthesis of Results

Only seven [4, 36, 37, 44-46, 49] out of the studies included were considered for the meta-analysis. The others did not have enough appropriate data for analysis. Although some authors were contacted by e-mail, no new data was retrieved. These seven articles resulted in two meta-analyses: 1) mean difference of alveolar bone loss between CBCT reconstruction and *in situ* measurements [4, 37, 44, 46, 49] and 2) agreement on the classification of the degree of furcation involvement between CBCT reconstruction and *in situ* assessment. [36, 45]

The results of the meta-analysis suggested no difference between the measurements of CBCT reconstruction and *in situ* for alveolar bone loss (-0.10, 95% IC -0.39 a 0.19; Figure 3), however, it is not possible to infer equality between the two methods of measuring alveolar bone loss. In relation to furcation involvement the results showed a significant concordance of 82.82% (95% CI: 75.84 - 88.84; n = 126; Figure 4) between CBCT and *in situ* for the classification of the degree of furcation involvement.

Grading the "body of evidence"

The analysis of the level of quality of evidence found by the GRADE tool (Table 2) indicated that there is moderate evidence to support the use of CBCT to provide periodontal bone defect linear measurements and evaluation of FI.

DISCUSSION

Summary of evidence

Alveolar bone loss is one of the consequences of periodontitis. Bone loss can occur in the mesio-distal and/or bucco-lingual tooth aspects, which limits the use of conventional 2D radiographs when measuring bucco-lingual periodontal defects. [4, 18, 51]

Meanwhile, 3D imaging can potentially add important information to the clinician. However, the last guideline published in 2012 by the European Commission, considers that there is no consistent scientific evidence to support its use as a routine in periodontal evaluation. [33]

The current systematic review suggests with a moderate level of evidence (Table 3) that CBCT can be a precise imaging method for the measurement of periodontal bone defects and evaluation of FI. However, CBCT should not be the first imaging choice in periodontal assessment.

There is no consensus among the studies regarding the comparison between the measurements of alveolar bone loss by means of CBCT compared to *in situ* measurements. Some studies report that there is no statistical difference between CBCT and *in situ* measurements [19, 41, 43, 46, 47, 50]; however, others report a statistical significant difference. [4, 43, 49]

Studies also report that CBCT may underestimate or overestimate the values of alveolar bone loss measurements [4, 43], as well as in cases of furcation involvement. [36, 45] One potential justification for these differences would be the voxel size used. [49] Nevertheless, when defining accuracy in terms of clinical impact, certainly a discrepancy in the range of 0.5–1 mm between actual bone level and estimated bone level on radiographs should normally be considered clinically acceptable. It may be more likely that small or large errors in locating the CEJ and the AC (landmark location errors) can respectively lead to a more significant under - and over-estimation of disease prevalence. [32, 47, 48, 52, 53]

Other factors that explain the differences found in CBCT measurements with those detected by probing *in situ*, are the variables such as: probing force [48], probe diameter and the presence of granulation tissue in defect base. [4] Additionally, access and visualization are often difficult in conventional real-life clinical assessment and can affect this measurement. [36]

However, a systematic review recently published by Walter *et al* [54] shows that CBCT is particularly useful in cases of FI in molars, as it provides high accuracy for detecting the degree of FI and morphology of surrounding periodontal tissues. The authors reported that CBCT can improve diagnosis validity and periodontal treatment planning optimization, especially in cases of FI in molars.

In cases of furcation, 3D reconstructions become more important because the correct classification of the FI degree directly affects treatment approaches. This becomes more relevant in the case of grade II where treatments, especially regenerative therapies, show higher success rates in relation to grade III of FI. [55] In addition, Qiao et al [36] also suggested that CBCT provides important additional imaging data on the morphology of the bifurcation and on the severity of the lesion.

However, just like any other radiographic examination, indicating 3D images must be justified and the ionizing radiation dose should be considered. The problem with CBCT imaging lies in its image resolution (voxel size). Not all machines produce voxel sizes that may have a diagnostic value for this specific problem. In addition, smaller voxel sizes are usually linked to increased imaging exposure time and ionizing radiation concomitantly.

The effective radiation dose of CBCT varies according to the brand and the selected exposure parameters during acquisition of the image, such as size of the field of view (FOV) and voxel, exposure time, kilovoltage and milliamperage. [56-59] When compared to the conventional radiography, the CBCT radiation dose is equivalent to a full-mouth series and approximately three to seven times the dose of a panoramic radiograph depending on the setting in use. [29]

Therefore, CBCT imaging should not be the first choice to measure bone periodontal defects. Its use should be preferably for cases where clinical and conventional images are insufficient or unclear for diagnosis and treatment decision. In addition, it is fundamental to choose the correct FOV size and exposure parameters in order to reduce the amount of radiation dose absorbed by the patient. This philosophy supports the ALARA (As Low As Reasonably Achievable)[60] principle.

LIMITATIONS

The main methodological limitations identified in the selected studies were heterogeneity between the examiners and the protocols for the acquisition of 3D images. Some studies were not clear or did not report whether the examiners of the images were radiologists and whether examiners who performed *in situ* measurement were periodontists.

In addition, acquisition protocols (FOV and voxel) of the images were very heterogeneous among included studies. The larger the FOV the greater the amount of noise in the image. On the other hand, the smaller the size of the voxel, the best spatial resolution of the image, which allows visualization of the bone tissue in areas with smaller thicknesses or lower bone density, for example, on the base of defects containing demineralized bone tissue.

Another point that interferes with the diagnostic process performed on cone beam computed tomography is the presence of metallic materials in the oral cavity. Only four studies [4, 36, 46, 47] excluded teeth with restorations or metal crowns, and teeth with endodontic fillings. The artifacts created by these objects are also defined as “missing value artefacts”, and they reduce image quality [61]. That is, the parameters for the acquisition of CBCT are directly related to the quality of the images and their diagnostic ability.

CONCLUSIONS

Based on a moderate level of evidence, CBCT could be useful for furcation involvement periodontal cases but it should only be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning.

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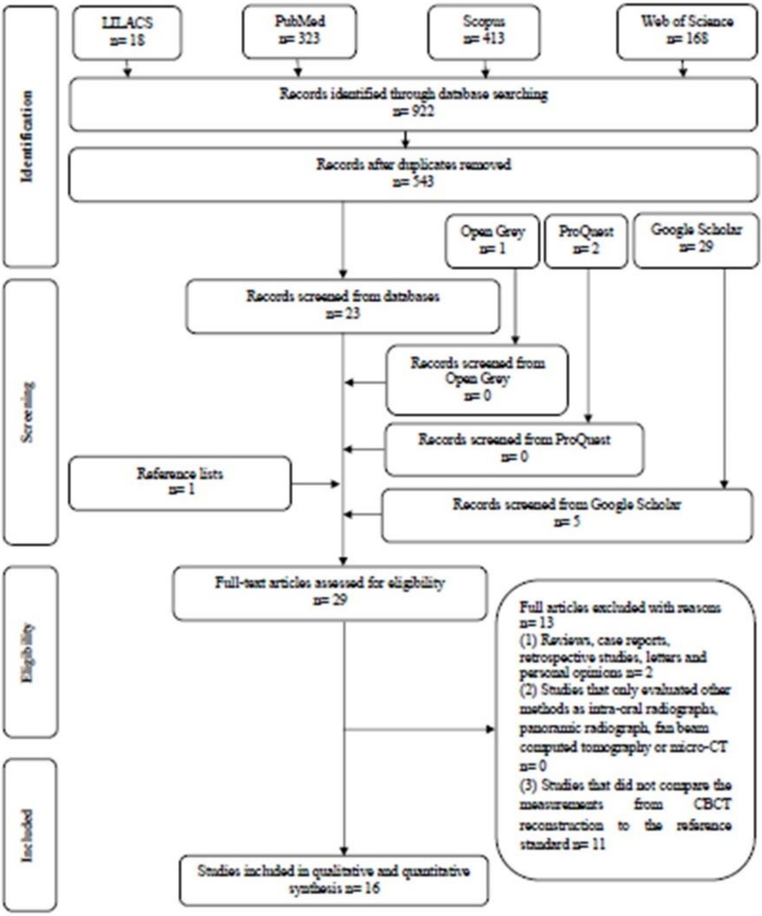
Figure 1 – Flow Diagram of Literature Search and Selection Creteria[1].



[1] Adapted from PRISMA.

Figure 2 – Criteria met, according to the QUADAS tool.

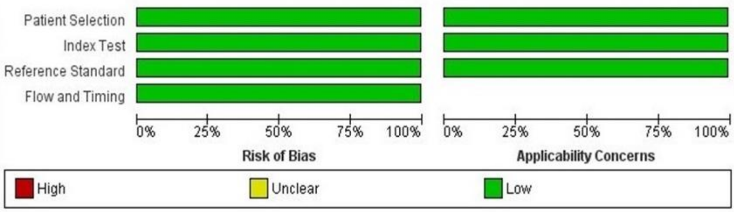


Figure 3 - Mean difference between the CBCT and *in situ* evaluation for the measurement of alveolar bone loss. Sample=632.

	CBCT			in situ				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Banodkar 2015	3.1	1.2	20	3.1	1.2	20	12.6%	0.00 [-0.62, 0.62]
Feijó 2012	6.1	2.3	72	5.8	1.9	72	21.7%	0.14 [-0.19, 0.47]
Haghgoo 2014	3.1	1	50	3.6	1.2	50	19.1%	-0.45 [-0.85, -0.05]
Leung 2010	10.6	1.9	446	10.3	2.1	446	28.4%	0.15 [0.02, 0.28]
Li 2015	8.1	1.6	44	8.9	1.7	44	18.2%	-0.48 [-0.90, -0.06]
Total (95% CI)			**632**			**632**	**100.0%**	**-0.10 [-0.39, 0.19]**

Heterogeneity: $Tau^2 = 0.07$; $Chi^2 = 14.61$, df = 4 (P = 0.006); $I^2 = 73\%$

Test for overall effect: Z = 0.68 (P = 0.49)

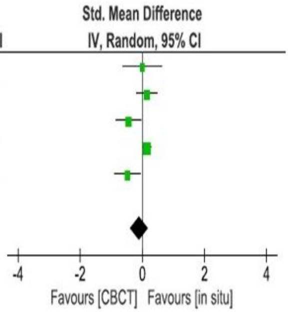
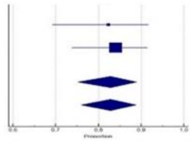


Figure 4 - Forest plot for the concordance between CBCT and *in situ* for the classification of the degree of furcation involvement. Sample=126.

Study	**Sample size**	**Proportion (%)**	**95% CI**
Qiao, 2014	51	82,353	69,127 to 91,599
Walter, 2010	75	84,000	73,719 to 91,450
Total (fixed effects)	126	82,829	75,161 to 88,917
Total (random effects)	126	82,829	75,836 to 88,838



Test for heterogeneity

Q	0,07115
DF	1
Significance level	P = 0,7897
I^2 (inconsistency)	0,00 %
95% CI for I^2	0,00 to 0,00

Appendix 1 – Search strategy in databases.

1. LILACS

((furcation AND defect*) OR (alveolar AND bone AND loss) OR (periodontal AND bone AND loss) OR (alveolar AND loss) OR (interproximal AND bone AND loss) OR (periodontal AND bone AND resorption) OR (alveolar AND bone AND resorption) OR (periodontal AND resorption) OR (periodontal AND bone AND defect*) OR (alveolar AND bone AND defect*) OR (infrabony AND defect*) OR (intrabony AND defect*) OR (defeito AND furca) OR (perda AND óssea AND alveolar) OR (perda AND óssea AND periodontal) OR (reasorção AND óssea AND periodontal) OR (reabsorção AND óssea AND alveolar) OR (reabsorção AND periodontal) OR (defeito AND infraósseo) OR (defeito AND intraósseo)) AND ((cone-beam AND computed AND tomography) OR (cone beam AND computed AND tomography) OR (cone AND beam AND computed AND tomography) OR (tomografia AND computadorizada AND de AND Feixe AND cônico))

2. PubMed

((((((((((("furcation defects"[MeSH Terms] OR ("furcation"[All Fields] AND "defects"[All Fields]) OR "furcation defects"[All Fields])) OR ("alveolar bone loss"[MeSH Terms] OR ("alveolar"[All Fields] AND "bone"[All Fields] AND "loss"[All Fields]) OR "alveolar bone loss"[All Fields])) OR ("alveolar bone loss"[MeSH Terms] OR ("alveolar"[All Fields] AND "bone"[All Fields] AND "loss"[All Fields]) OR "alveolar bone loss"[All Fields] OR ("periodontal"[All Fields] AND "bone"[All Fields] AND "loss"[All Fields]) OR "periodontal bone loss"[All Fields])) OR (alveolar[All Fields] AND loss[All Fields])) OR (interproximal[All Fields] AND ("bone diseases, metabolic"[MeSH Terms] OR ("bone"[All Fields] AND "diseases"[All Fields] AND "metabolic"[All Fields]) OR "metabolic bone diseases"[All Fields] OR ("bone"[All Fields] AND "loss"[All Fields]) OR "bone loss"[All Fields]))) OR (periodontal[All Fields] AND ("bone resorption"[MeSH Terms] OR ("bone"[All Fields] AND "resorption"[All Fields]) OR "bone resorption"[All Fields]))) OR (alveolar[All Fields] AND ("bone resorption"[MeSH Terms] OR ("bone"[All Fields] AND "resorption"[All Fields]) OR "bone resorption"[All Fields]))) OR ("alveolar bone loss"[MeSH Terms] OR ("alveolar"[All Fields] AND "bone"[All Fields] AND "loss"[All Fields]) OR "alveolar bone loss"[All Fields] OR ("periodontal"[All Fields] AND "resorption"[All Fields]) OR "periodontal resorption"[All Fields])) OR (periodontal[All Fields] AND ("bone and bones"[MeSH Terms] OR ("bone"[All Fields] AND "bones"[All Fields])

OR "bone and bones"[All Fields] OR "bone"[All Fields]) AND ("abnormalities"[Subheading] OR "abnormalities"[All Fields] OR "defects"[All Fields]))) OR (alveolar[All Fields] AND ("bone and bones"[MeSH Terms] OR ("bone"[All Fields] AND "bones"[All Fields]) OR "bone and bones"[All Fields] OR "bone"[All Fields]) AND ("abnormalities"[Subheading] OR "abnormalities"[All Fields] OR "defects"[All Fields]))) OR (infrabony[All Fields] AND ("abnormalities"[Subheading] OR "abnormalities"[All Fields] OR "defects"[All Fields]))) OR (intrabony[All Fields] AND ("abnormalities"[Subheading] OR "abnormalities"[All Fields] OR "defects"[All Fields])) AND ("cone-beam computed tomography"[MeSH Terms] OR ("cone-beam"[All Fields] AND "computed"[All Fields] AND "tomography"[All Fields]) OR "cone-beam computed tomography"[All Fields] OR ("cone"[All Fields] AND "beam"[All Fields] AND "computed"[All Fields] AND "tomography"[All Fields]) OR "cone beam computed tomography"[All Fields])

3. Scopus

(((“furcation” W/5 “defect*”) OR (“alveolar” W/5 “bone” W/5 “loss”) OR (“periodontal” W/5 “bone” W/5 “loss”) OR (“alveolar” W/5 “loss”) OR (“interproximal” W/5 “bone” W/5 “loss”) OR (“periodontal” W/5 “bone” W/5 “resorption”) OR (“alveolar” W/5 “bone” W/5 “resorption”) OR (“periodontal” W/5 “resorption”) OR (“periodontal” W/5 “bone” W/5 “defect*”) OR (“alveolar” W/5 “bone” W/5 “defect”*) OR (“infrabony” W/5 “defect*”) OR (“intrabony” W/5 “defect*”)) AND ((“cone-beam” W/5 “computed” W/5 “tomography”) OR (“cone-beam” W/5 “computed” W/5 “tomography”) OR (“cone” W/5 “beam” W/5 “computed” W/5 “tomography”)))

4. Web of Science

((“furcation” AND “defect*”) OR (“alveolar” AND “bone” AND “loss”) OR (“periodontal” AND “bone” AND “loss”) OR (“alveolar” AND “loss”) OR (“interproximal” AND “bone” AND “loss”) OR (“periodontal” AND “bone” AND “resorption”) OR (“alveolar” AND “bone” AND “resorption”) OR (“periodontal” AND “resorption”) OR (“periodontal” AND “bone” AND “defect*”) OR (“alveolar” AND “bone” AND “defect”*) OR (“infrabony” AND “defect*”) OR (“intrabony” AND “defect*”)) AND ((“cone-beam” AND “computed” AND “tomography”) OR (“cone-beam” AND “computed” AND “tomography”) OR (“cone” AND “beam” AND “computed” AND “tomography”))

5. Open Grey and Google Scholar

(“furcation defect” OR “alveolar bone loss” OR “periodontal bone loss” OR “alveolar loss” OR “interproximal bone loss” OR “periodontal bone resorption” OR “alveolar bone resorption” OR “periodontal resorption” OR “periodontal bone defect” OR “alveolar bone defect” OR “infrabony defect” OR “intrabony defect”) AND (“cone-beam computed tomography” OR “cone beam computed tomography”)

6. ProQuest

all("furcation defects") OR all(("alveolar bone loss" OR "periodontal bone loss")) OR all(("alveolar loss" OR "interproximal bone loss")) OR all(("periodontal bone resorption" OR "alveolar bone resorption")) OR all(("periodontal resorption" OR "periodontal bone defects")) OR all(("alveolar bone defects" OR "infrabony defects")) OR all("intrabony defects") AND all(("cone-beam computed tomography" OR "cone beam computed tomography"))

Appendix 2 - Articles excluded and the reasons for exclusion (n=13).

	Author	Reasons for exclusion*
1.	Almeida et al 2014	1
2.	Bagis et al 2015	3
3.	Cimbaljevic et al 2015	3
4.	Darby et al 2015	1
5.	De Farias Vasconcelos et al 2012	3
6.	Dehghani et al 2011	3
7.	Ma et al 2015	3
8.	Marinescu et al 2014	3
9.	Minami et al 2015	3
10.	Noujeim et al 2009	3
11.	Rost 2014	3
12.	Walter et al 2009	3
13.	Zhong et al 2010	3

*(1) Reviews, case reports, retrospective studies, letters and personal opinions; (2) Studies that only evaluated other methods such as intra-oral radiographs, panoramic radiograph, fan beam computed tomography or micro-CT; (3) Studies that did not compare the measurements from CBCT reconstruction to the reference standard.

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Appendix 3 - QUADAS-2 criteria fulfilled (n= 16).

	Item	Banodkar et al, 2015	Deng et al, 2015	Feijó et al, 2012	Fleiner et al, 2013	Grimard et al, 2009	Haghgoo et al, 2014	Li, Jia and Ouyang, 2015
Domain 1: Patient Selection	Was a consecutive or random sample of patients enrolled?	Y	Y	Y	Y	Y	Y	Y
	Was a case-control design avoided?	Y	Y	Y	Y	Y	Y	Y
	Did the study avoid inappropriate exclusions?	Y	Y	Y	Y	Y	Y	Y
	Could the selection of patients have introduced bias?	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the included patients do not match the review question?	L	L	L	L	L	L	L
Domain 2: Index Test	Were the index test results interpreted without knowledge of the results of the reference standard?	U	U	U	N	U	U	U
	If a threshold was used, was it pre-specified?	U	U	U	U	U	U	U
	Could the conduct or interpretation of the index test have introduced bias?	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the index test, its conduct, or interpretation differ from the review question?	L	L	L	L	L	L	L
Domain 3: Reference Standard	Is the reference standard likely to correctly classify the target condition?	Y	Y	Y	Y	Y	Y	Y
	Were the reference standard results interpreted without knowledge of the results of the index test?	Y	Y	Y	Y	Y	Y	Y
	Could the reference standard, its conduct, or its interpretation have introduced bias?	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the target condition as defined by the reference standard does not match the review question?	L	L	L	L	L	L	L
Domain 4: Flow and Timing	Was there an appropriate interval between index test(s) and reference standard?	U	U	U	Y	Y	U	U
	Did all patients receive a reference standard?	Y	Y	Y	Y	Y	Y	Y
	Did patients receive the same reference standard?	Y	Y	Y	Y	Y	Y	Y
	Were all patients included in the analysis?	Y	Y	Y	Y	Y	Y	Y
	Could the patient flow have introduced bias?	L	L	L	L	L	L	L

	Item	Leung et al, 2010	Misch, Yi and Sarment, 2006	Mol and Balasundaram, 2008	Qiao et al, 2014	Raichur et al, 2012	Takeshita et al, 2015	Vandenberghe, Jacobs and Yang, 2007	Vandenberghe, Jacobs and Yang, 2008	Walter, Weiger and Zitzmann, 2010
Domain 1: Patient Selection	Was a consecutive or random sample of patients enrolled?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Was a case-control design avoided?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Did the study avoid inappropriate exclusions?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Could the selection of patients have introduced bias?	L	L	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the included patients do not match the review question?	L	L	L	L	L	L	L	L	L
Domain 2: Index Test	Were the index test results interpreted without knowledge of the results of the reference standard?	U	Y	U	Y	U	U	U	Y	U
	If a threshold was used, was it pre-specified?	U	U	U	U	U	U	U	U	U
	Could the conduct or interpretation of the index test have introduced bias?	L	L	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the index test, its conduct, or interpretation differ from the review question?	L	L	L	L	L	L	L	L	L
Domain 3: Reference Standard	Is the reference standard likely to correctly classify the target condition?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Were the reference standard results interpreted without knowledge of the results of the index test?	U	Y	Y	Y	Y	Y	Y	Y	Y
	Could the reference standard, its conduct, or its interpretation have introduced bias?	L	L	L	L	L	L	L	L	L
	Concerns regarding applicability: Is there concern that the target condition as defined by the reference standard does not match the review question?	L	L	L	L	L	L	L	L	L
Domain 4: Flow and Timing	Was there an appropriate interval between index test(s) and reference standard?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Did all patients receive a reference standard?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Did patients receive the same reference standard?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Were all patients included in the analysis?	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Could the patient flow have introduced bias?	L	L	L	L	L	L	L	L	L

Yes (Y), no (N), nuclear (U). Risk: Low (L)/HIGH (H)/UNCLEAR (U).

Table 1 - Summary of descriptive characteristics of included studies (n= 16).

STUDIES CARACHTERISTICS		POPULATION		INTERVENTION		OUTCOMES	
AUTHOR, YEAR	**COUNTRY**	**SAMPLE (SIZE/TYPE/ DEFECT/ DENTAL GROUP)**	**OBSERVERS (NUMBER/TYPE/ CALIBRATION)**	**INSTRUMENT FOR MEASURING *IN SITU***	**IMAGE ACQUISITION PROTOCOL -CBCT Unit, FOV(cm), voxel(mm), Kv, mA, s.**	**STATISTICAL ANALYSIS**	**FINDINGS OVERALL**
Banodkar et al, 2015	India	15 patients; 100 sites; Horizontal and vertical defects; Dental Group: U.	1 examiner (*in situ* and image); Calibration: Y.	Digital vernier caliper.	Promax 3D£. FOV: 4×4cm; voxel: 0.4mm; 90kV; 10mA; 13s.	Pearson's correlation test.	CBCT was 100% accurate in identifying the type of defect in all the patients. When the correlation between horizontal and vertical defects was compared the horizontal defect correlation was higher than the vertical defects.
Deng et al, 2015	China	75 patients; 8.964 sites; Horizontal and vertical defects; Incisor, canine, premolars and molars¥.	2 residents (*in situ*); 2 radiologists (image); Calibration: Y.	Manual periodontal probe.	Vatech†. FOV: U; voxel: U; 90kV; 7mA; 24s.	t-test and one-way ANOVA.	No significant difference between clinical probing and CBCT. CBCT have the highest consistency with clinical probing in detecting the alveolar bone loss in chronic periodontitis.
Feijó et al, 2012	Brazil	6 patients; 72 sites; Horizontal; Upper molars.	1 professional (*in situ*); 1 radiologist (image); Calibration: U.	Manual periodontal probe.	i-CAT*. FOV: U; voxel: 0.2mm; kV: U; mA: U; 40s.	Wilcoxon test; Mann-Whitney test.	There was no statistically significant difference between clinical and CBCT measurements. There was a statistical difference between the CBCT and surgical measurements on the palatal surfaces and vestibular.
Fleiner et al, 2013	Belgium	1 dry skull; 72 sites; Circumferential bone level, infrabony crater; Upper and lower premolars and molars.	3 observers (*in situ* and image*)*. Calibration: Y.	Manual periodontal probe.	Promax 3D£. FOV: 8x8cm; voxel: 0.16mm; 80kV; 12mA; 12 and 22s.	Pearson product–moment correlation coeficient; One-way ANOVA; Paired t-test; Pearson's; chi-square test, and Fisher's exact test.	The CBCT showed accurate measurements of periodontal bone circumferential level as compared to the gold standard and 100% of the detected furcation.
Grimard et al, 2009	USA	29 patients; 33 sites; Infrabony defects;	2 Periodontics – Board Certified Periodontists (*in*	Manual periodontal probe.	3DX Accuitomo¶. FOV: U;	Pearson product-moment correlation	None of the differences between surgical

		Upper and lower teeth.	*situ*); 1 author (image); Calibration: U.		voxel: 0.125mm; kV: U; mA: U; 18s.	coefficients; Spearman rank-order correlation coefficints; paired t-test; McNemar.	cemento-enamel junction to alveolar crest measurements and the CBCT were statistically significant.
Haghgoo et al, 2014	Iran	Patients: U; 50 sites; Interproximal defects; Anterior and posterior teeth¥.	2 clinicians (*in situ* and image). Calibration: Y.	Manual periodontal probe and digital caliper.	Newtom 3G§. FOV: 6x6cm; voxel: 0.2mm; 110kV; 10.65mA; s: U.	Paired t-test.	The accuracy of CBCT in evaluating vertical dimension of periodontal bony defects was high.
Li, Jia and Ouyang, 2015	China	44 patients; 44 sites; Infrabony defects; Anterior tooth, premolars and molars¥.	1 periodontist (*in situ*); 1 radiologist (image). Calibration: Y.	Manual periodontal probe.	Newtom VG§. FOV: U; voxel: 0.125mm; 110kV; 12 to 17mA; s: U.	Paired t-test.	CBCT measurements for the bucco-lingual width and mesio-distal width of the defect were similar to the intra-surgical measurements. CBCT for the cemento-enamel junction to bone loss and the depth of the defect were significantly underestimated in respect to the intra-surgical measurements.
Leung et al, 2010	USA	13 dry skulls 446 sites; Bone height; Upper and lower molars, premolars, canine and incisors.	1 operator (*in situ* and image); Calibration: Y.	Digital caliper.	CBCT⁋. FOV: 12x12cm; voxel: 0.38mm; 110kV; 2mA; s: 9.6.	Two-tailed paired t-test, Pearson correlation coefficients.	The CBCT measurements were essentially equal to the direct measurements. The correlation between CBCT and direct method was high.
Misch, Yi and Sarment, 2006	USA	2 dry skulls; Site: U; Infrabony buccal, lingual, and interproximal defects; Lower premolar and molar.	3 examiners (*in situ* and image); Calibration: Y.	Periodontal probe (direct measurements) and electronic caliper (indirect measurements).	i-CAT*. FOV: U; voxel: 0.4mm; 120kV; 47.74mA; 20s.	Pearson correlation coefficients and two-way ANOVA.	All infrabony defects were detected using CBCT and the probe and the results of measures were not statistically different.
Mol and Balasundaram, 2008	USA	5 dry skulls; 146 sites; Horizontal and vertical defects; Upper and lower molar, premolar and anterior.	1 examiner (*in situ*); 4 board-certified oral and maxillofacial radiologists (image); 1 oral and maxillofacial radiology resident (image), and 1 periodontist (image); Calibration: Y.	Digital caliper.	NewTom 9000§. FOV: U; voxel: 0.3mm; kV: U; mA: U; s: U.	ANOVA and Tukey's honestly significant difference post hoc test.	The diagnostic accuracy of CBCT was lower for anterior teeth than for molars and premolars.
Qiao et al, 2014	China	15 patients; 51 furcation involvement; Upper molars.	2 periodontists (pre-surgical clinical measurements); 2 periodontists (intra-surgical	Pre-surgical clinical measurements: periodontal probe; Intra-surgical	3D Accuitoo 60, XYZ Slice View Tomograph ¶.	Paired t-test.	CBCT confirmed 82.4% of surgical measurements performed,

			clinical measurements); 2 radiographers (image); Calibration: Y.	clinical measurements: curved probe and manual periodontal probe.	FOV: 4x4 – 6x6 cm; voxel: 0.125 mm; 74–90kV;5–8 mA; s: U.		indicating a high degree of accuracy of CBCT. CBCT underestimated measurements in 11.8% of furcation lesions analyzed and overestimated in 5.9% of cases.
Raichur et al, 2012	India	7 patients; 28 sites; Infrabony defects; Dental Group: U.	Observers: U; Calibration: U.	Manual periodontal probe.	Planmeca Prostyle Intra£. FOV: 50x37 mm; voxel: U; 70-74 kV; 10 mA; 10.8s.	One-way ANOVA; Newman Keuls multiple post hoc.	No significant differences were observed between digital volume tomography and direct surgical measurements.
Takeshita et al, 2015	Brazil	10 macerated human mandibles; Site: U; Proximal alveolar bone loss; Lower teeth.	1 radiologist (*in situ* and image); Calibration: Y.	Digital caliper.	i-CAT*. FOV: 6x6cm; voxel: 0.125 mm; kV: U; 36.2mA; s: U.	ANOVA and Tukey's test.	The values of CBCT were the closest to the control method.
Vandenberghe, Jacobs and Yang, 2007	Belgium	2 skulls, a cadaver head and a dry skull; 30 sites; Linear defects, three-dimensional craters; Dental Group: U.	3 postgraduate students at the Oral Imaging Centre (*in situ* and image); Calibration: Y.	Digital sliding caliper.	i-CAT*. FOV: U; voxel: 0.4mm; 120kV; 23.87 mA; s: U.	Kruskal Wallis; Friedman ANOVA test; Wilcoxon Signed Rank test, and Mann Whitney.	The linear measurement deviations of periodontal bone levels from the gold standard ranged from 0.13 to 1.67 mm for CBCT.
Vandenberghe, Jacobs and Yang, 2008	Belgium	2 skulls; 71 sites; Linear defects, three-dimensional craters; Molar region of the upper and lower jaws.	3 observers (a Medical Imaging Master and PhD student, and 2 radiology faculty members, Temple University, School of Dentistry, Philadelphia, PA) (*in situ* and image); Calibration: Y.	Digital sliding caliper.	i-CAT*. FOV: 6x2cm; voxel: 0.4mm; 120 kV; 23.87 mA; 20s.	Wilcoxon Signed Rank test; Mann Whitney, and Kruskal-Wallis.	No statistical difference between the CBCT and *in situ* measurements.
Walter, Weiger and Zitzmann, 2010	Switzerland	14 patients; 75 furcation involvement; Upper molars.	2 periodontists (*in situ* and image); Calibration: Y.	Curved scaled probe.	3D Accuitomo 60, XYZ Slice View Tomograph¶. FOV: 4X4 – 6X6cm; voxel: 0.08–0.25mm; 74–90 kV; 5–8mA; s: U.	Weighted k.	Overall, 84% of the CBCT data were confirmed by the intra-surgical findings. However, 14.7% of the cases were underestimated (CBCT less than surgical value) and 1.3% revealed an overestimation in the CBCT as compared with the surgical analysis.

CBCT = Cone beam computed tomography; FOV = fiew of field; kV = kilovoltagem; mA = millisecunds; s = seconds; Y = Yes; U = Unclear; ¥ Absence of information whether it is upper or lower teeth; £ Planmeca Oy, Helsinki, Finland;

†Vatch, E-WOO Technology Co, Ltd. Republic of Korea; * Imaging Sciences International, Hatfield, PA; ¶ J. Morita, Kyoto, Japan; § QR-NIM s.r.l., Verona, Italy; ∏ CB MercuRay, Hitachi Medical Systems American, Twinsburg, Ohio.

Table 2 - Summary of findings (GRADE 2014) for the measurements of cone beam computed tomography compared with *in situ* measurements.

OUTCOME	IMPACT	Nº OF PARTICIPANTS (SITES) (STUDIES)	QUALITY
Measures fixed reference point – Alveolar crest	There was no statistical difference between the CBCT and *in situ* measurements in the studies: Banodkar et al, 2015; Deng et al, 2015; Feijó et al, 2012; Grimard et al, 2009; Leung et al, 2010; Misch, Yi and Sarment, 2006; Raichur et al, 2012; Takeshita et al, 2015; Vandenberghe, Jacobs and Yang, 2008. In the study by Mol and Balasundaram, 2008 the average difference between CBCT and *in situ* measurements was -0.23mm. In the study by Vandenberghe, Jacobs and Yang, 2007 the average was between -1 and 1mm CBCT and *in situ* measurements, with an underestimation of the measures of CBCT. Study by Fleiner et al, 2013,	9962 (12 observational studies)	⊕⊕⊕◯ MODERATE

	CBCT and *in situ* measurements varied 0.36 and 0.69mm, in which 83% of all results were <0.5mm.		
Measures fixed reference point – Base of the defect	There was no statistical difference between the CBCT and *in situ* measurements in the studies: Banodkar et al, 2015; Misch, Yi and Sarment, 2006. There was statistical difference between the CBCT and *in situ* measurements in the studies: Grimard et al, 2009; Haghgoo et al, 2014; Li, Jia and Ouyang, 2015; Raichur et al, 2012.	255 (6 observational studies)	⊕⊕⊕◯ MODERATE
Concordance of FI classification according to Hamp *et al* (1975)	Qiao et al, 2014: 82.4% of the CBCT measurements were confirmed *in situ*. Underestimated: 11.8%. Overestimation: 5.9%. Walter, Weiger and Zitzmann, 2010: 84% of the CBCT measurements were confirmed *in situ*. Underestimated: 14.7%. Overestimation: 1.3%.	126 (2 observational studies)	⊕⊕⊕◯ MODERATE

3 CONCLUSÃO

Conclui-se que a TCFC é útil para a mensuração da perda óssea ósseas e para os casos com envolvimento de furca, no entanto, só deve ser utilizada nos casos em que a avaliação clínica e as imagens radiográficas convencionais não fornecem as informações necessárias para o diagnóstico e planejamento do tratamento periodontal.

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ANEXO A – Artigo aceito para publicação na revista *DentoMaxilloFacial Radiology*.

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Precision of cone beam computed tomography to assess periodontal bone defects: a systematic review and meta-analysis.

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Abstract

OBJECTIVES: Evaluate the precision of cone beam computed tomography in measuring periodontal bone defects when compared to the reference standard (in situ measurement).

METHODS: Studies in which the main objective was to evaluate the precision of cone beam computed tomography in measuring periodontal bone defects when compared to the reference standard were selected. Four databases were searched. The studies were selected by two independently reviewers. The methodology of selected studies was assessed using the 14-item Quality Assessment Tool for Diagnostic Accuracy Studies. The quality of evidence and strength of recommendation was assessed by The Grading of Recommendations Assessment Tool, Development and Evaluation.

RESULTS: Using a selection process in two phases, 16 studies were identified and, in seven articles meta-analysis was performed. The results from these meta-analyses showed that no difference between the measurements of CBCT and in situ for alveolar bone loss, and demonstrated a concordance of 82.82% between CBCT and in situ for the classification of the degree of furcation involvement.

CONCLUSIONS: Based on a moderate level of evidence, CBCT could be useful for furcation involvement periodontal cases but it should only be used in cases where clinical evaluation and conventional radiographic imaging do not provide the information necessary for an adequate diagnosis and proper periodontal treatment planning.

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