UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL
FACULDADE DE ODONTOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

JORGE JAVIER DE LIMA MORENO

ACURACIA DA TCFC DE ALTA RESOLUÇÃO PARA DIAGNOSTICO DE FRATURAS EM DENTES OBTURADOS E COM PINO INTRACANAL - UM ESTUDO IN VITRO

Porto Alegre
2020

JORGE JAVIER DE LIMA MORENO

ACURACIA DA TCFC DE ALTA RESOLUÇÃO PARA DIAGNOSTICO DE FRATURAS EM DENTES OBTURADOS E COM PINO INTRACANAL - UM ESTUDO IN VITRO

Tese apresentada ao Programa de Pós-Graduação em Odontologia, linha de pesquisa Diagnóstico das Afecções Buco-Faciais, da Universidade Federal do Rio Grande do Sul, como parte dos pré-requisitos necessários para a obtenção do título de Doutor em Clínica Odontológica.

Orientador: Prof. Dr. Heraldo Luís Dias da Silveira

Porto Alegre
2020

CIP - Catalogação na Publicação

de Lima Moreno, Jorge Javier
ACURACIA DA TCFC DE ALTA RESOLUÇÃO PARA DIAGNOSTICO DE FRATURAS EM DENTES OBTURADOS E COM PINO INTRACANAL - UM ESTUDO IN VITRO / Jorge Javier de Lima Moreno. -- 2020.
38 f.
Orientador: Heraldo Luís Dias da Silveira.

Tese (Doutorado) -- Universidade Federal do Rio Grande do Sul, Faculdade de Odontologia, Programa de Pós-Graduação em Odontologia, Porto Alegre, BR-RS, 2020.

1. Fratura radicular vertical. 2. Tomografia computadorizada cone beam. 3. Oral radiology. I. Dias da Silveira, Heraldo Luís, orient. II. Título.

Elaborada pelo Sistema de Geração Automática de Ficha Catalográfica da UFRGS com os dados fornecidos pelo(a) autor(a).

Agradecimentos

À minha esposa Karina, por sua compreensão e apoio incondicional sempre.

Aos meus filhos Santiago e Guillermo, por estarem sempre sorridentes.

A minha Mãe, Susana, pelo apoio constante em tudo.

Ao meu orientador, Prof Dr Heraldo Luis Dias da Silveira, por sua bondade, ensinamentos e apoio permanente.

Aos avaliadores Priscila, Morgana y Maria Laura, pelo constante apoio, entusiasmo e confiança neste projeto.

Ao meu amigo Henrique que facilitou o uso de seus aparelhos neste projeto.

Aos meus companheiros de batalha no dia a dia que ficam em minha clínica para que eu possa estudar, pelo constante apoio.

À coordenação e professores do Programa de Pós-graduação da FO-UFRGS.

Resumo

As fraturas radiculares verticais (FRV), tanto em dentes vitais como tratados endodonticamente e restaurados com pinos intracanais, são de difícil diagnóstico por meio de exames radiográficos convencionais devido à sobreposição de estruturas. A tomografia computadorizada de feixe cônico (TCFC) apresenta um poder diagnóstico superior quando comparada à radiografia convencional. Dessa forma, realizou-se o presente estudo com o intuito de avaliar a capacidade diagnóstica da TCFC, com diferentes protocolos, adquiridas em três aparelhos de marcas diferentes para detecção de FRV simuladas e a interferência do artefato metálico na visualização das mesmas. Para isso, 240 imagens de dentes unirradiculares foram incluídos neste estudo, divididos em dois grupos (fraturados) grupo teste e grupo controle (não fraturados). Os dois grupos, após a endodontia, foram preparados para a colocação de pinos metálicos e pinos de fibra. Foram obtidas imagens multiplanares com o menor FOV disponível no equipamento e em dois protocolos *standard e high definition*. Os tomógrafos utilizados foram um Ortophos SL 3D (DensplaySirona), ORTHOPANTOMOGRAPH OP300 (KaVo), e PaX.i-3D (VATECH). As imagens tomográficas foram analisadas por três examinadores, individualmente, chegando a um consenso entre eles quando foi necessário. Os resultados obtidos das avaliações foram analisados por meio das medidas de, sensibilidade, especificidade e acurácia. O teste de qui-quadrado foi realizado para comparar o rendimento diagnóstico em imagens obtidas pelos diferentes aparelhos, protocolos e retentores intrarradiculares. Também foi realizado o índice de incerteza com 20 % da amostra. O nível de significância aceito foi de 5%. Os resultados mostram que do total de erros de diagnóstico encontrados, 41,7% ocorreram nas imagens obtidas do aparelho Pax.i3D, 36,1% do Orthophos SL3D e 22,2% do OP300. Quanto ao o protocolo utilizado padrão ou de alta definição não houve diferenças. Já quanto ao retentor intrarradicular, 61,1% dos erros foram na presença do pino metálico e, 38,9% na presença do pino de fibra. A partir desses resultados, concluímos que o tipo de equipamento e retentor intrarradicular influenciam o diagnóstico de FRV em exames de TCFC.

Palavras-chave: Diagnóstico; Fratura radicular vertical; Tomografia computadorizada cone beam.

Abstract

Vertical root fractures (FRV), both in vital teeth and endodontically treated and restored with intracanal pins, are difficult to diagnose by means of conventional radiographic examinations due to overlapping structures. Cone beam computed tomography (CBCT) has a superior diagnostic power when compared to conventional radiography. Thus, the present study was carried out with the aim of evaluating the diagnostic capacity of CFFC, with different protocols, acquired in three different brands of devices for the detection of simulated FRV and the interference of the metallic artifact in their visualization. For this, 240 images of uniradicular teeth were included in this study, divided into two groups (fractured) test group and control group (non-fractured). The two groups, after endodontics, were prepared to place metallic pins and fiber pins. Multiplanar images were obtained with the lowest FOV available on the equipment and in two standard and high definition protocols. The CT scanners used were an Ortophos SL 3D (DensplaySirona), ORTHOPANTOMOGRAPH OP300 (KaVo), and PaX.i-3D (VATECH). The tomographic images were analyzed by three examiners, individually, reaching a consensus between them when necessary. The results obtained from the evaluations were analyzed using measures of, sensitivity, specificity and accuracy. The chi-square test was performed to compare the diagnostic yield in images obtained by different devices, protocols and intraradicular retainers. The uncertainty index was also performed with 20% of the sample. The level of significance accepted was 5%. The results show that of the total diagnostic errors found, 41.7% occurred in the images obtained from the Pax.i3D device, 36.1% from Orthophos SL3D and 22.2% from OP300. As for the standard or high definition protocol used, there were no differences. As for the intraradicular retainer, 61.1% of the errors were in the presence of the metallic pin and 38.9% in the presence of the fiber pin. From these results, we conclude that the type of equipment and intraradicular retainer influence the diagnosis of FRV in CBCT exams.

Key-words**:** diagnosis, vertical root fracture, cone beam CT

TCFC	Tomografia computadorizada de feixe cônico
CBCT	*Cone Beam Computed Tomography*
DICOM	*Digital Imaging and Communication in Medicine*
FOV	*Fiel of View*
FRV	Fratura radicular vertical
VRF	*Vertical root fractures*
mA	*Milliamperes*
kVp	*peak kilovoltage*
HD	*High Definition*
STD	*Standard*
MP	*Metal post*

Sumário

As fraturas de raiz representam um desafio para os dentistas, especialmente quando elas são orientadas verticalmente (GASSNER, 1999; ANDREASEN, et al 2002; LEGAN, BROWN e ANDRES, 1995; LUEBKE 1984; SCHETRITT, 1995; TESTORI, BADINO, e CASTAGNOLA, 1993; ROSEN, RIVERA, 1986; WILCOX, ROSKELLEY, 1997; LERTCHIRAKARN, PALAMARA e MESSER, 1999; FELTON, et al., 1991; YEH. 1997; YANG, RIVERA e WALTON, 1995). As fraturas radiculares verticais (FRV) que envolvem o cemento, dentina e polpa tem uma incidência de aproximadamente 1% na dentição permanente e são uma complicação de ruim prognóstico para o paciente, (YATES, 1992; TAMSE, 1988; TAMSE, et al., 1999; CLARK, ELEAZER, 2000; MAJORANA., et al., 2002) e são responsáveis por 10,9% das extrações dentárias em dentes tratados endodonticamente (FUSS, LUSTIG e TAMSE, 1999). A presença de pino no interior de condutos radiculares representa risco para a ocorrência dessas fraturas (SANTOS et al. 2009).

A visualização direta de uma linha de fratura radiolucente em radiografias é a característica fundamental para a detecção de FRV nem sempre de fácil observação (OBERMAYR, et al., 1991). Muitas vezes, sinais e sintomas podem simular outras condições dentárias que requerem terapêuticas diferentes, tornando-se fundamental o diagnóstico preciso e o mais precoce possível (COHEN et al., 2003). Quando ocorre uma FRV, essa estende-se para o ligamento periodontal. Assim, alimentos e bactérias podem ter acesso à essa área induzindo um processo inflamatório e resultando em lesão do ligamento periodontal, perda óssea alveolar, e formação de tecido granular. Portanto, a rápida decisão em relação ao tratamento é necessária para minimizar o processo de perda óssea pensando na reabilitação oral do paciente (WALTON, MICHELICH E SMITH, 1984).

As informações fornecidas pelo paciente, os sinais e sintomas clínicos e as radiografias periapicais norteiam o diagnóstico de FRV (COHEN et al., 2003). Todavia, estudos têm mostrado o baixo poder do diagnóstico radiográfico, estimado entre 23 e 37,1% (YOUSSEFZADEH et al., 1999; HASSAN et al., 2009). Para as fraturas mesio-distais situadas transversalmente à incidência do feixe de raios X faz que a sensibilidade do exame radiográfico é ainda mais baixa, 7,7% (HASSAN et al., 2009). A radiografia digital com sensor intra oral e radiografia convencional não apresentam diferenças na capacidade diagnóstica de FRV, já que ambas apresentam sobreposição de estruturas inerentes as imagens bidimensionais (TSESIS et al., 2008).

A possibilidade de obtenção de imagens sem sobreposição das demais estruturas faz com que a TCFC seja utilizada no manejo de problemas endodônticos (PATEL et al., 2007; PATEL 2009). TCFC apresenta vantagens em relação à tomografia computadorizada médica (CT), como dose de radiação inferior e menor presença de artefatos (TSIKLAKIS et al., 2005; MAH et al. 2003; SWENNEN et al., 2006; SCARFE, FARMAN e SUKOVIC 2006; HOLBERG et al., 2005).

A TCFC permite que o clínico possa analisar o dente a partir de múltiplos planos, superando as limitações da imagem bidimensional na detecção de FRV (HASSAN et al., 2010; BERNARDES et al., 2009). Vários equipamentos de TCFC estão atualmente no mercado. Esses variam na sua qualidade de imagem e desempenho, especialmente em tarefas altamente exigentes de diagnóstico, como a detecção de FRV (KOBAYASHI et al., 2004; ARAKI, et al., 2004; LOUBELE, et al., 2007; KWONG, et al., 2008; BRYANT, DRAGE e RICHMOND, 2008; MISCHKOWSKI, et al., 2008; FAYAD, ASHKENAZ e JOHNSON 2012, FISEKCIOGLU et al. 2014, KOLSUZ et al. 2015, SAFI et al. 2015).

A TCFC tem sido utilizada para complementação de diagnóstico e plano de tratamento, principalmente quando exames radiográficos convencionais não apresentam dados suficientes para o diagnóstico (SCARFE; FARMAN, 2008). Especialmente na área da endodontia, a aplicação da TCFC vem sendo destacada pela qualidade das imagens e também pelo ganho real no diagnóstico das afecções radiculares e periapicais (COTTON et al., 2007; PATEL et al., 2007). Estudos sugerem que, dentre as aplicações da TCFC, destacam-se a avaliação de achados anatômicos inesperados, avaliação de canais não encontrados, análise de erros iatrogênicos como perfurações, fraturas de instrumentos, extravasamento de material obturador, além de reabsorções e fraturas radiculares (BALL, BARBIZAN e COHENCA ,2013; Menezes et al., 2016).

Diferentes estudos foram realizados com o objetivo de avaliar o diagnóstico de FRV em exames de TCFC e revelaram que os mesmos são superiores na detecção das fraturas quando comparadas com radiografias convencionais (YOUSSEFZADEH et al., 1999; NAIR et al., 2001; MORA et al., 2007; TAYLOR et al. 2007; PATEL et al.

,2007; PATEL et al., 2009). O exame por tomografia alcançou valores de sensibilidade e especificidade entre 70 e 79,4% e 92,5 e 100%, respectivamente. Da mesma forma, YOUSSEFZADEH et al. (1999) afirma que a tomografia computadorizada é superior à radiografia dentária na detecção de fraturas radiculares verticais, mesmo na presença de retentores metálicos intrarradiculares.

Melo et al. (2010) encontraram que a capacidade de diagnóstico TCFC não foi influenciada pela presença de pinos de ouro e de guta-percha, e que as imagens de resolução voxel 0,3 mm não foram um protocolo fiável para a investigação das FRV. Em casos de suspeita de fratura de raiz, estudos indicam que após a investigação por imagens 2D, a TCFC pode ser indicada. A condição de raiz deve então guiar a escolha de resolução de voxel, selecionando voxel 0,3 para dentes sem obturação endodontica e 0,2 para dentes com obturação ou pino metálico (DA SILVEIRA et al. 2013).

Brady et al. (2014) estudaram a capacidade diagnóstica de radiografias periapicais e TCFC e concluíram que nenhum dos métodos é confiável para a detecção de FRV incompleta. Entretanto o aparelho de TCFC foi mais preciso para o diagnóstico da FRV completas, sendo que a largura das fraturas teve um impacto sobre o diagnóstico. Jakobson, et al. (2014) afirmam que é importante a orientação da fratura a ser diagnosticada. A presença do pino metálico não influencia a sensibilidade dos exames radiográficos convencionais e digitais, excluindo os exames de TCFC devido aos artefatos gerados.

Ferreira et al. (2013) utilizaram 2 aparelhos de TCFC para detectar fraturas verticais em dentes com pino de fibra de resina ou pino metálico de titânio. O desempenho em diagnóstico para detectar fraturas verticais foi maior para as raízes com pino de fibra.

Sabe-se que os aparelhos de TCFC apresentam oscilações na dose de radiação dependendo da marca comercial e do protocolo adotado, principalmente devido às variações no tempo de escaneamento, o qual está diretamente relacionado com a resolução de voxel utilizada (LUDLOW et al., 2007). Da mesma forma, a dose de radiação está diretamente relacionada com o número de imagens base realizados, devendo-se solicitar o menor número necessário para o diagnóstico (SCARFE, FARMAN e SUKOVIC, 2006).

Hassan et al (2010) compararam 5 aparelhos TCFC na detecção de FVR quais foram: NewTom 3G (Quantitative Radiologia, Verona, Itália), Next Generation i-CAT

(Imaging Sciences International, Hatfield, PA), Galileos 3D (Sirona Dental Systems, Bensheim, Alemanha), Scanora 3D (Soredex, Tuusula, na Finlândia), e Accuitomo 3D (J. Morita, Quioto, Japão). Os autores concluíram que há uma grande variação entre os diferentes sistemas de TCFC em sua capacidade de detectar FRV devido a características do detector, seleções de voxel artefatos de imagem específicos da TCFC, mas que o i-CAT foi o melhor. Outro estudo recente que analisou 5 equipamentos de última geração de TCFC concluiu que todos são aptos para diagnostico de fraturas, entretanto o iCAT apresentou maior accurácia diagnóstica na detecção FRV (Elsaltani, Farid e Eldin 2016).

Spin-Neto R, Gotfredsen E e Wenzel (2013) e de Baageel et al (20.16), em suas revisões sistemáticas, afirmam que o número de estudos avaliando o impacto do tamanho voxel no resultado de diagnóstico em TCFC em odontologia é pequeno. E, estudos de alta qualidade são necessários para produzir elementos concretos para orientar o uso da TCFC no diagnóstico de FRV.

Tendo em vista o exposto acima e considerando a constante evolução dos aparelhos de TCFC, achamos importante comparar exames de 3 aparelhos de TCFC de última geração na detecção de FRV. Assim, foi realizado um estudo para verificar a capacidade diagnóstica frente a imagens obtidas com diferentes protocolos de aquisição em diferentes aparelhos e a interferência na imagem causada pela presença de pinos de fibra e pinos de metal dentro da raiz.

Geral

Avaliar a acurácia do diagnóstico de fraturas radiculares verticais da raiz dentaria em exames de Tomografia Computadorizada de Feixe Cônico.

Específicos

a. Avaliar a acurácia do diagnóstico de FRV, em exames de TCFC adquiridos em diferentes equipamentos.
b. Avaliar a acurácia do diagnóstico de FRV, em exames de TCFC com diferentes protocolos de aquisição, padrão e alta resolução.
c. Avaliar a acurácia do diagnóstico de FRV, em exames de TCFC de dentes com pino de fibra de vidro e com pino metálico no interior do canal radicular.

Vertical Root Fractures: Diagnosis accuracy using different high-resolution CBCT scans

ABSTRACT

Vertical root fractures (VRF), both in vital teeth and in teeth with endodontic treatment restored with intracanal posts, are difficult to diagnose using conventional X-ray methods. Cone beam computer tomography (CBCT) offers superior diagnostic power compared to conventional X-ray methods. We evaluated the diagnostic capacity of three different brands of CBCT devices, with the lowest available field of view for each equipment and two predetermined protocols, standard and high definition, for the detection of simulated VRF and of the interference of metal posts in the visualization of VRFs. To this end, 240 images of single root teeth were included in this study, divided into two groups: the test group in which teeth were artificially fractured, and the control group, without fractures.

The CBCT images were assessed reaching a consensus between three examiners. Results indicated that two of the scanners studied contributed 77.8% of diagnostic errors, and 61.1% of the errors in the presence of metal in the root canal. There were no significant differences between the standard and high definition protocols. We concluded that the equipment brand and the condition of the tooth are important factors in the assessment of cone beam computed tomography.

Key words: diagnosis; vertical root fracture; cone beam computed tomography

Introduction

Root fractures pose a challenge to dentists, especially when they are oriented vertically (1-2). Vertical root fractures involving cement, dentine and pulp have an incidence of approximately 1% in permanent dentition and are a complication with a poor prognosis for the patient (3-4). They are responsible for 10.9% of extractions of endodontically treated teeth (5). Direct visualization of a radiolucent fracture line is fundamental for detection of VRF, but this is not always easy to observe (6). Often, signs and symptoms can simulate other dental conditions that require different therapeutic treatment; thus, it is extremely important to reach an accurate diagnosis as early as possible (7). When a VRF occurs, it extends to the periodontal ligament; so detritus and bacteria can gain entrance to this area and induce an inflammatory process, resulting in lesion of the periodontal ligament, loss of alveolar bone and formation of granular tissue. Therefore, an early decision with regard to treatment is necessary to minimize bone loss, in the interests of the patient´s oral rehabilitation (8).

Information furnished by the patient, together with clinical signs and symptoms and periapical X-rays, orient the diagnosis of VRF (7). Studies have shown the low power of diagnosis by radiography, estimated as between 23 and 37.1% (9,10). For mesiodistal fractures transversal to the incidence of the X-ray beam makes the sensitivity of radiographic examination is even lower, at 7.7% (10). Digital radiography with intra-oral sensors did not differ significantly with respect to diagnostic capacity for VRF compared with conventional radiography; both techniques produced the superposition of visibilized structures inherent to two-dimensional images (11).

Cone beam computed tomography (CBCT) provides the possibility of obtaining images without overlapping with other structures, and therefore it is useful in the management of endodontic problems (12,13). CBCT as used in dentistry has advantages over medical computed tomography (CT), such as lower radiation dose and fewer artefacts (14-17). CBCT allows the clinician to analyze the tooth in several planes, overcoming the limitations of two-dimensional images for detection of VRF (18, 19). There are several CBCT scanners on the market nowadays. They vary in the rigor of their diagnoses, for example for detection of VRF (20-23).

Several studies have been carried out with the aim of assessing the diagnostic power of CBCT for VRF. They have demonstrated statistically significant differences in detection of fractures when CBCT images were compared with X-ray images (12,13,24,25). Likewise, YOUSSEFZADEH et al. (1999) describe that computed tomography is superior to dental radiography in detecting vertical root fractures, although the root canals have metal inside the canal (13). Other studies evaluated the presence of metallic posts inside the root canal (25) and confirmed that the diagnostic capability of CBCT was not affected by the presence of such posts. In cases of suspected root fracture, studies have suggested that after investigation with two-dimensional images, CBCT may be indicated (26).

Brady et al. (2014) studied the diagnostic capability of periapical X-rays and CBCT, and concluded that neither method is reliable for detecting incomplete VRF (27). However, the CBCT scanner was more precise for the diagnosis of complete VRF, and the width of the fractures affected the diagnosis. Jakobson et al. (2014) reported that CBCT scanners had greater sensitivity than conventional and digital X-ray examination for the detection of VRF in teeth treated endodontically with and without posts; overall accuracy depended on the CBCT scanner used (28). Many studies carried out since the advent of cone beam computed tomography have studied different protocols for the diagnosis of VRF, with different scanners, protocols and root conditions (18,29-31).

In vitro microtomography studies showed what type of fracture, according to width and shape, can be diagnosed by CBCT. The results suggested that the width of the fracture in teeth with VRF defines what voxel size is useful for VRF diagnosis. They indicated that CBCT with voxel size greater than 200 microns may not be appropriate for clinical identification of most VRF because the majority of these are less than 200 microns wide. VRF wider than this measure can be diagnosed by periapical radiography, or even clinically. The problem arises with VRF less than 200 microns wide; the studies showed 56% of their entire working sample of teeth had fractures between 100 and 200 microns wide. They postulated that these can be diagnosed with CBCT voxel size under 80 microns, although they emphasized that the properties of the maxillary and mandibular bones, the material used to fill the root canal, and the presence of metal posts could create artifacts in the images of horizontal or vertical root fractures, and may have affected the precision of VRF diagnosis (32).

According to European guidelines, use of CBCT with restricted field of view (FOV) and high resolution is indicated for evaluation of suspected root fracture when conventional radiography does not provide enough information to develop a treatment plan (33). Considering all of the above, and in view of the constant development of CBCT scanners, this study compared the accuracy of VRF diagnosis in teeth treated endodontically and with posts in root canals, using images acquired by three different CBCT scanners and with different acquisition protocols, varying FOV, voxel size, kilovoltage (KVp) and milliamperes (mA).

Materials and methods

A transversal “in vitro” experimental study was carried out with the approval of the research committee and the ethics committee of the School of Dentistry, Federal University of Rio Grande do Sul (UFRGS) under the number: 17259.

The test items (Fig.1) studied were 20 single root human teeth that had been stored in a glass flask containing 5% buffered formaldehyde. The teeth were placed in 20 self-polymerizing acrylic cubes with a cylindrical empty space at the center, and surrounded by plastified wax (Cera Articulação, Epoxiglass, Brazil). The 20 teeth were divided into two groups: experimental and control, with and without fractures, respectively. The teeth were prepared for endodontic and subsequently sealed with gutta percha. The teeth were prepared with a number 2 width file (Maillefer/Caulk/Dentsply, Brazil) for inserting prefabricated metal posts (Agelus, Brazil) or fiberglass posts (Macro-Lock Post/X-RO/RTD, France), respectively. Prefabricated metal posts were inserted in all teeth and the teeth were subjected to CBCT. Afterwards, the metal posts were withdrawn and replaced with fiberglass posts (Macro-Lock Post/X-RO/RTD, France), and CBCT was repeated on all teeth. The 10 teeth in the experimental / test group were immobilized and artificially fractured by means of a specially designed hammer and chisel (26). The control group was not subjected to fracturing. The same 20 teeth were subjected to tomography at two timepoints, once with metal posts inside them and the second time with fiberglass posts, making a total of 40 images. Thus, the sample was made up of the images acquired from the 40 test items, using two different protocols, namely standard and high definition. These were used with each CBCT scanner, so 80 images were acquired from each scanner, making a total of 240 images of single-root teeth with root canals sealed with gutta percha and metal or fibreglass posts.

For the acquisition of volumetric images, the 40 test items were placed in a container full of water; this aqueous environment was used to simulate intraoral conditions. The scanners used were an Ortophos SL 3D (Dentsply Sirona International Headquarters, Salzburg, Austria), an ORTHOPANTOMOGRAPH OP300 Maxio (KaVo Dental GmbH Biberach, Riß, Germany), and a PaX.i-3D (VATECH CO, South Korea).

Multiplanar reconstruction images with the lowest available FOV for the scanner used were acquired, using two predefined protocols: standard and high definition (HD) (Table 1). All the images were exported in Digital Imaging and Communications in Medicine (DICOM) format to an external compact disc.

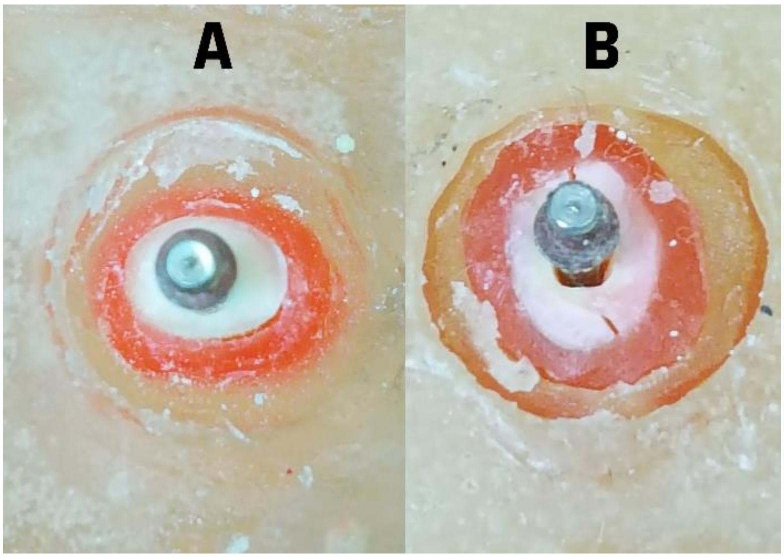

Figure 1. The test items. A - Non fracture tooth, B - Fracture tooth.

Table 1. Image acquisition protocols adopted in each of the CBCT scanners used.

Scanners / Protocols	Equipment 1 OP300 (Kavo, Dental)	Equipment 2 Ortophos SL3D (Sirona)	Equipment 3 PaX.i-3D (Vatech)
Protocol 1 Standard	FOV: 4.7 X 4.7 cm Voxel: 0.13 kVp: 89 mA: 8 Images base 452	FOV: 5 X 5.5 cm Voxel: 0.16 mm kVp: 85 mA: 10 Images base 385	FOV: 6.24 X 6.24 cm Voxel: 0.13mm kVp: 89 mA: 5 Images base 450
Protocol 2 High Definition	FOV: 4.7 X 4.7 cm Voxel: 0,08 kVp:89 mA: 10 basis projections 706	FOV: 5 X 5.5 cm Voxel: 0.08 kVp:85 mA: 6 basis projections 768	FOV: 6.24 X 6.24 cm Voxel: 0.08 kVp:89 mA: 5 basis projections 624

The images were analyzed using OnDemand software (KaVo Dental GmbH Biberach, Riß, Germany) by three well-qualified examiners, who did not know which teeth had been fractured and which had not. They evaluated the CBCT images for the presence or absence of VRF and reached consensus on the diagnoses (Figure 2). Each examiner carried out their evaluation using the 5-point Likert scale (Table 2). They answered the following question: Is there a vertical root fracture?

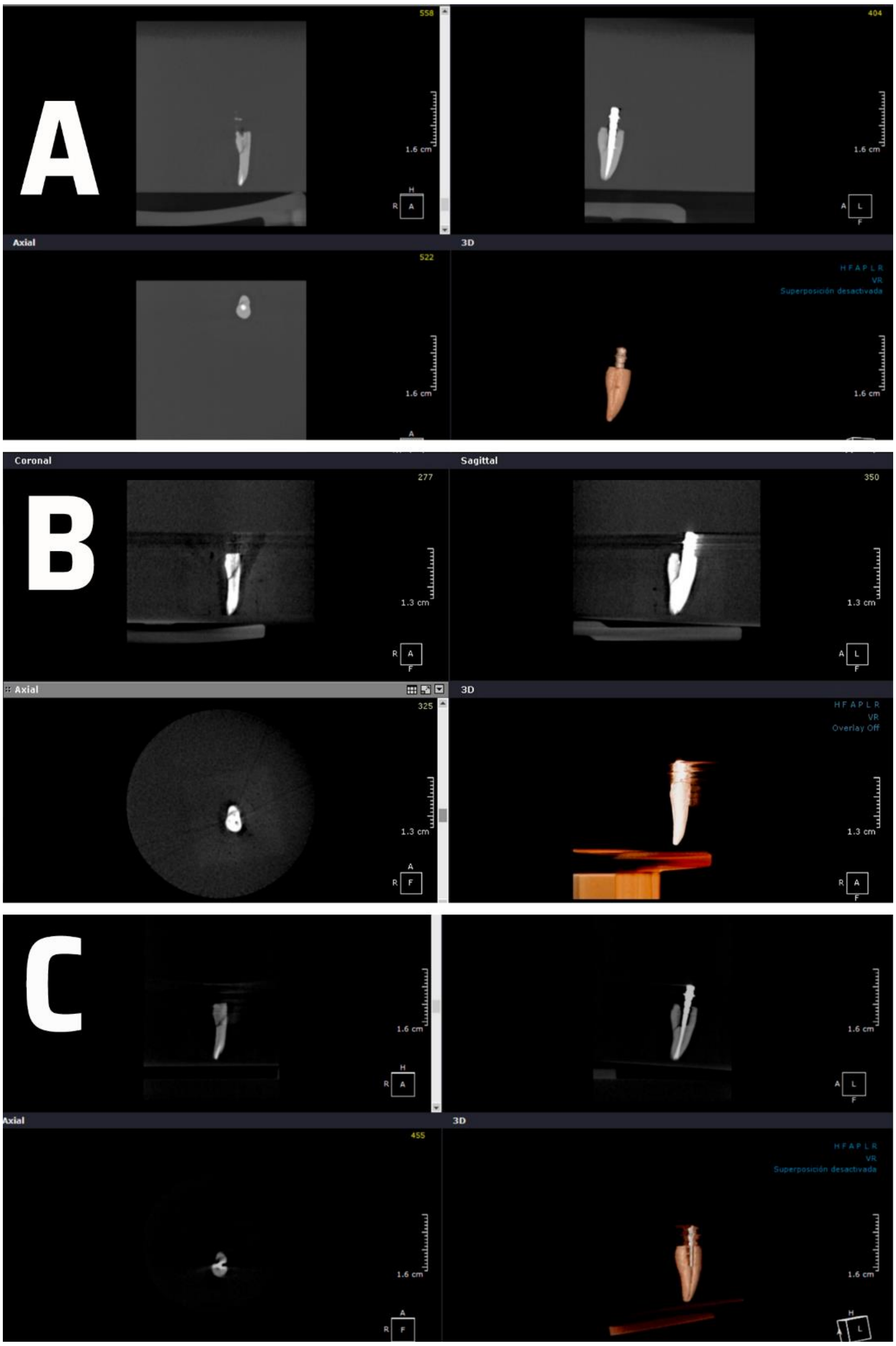

Figure 2. Image of: A) Ortophos SL3D B) PaX.i-3D C) OP300

Table 2. Evaluation table used by the examiners according to the Likert scale, to answer the question: Is there a vertical root fracture?

1	**2**	**3**	**4**	**5**
DEFINITELY YES	**PROBABLY YES**	**UNCERTAIN**	**PROBABLY NOT**	**DEFINITELY NOT**

Results

Firstly, the results were analyzed looking for differences when the examiners were most mistaken in their diagnosis of VRF, and the conditions that were most often repeated when the examiners´ diagnoses were mistaken. The percentage of errors was calculated for the different conditions studied (Table 3).

Table **3.** Percentage of errors in diagnosing vertical root fractures.

		(%)
Scanners	PaX.i-3D (Vatech)	41.7
	Orthophos SL	36.1
	OP300	22.2
Protocols	Standard	52.8
	HD	47.2
Material in root canal	Fiberglass	38.9
	Metal	61.1

The results show that the examiners made 41.7% of their errors using the PaX.i-3D (Vatech) scanner; 36.1%of their errors were made using the Ortophos SL 3D; and 22.1% of the examiners´ errors were made using the OP300.

This shows that out of the total of diagnostic errors, more than three-quarters arose from images taken by the PaX.i-3D (Vatech) and Ortophos SL 3D scanners; the images from both these scanners gave rise to 77.8% of the errors. In regard to the standard and high definition protocols, there was no effect on diagnoses as the errors were distributed almost equally between them. When analyzed according to the material in the root canals, the results show that 61% of the errors arose when the teeth had metal posts, while when the root canals were filled with fiberglass the errors were 39%. In other words, for every two errors arising in teeth with fiberglass posts, there were three errors among the teeth with metal posts.

Secondly, we applied a technique that allowed us to explain and predict the behavior of the gold standard of results. This was a binary or dichotomic technique examining limited dependent variables, in which the distribution was calculated for variables each having only two possible results. This Binary Logistic Regression technique, also known as the Binomial technique, permits prediction of the value of the variable considering the particular distribution of the results.

The closer the result is to 5.0, the greater the certainty of without fracture diagnosis. In opposite, the closer the result is to 1.0, the greater the certainty of fracture diagnosis. The OP300 scanner was the one providing the greatest certainty to the examiners for correct diagnosis of absence and presence of VRF, with the closest values to 5 and 1, respectively.

Table 4. Mean and standard deviation (SD) of Likert scale results, by scanner, protocol, and pin material. According to the Likert scale, 1 = DEFINITE Vertical Root Fracture and 5 = DEFINITELY NOT a Vertical Root Fracture.

Scanners	Protocol	Pino	Cases without fracture		Cases with fracture	
			Mean	SD	Mean	SD
PaX.i-3D (Vatech)	Standard	fiberglass	4,20	1,317	1,40	1,265
		Metal	3,00	1,333	1,60	0,843
		Total	3,60	1,429	1,50	1,051
	HD	fiberglass	3,60	1,506	1,30	0,949
		Metal	3,20	1,135	1,40	0,966
		Total	3,40	1,314	1,35	0,933*
	Total	fiberglass	3,90	1,410	1,35	1,089
		Metal	3,10	1,210	1,50	0,889
		Total	3,50	1,359	1,43	0,984
Orthophos SL 3D	Standard	fiberglass	3,90	1,595	1,70	1,252
		Metal	3,30	0,949	1,80	1,229
		Total	3,60	1,314	1,75	1,209
	HD	fiberglass	4,20	0,919	1,50	0,972
		Metal	3,50	0,972	1,70	0,949
		Total	3,85	0,988	1,60	0,940
	Total	fiberglass	4,05	1,276	1,60	1,095
		Metal	3,40	0,940	1,75	1,070
		Total	3,73	1,154	1,68	1,071
OP300	Standard	fiberglass	4,10	1,197	1,10	0,316
		Metal	3,60	0,966	1,40	0,516
		Total	3,85	1,089	1,25	0,444
	HD	fiberglass	4,30	1,252	1,40	1,265
		Metal	3,40	1,075	1,70	0,823
		Total	3,85	1,226	1,55	1,050
	Total	fiberglass	4,20	1,196	1,25	0,910
		Metal	3,50	1,000	1,55	0,686
		Total	3,85	1,145	1,40	0,810
Total	Standard	fiberglass	4,07	1,337	1,40	1,037
		Metal	3,30	1,088	1,60	0,894
		Total	3,68	1,269	1,50	0,966
	HD	fiberglass	4,03	1,245	1,40	1,037
		Metal	3,37	1,033	1,60	0,894
		Total	3,70	1,183	1,50	0,966
	Total	fiberglass	4,05	1,281	1,40	1,028
		Metal	3,33	1,052	1,60	0,887
		Total	3,69	1,222	1,50	0,961

Table 5. Sensitivity, specificity and accuracy of vertical root fracture diagnosis, by scanner type, protocol (STD = standard, HD = high definition) and post material (FP = fiberglass post, MP = metal post) Results of comparison between variables.

		Sensitivity	Specificity	Accuracy
CBCT device	Vatech	0,88	0,75	0,81
	Ortophos	0,88	0,80	0,84
	OP300	**0,92**	**0,88**	**0,90**
Protocols	STD	**0,90**	0,78	0,84
	HD	0,88	**0,84**	**0,86**
Posts	Fiberglass	**0,92**	**0,85**	**0,88**
	Metal	0,87	0,77	0,82
STD & Posts	Fiberglass	**0,93**	**0,83**	**0,88**
	Metal	0,87	0,73	0,80
HD & Posts	Fiberglass	**0,90**	**0,87**	**0,88**
	Metal	0,87	0,80	0,83
CBCT device x Protocols	OP300 STD	**1,00**	**0,90**	**0,95**
	OP300 HD	**1,00**	**0,90**	**0,95**
	Vatech STD	0,85	0,75	0,80
	Vatech HD	**0,90**	**0,75**	**0,83**
	Ortophos STD	0,85	0,70	0,78
	Ortophos HD	**0,90**	**0,90**	**0,90**
OP300 & Protocols & Posts	STD & PF	**1,00**	**0,90**	**0,95**
	STD & PM	**1,00**	**0,90**	**0,95**
	HD & PF	**0,89**	**0,91**	**0,90**
	HD & PM	0,80	0,80	0,80

Using the OP300 scanner, comparison of both protocols yielded no numerical difference in Likert scores for the diagnosis of VRF. With the PaX.i-3D (Vatech) scanner, higher accuracy in VRF diagnosis was achieved using the high definition (HD) protocol. Using the Ortophos SL 3D scanner, we found a greater influence on higher accuracy with VRF diagnosis when the HD protocol was employed.

Discussion

Several studies have been carried out with the aim of evaluating the diagnostic power of CBCT scanners for VRF. The authors found statistically significant differences in fracture detection when CBCT images were compared with conventional radiography: values for sensitivity and specificity were between 70 and 79.4%, and 92.5 and 100%, respectively

(12,24,34). Likewise, YOUSSEFZADEH et al. (1999) descibe that computed tomography is superior to dental radiography in detecting vertical root fractures, although the root canals have metal inside the canal (13). The present study found similar results: sensitivity of 88% to 92% and specificity of 75% to 78% when the scanners were compared with each other. However, evaluation according to the material filling the root canal yielded higher results, with sensitivity of 92% and specificity of 85% when the root canals were filled with gutta percha or fiberglass pins; but when metal pins were present, sensitivity was 87% and specificity was 77%. In summary: If we ask, what were the best results? We must opt for the OP300 scanner with the HD protocol. The results show that in the presence of fiberglass or metal pins, diagnosis was more precise when pins were fiberglass rather than metal. This is in agreement with the 2013 study by Ferreira, who used two different CBCT scanners with restricted FOV to detect VRF in teeth with fiber resin posts and titanium posts. The scanners were i-CAT (FOV 6 x 8 cm, 120 kVp, 36.12 mA, voxel 0.125 mm) and Scanora 3D (FOV 6 x 6 cm, 85 kVp, 8 mA, voxel 0.33 mm). Higher sensitivity of detection was obtained with the i-CAT images, and diagnostic accuracy was greater for root canals with fiber resin posts (29).

The condition of the root must therefore guide the choice of voxel resolution, with 0.3-voxel being selected for teeth without endodontic fillings and 0.2-voxel for teeth with the root canals endodontically filled with metal posts (26). This shows that research investigations using voxel of 0.2 and 0.3 are not so precise when diagnosing VRF. Recently studies determined that there was no difference based on voxel size nor on the specific scanner used, but that there were significant differences depending on the width of the fracture (27,35). These studies reported that all fractures over 200 microns wide may be seen under conventional X-ray techniques, and even by clinical examination; what is important, then, is the ability to diagnose fractures between 100- and 200-microns width which were indeed the most difficult to diagnose and could only be visualized in images with voxel lower than 80 microns (32). In the present study we compared different voxel sizes and three different scanners. Whilst there was no significant difference in VRF diagnosis with different voxels, in this study the sensitivity of 0.90 was higher the smaller the voxel size when we compare all scanners, achieving best results of specificity of 0.95 % and accuracy of 0.86 when the voxels were smaller when we looked at the scanner that gave us the best results, which was the OP300, associating voxels sizes and metal and fiberglass posts the achieving results of 100% for sensitivity, 90% for specificity and 95% for accuracy.

A systematic review of the literature revealed that there are only a few studies that evaluate the impact of voxel size on diagnostic results of CBCT in the field of dentistry. Further high-quality studies are needed to determine concrete criteria to guide the use of CBCT for diagnosis of VRF (31). In this study we affirm that when a patient has a suspected root fracture and a metal post, it is better to use a Std protocol, since sensitivity is similar for standard and

HD protocols. The specificity is greater with the HD protocols but the difference between Std and HD does not justify the greater radiation received. Where there is no fracture, a HD protocol identifies this more precisely, but where there is a fracture the diagnostic capability is similar with either protocol. Assessing that errors occurred more frequently when there was a fracture, in this case it would not be It is necessary to indicate an HD protocol avoiding a higher radiation dose to the patient. Certainly, further high-quality studies are necessary to enable and support systematic reviews..

Jakobson et al. (2014) reported that CBCT systems provided greater sensitivity than conventional X-ray and digital examinations for diagnosis of VRF in endodontically treated teeth with or without posts; overall accuracy depended on the CBCT system used (28). In agreement with these results, we report that there is a difference between the different scanners used, as in our study the scanners showed differences when compared. The percentage of errors was 41.7% with the PaX.i-3D scanner, 36.1% with the Ortophos SL 3D, and 22.1% with the OP300. Of the total diagnostic errors, more than three-quarters arose from images obtained from the Pax.i-3D and the Ortophos SL 3D, which between them gave rise to 78% of the mistaken results. It is important to clarify that of the total sample 15% were errors.

Several types of equipment and different protocols have been used in research studies to determine or compare their effectiveness for early diagnosis of VRF, using different FOV, kVp, mA and voxel size, but nowadays all CBCT systems have [the same or] similar protocols with respect to the variables used to obtain images. In this study we reach the general conclusion that we agree with European guidelines that indicate the use of CBCT with restricted FOV and high resolution to evaluate cases of suspected root fracture when conventional X-rays do not provide enough information on which to base a treatment plan (10,18,33).

There were a number of limitations to this study. It was a laboratory study which excluded patient movements, metal crowns, implants or radio opaque materials in root canals of juxtaposed teeth, so avoiding artifacts arising from real clinical situations. We used 3 of the existent scanners and there are more CBCT scanners on the market to be studied. The experiment lacked clinical signs and symptoms which might have aided VRF diagnosis. While the greatest of care was taken in the methodology used for creating root fractures, and we believe it was a simulation that was / very / close to reality, we cannot say that the resulting fractures were identical to real fractures arising in patients´ mouths in clinical practice.

Conclusion

The study allows us to affirm that CBCT scanners have high diagnostic capabilities in cases of VRF. When making a diagnosis of VRF it is important to know what type of equipment we are using, as there are differences in diagnostic capability between them. It is also very important to know the condition of the tooth, i.e. if there are metal posts the diagnostic capability is lower.

From these results, we recommend that when there is a root fracture suspected, it is not necessary a high definition protocol since the results are similar to the Standard protocol and we avoid a higher radiation dose to the patient.

References

1. Lertchirakarn V, Palamara J, Messer H. Load and strain during lateral condensation and vertical root fracture. J Endod, 25 (1999), pp. 99–104.
2. Andreasen J.O., F.M. Andreasen, A. Skeie, et al. Effect of treatment delay upon pulp and periodontal healing of traumatic dental injuries — a review article. Dent Traumatol, 18 (2002), pp. 116–12
3. Matsuda K, Ikebe K, Enoki K, *et al.* Incidence and association of root fractures after prosthetic treatment. J Prosthodont Res 2011; 55: 137–140.
4. Gassner R, Bosch R, Tuli T, *et al.* Prevalence of dental trauma in 6000 patients with facial injuries: implications for prevention. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 87 (1999), pp. 27–33.
5. Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J 1999;32:283-286.
6. Obermayr G., R.E. Walton, J.M. Leary, *et al.* Vertical root fracture and relative deformation during obturation and post cementation, J Prosthet Dent, 66 (1991), pp. 181–187.
7. Cohen S, Blanco L, Berman L. Vertical root fractures: clinical and radiographic diagnosis. J Am Dent Assoc 2003;134:434-441.
8. Walton RE, Michelich RJ, Smith GN. The histopathogenesis of vertical root fractures. J Endod. 1984;10:48–56.
9. Patel S. New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. Int Endod J 2009;42:463-475.
10. Hassan B, Metska ME, Ozok AR, *et al*. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endod 2009;35:719-722.
11. Tsesis I, Kamburoglu K, Katz A, Tamse A, Kaffe I, Kfir A. Comparison of digital with conventional radiography in detection of vertical root fractures in endodontically treated maxillary premolars: an ex vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:124-128.
12. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. International Endodontic Journal. 2007;40(10):818-30.
13. Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. Radiology 1999;210:545-549.

14. Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. Dose reduction in maxillofacial imaging using low dose Cone Beam CT. Eur J Radiol 2005;56:413-417.
15. Holberg C, Steinhauser S, Geis P, Rudzki-Janson I. Cone-beam computed tomography in orthodontics: benefits and limitations. J Orofac Orthop 2005;66:434-444.
16. Swennen GR, Schutyser F, Barth EL, De Groeve P, De Mey A. A new method of 3-D cephalometry Part I: the anatomic Cartesian 3-D reference system. J Craniofac Surg 2006;17:314-325.
17. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75-80.
18. Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Comparison of Five Cone Beam Computed Tomography Systems for the Detection of Vertical Root Fractures. Journal of Endodontics 2010;36(1):126-9.
19. Bernardes RA, de Moraes IG, Hungaro Duarte MA, *et al*. Use of cone-beam volumetric tomography in the diagnosis of root fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:270–7.
20. Mischkowski R.A., P. Scherer, L. Ritter, *et al.* Diagnostic quality of multiplanar reformations obtained with a newly developed cone beam device for maxillofacial imaging. Dentomaxillofac Radiol, 37 (2008), pp. 1–9.
21. Fayad MI, Ashkenaz PJ, Johnson BR. Different representations of vertical root fractures detected by cone-beam volumetric tomography: a case series report. J Endod. 2012 Oct;38(10):1435-42.
22. Kolsuz ME, Bagis N, Orhan K, *et al*. Comparison of the influence of FOV sizes and different voxel resolutions for the assessment of periodontal defects. Dentomaxillofac Radiol. 2015; 44(7): 20150070.
23. Safi Y, Aghdasi MM, Ezoddini-Ardakani F *et al*. Effect of Metal Artifacts on Detection of Vertical Root Fractures Using Two Cone Beam Computed Tomography Systems. Iran Endod J.2015 Summer;10(3):193-8.
24. Mora MA, Mol A, Tyndall DA, Rivera EM. In vitro assessment of local computed tomography for the detection of longitudinal tooth fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:825-829.
25. Melo SL, Bortoluzzi EA, Abreu M Jr, *et al*. Diagnostic ability of a cone-beam computed tomography scan to assess longitudinal root fractures in prosthetically treated teeth. J Endod. 2010 Nov;36(11):1879-82.
26. da Silveira PF, Vizzotto MB, Liedke GS, *et al*. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography – an in vitro analysis. Dental Traumatology. 2013;29(1):41-6.

27. Brady E, Mannocci F, Brown J, *et al*. A comparison of cone beam computed tomography and periapical radiography for the detection of vertical root fractures in non endodontically treated teeth. Int Endod J. 2014 Aug;47(8):735-46.
28. Jakobson SJM, Westphalen VPD, Silva Neto UX, *et al*. The influence of metallic posts in the detection of vertical root fractures using different imaging examinations. Dentomaxillofacial Radiology (2014) 43, 20130287.
29. Ferreira RI, Bahrami G, Isidor F, *et al*. Detection of vertical root fractures by cone-beam computerized tomography in endodontically treated teeth with fiber-resin and titanium posts: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013 Jan;115(1):e49-57.
30. Elsaltani MH, Farid MM, Eldin Ashmawy MS. Detection of Simulated Vertical Root Fractures: Which Cone-beam Computed Tomographic System Is the Most Accurate? J Endod. 2016 Jun;42(6):972-7.
31. Spin-Neto R, Gotfredsen E, Wenzel A. Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review. J Digit Imaging. 2013 Aug;26(4):813-20.
32. Huang CC, Chang YC, Chuang MC, Lin HJ, Tsai YL, Chang SH, Chen JC, JengJH.Analysis ofthe width of vertical root fracture in endodontically treated teeth by 2 micro-computed tomography systems. J Endod. 2014 May;40(5):698-702. doi: 10.1016/j.joen.2013.12.015. Epub 2014 Feb 15.
33. SEDENTEX CT PROJECT. Evidence Based Guideline. 2011. www.sedentex.eu
34. *Taylor P. Cotton, DDS, Todd M. Geisler, DDS, David T. Holden, DMD, Scott A. Schwartz, DDS,and William G. Schindler, DDS, MS* Endodontic Applications of Cone-Beam Volumetric Tomography. J Endod 2007;33:1121–1132
35. Assessment of the Influence of Different Intracanal Materials on the Detection of Root Fracture in Birooted Teeth by Cone-beam Computed Tomography
36. *Guo XL, Li G, Zheng JQ, Ma RH, Liu FC, Yuan FS, Lyu PJ, Guo YJ, Yin S.* Accuracy of detecting vertical root fractures in nonroot filled teeth using cone beam computed tomography: effect of voxel size and fracture width. Int Endod J. 2019 Jun;52(6):887-898. doi: 10.1111/iej.13076. Epub 2019 Feb 12

O presente estudo apresenta algumas limitações tendo em vista tratar-se de um estudo laboratorial, que não possui o movimento do paciente, coroas metálicas, implantes ou material radiopaco nos dentes vizinhos, não possuindo assim artefatos criados a partir de uma situação clínica real. Faltaram também os sintomas e sinais clínicos que poderiam auxiliar no diagnóstico de VRF. Por outro lado, este estudo possibilitou isolar variáveis e assim realizar o estudo comparativo da influência do tipo de retentor intrarradicular, bem como do equipamento e protocolo de aquisição usados, com menor interferência de vieses.

Referências

Araki, K. Maki, K. Seki, *et al.* Characteristics of a newly developed dentomaxillofacial X-ray cone beam CT scanner (CB MercuRay): system configuration and physical properties. Dentomaxillofac Radiol, 33 (2004), pp. 51–59.

Baageel TM, Allah EH, Bakalka GT, Jadu F, Yamany I, Jan AM, Bogari DF, Alhazzazi TY. Vertical root fracture: Biological effects and accuracy of diagnostic imaging methods. J Int Soc Prev Community Dent. 2016 Aug;6(Suppl 2):S93-S104.

Ball RL, Barbizan JV, Cohenca NC. Intraoperative Endodontic Applications of ConeBeam Computed Tomography. Journal of Endodontics. 2013: 39:(4)548-557.

Bakland LK. Pulp biology research--is the frog still deaf? Journal of dental research. 1992;71(10):1752-3.

Bernardes RA, de Moraes IG, Hungaro Duarte MA, *et al*. Use of cone-beam volumetric diagnosis of root fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:270 tomography in the –7.

Bernardes RA, de Moraes IG, Hungaro Duarte MA, *et al*. Use of cone-beam volumetric diagnosis of root fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108:270 tomography in the –7.

Brady E, Mannocci F, Brown J, *et al*. A comparison of cone beam computed tomography and periapical radiography for the detection of vertical root fractures in non endodontically treated teeth. Int Endod J. 2014 Aug;47(8):735-46.

Bryant JA, Drage NA, Richmond S. Study of the scan uniformity from an i-CAT cone beam computed tomography dental imaging system. Dentomaxillofac Radiol, 37 (2008), pp. 365–74.

Clark S.J., Eleazer P. Management of a horizontal root fracture after previous root canal therapy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 89 (2000), pp. 220–223.

Cohen S, Blanco L, Berman L. Vertical root fractures: clinical and radiographic diagnosis. J Am Dent Assoc 2003;134:434-441.

Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic Applications of Cone-Beam Volumetric Tomography. Journal of Endodontics. 2007;33(9):1121-32.

da Silveira PF, Vizzotto MB, Liedke GS, *et al*. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography – an in vitro analysis. Dental Traumatology. 2013;29(1):41-6.

Elsaltani MH, Farid MM Eldin Ashmawy MS. Detectio of Simulated Vertical Root Fractures: Which Cone-beam Computed Tomographic System Is the Most Accurate? J Endod. 2016 Jun;42(6):972-7.

Fayad MI, Ashkenaz PJ, Johnson BR Different representations of vertical root fractures detected by cone-beam volumetric tomography: a case series report. J Endod.2012 Oct;38(10):1435-42.

Felton D.A., E.L. Webb, B.E. Kanoy, *et al.* Threaded endodontic dowels: effect of post design on incidence of root fracture. J Prosthet Dent, 65 (1991), pp. 179–187.

Ferreira RI, Bahrami G, Isidor F, *et al*. Detection of vertical root fractures by cone-beam computerized tomography in endodontically treatedteeth with fiber-resin and titanium posts: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013 Jan;115(1):e49-57.

Fisekcioglu E, Semanur D, Mehmet I, *et al. In Vitro* Detection of Dental Root Fractures with Cone Beam Computed Tomography (CBCT). Iran J Radiol. 2014 January; 11(1): e11485.

Fuss Z, Lustig J, Tamse A. Prevalence of vertical root fractures in extracted endodontically treated teeth. Int Endod J 1999;32:283-286.

Gassner R, Bosch R, Tuli T, *et al.* Prevalence of dental trauma in 6000 patients with facial injuries: implications for prevention.Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 87 (1999), pp. 27–33.

Hassan B, Metska ME, Ozok AR, *et al*. Detection of vertical root fractures in endodontically treated teeth by a cone beam computed tomography scan. J Endod 2009;35:719-722.

Hassan B, Metska ME, Ozok AR, van der Stelt P, Wesselink PR. Comparison of Five Cone Beam Computed Tomography Systems for the Detection of Vertical Root Fractures. Journal of endodontics. 2010;36(1):126-9.

Holberg C, Steinhauser S, Geis P, Rudzki-Janson I. Cone-beam computed tomography in orthodontics: benefits and limitations. J Orofac Orthop 2005;66:434-444.

Jakobson S J M, Westphalen V P D, Silva Neto U X, *et al*. The influence of metallic posts in the detection of vertical root fractures using different imaging examinations. Dentomaxillofacial Radiology (2014) 43, 20130287.

Kolsuz ME, Bagis N, Orhan K, *et al*. Comparison of the influence of FOV sizes and different voxel resolutions for the assessment of periodontal defects. Dentomaxillofac Radiol. 2015; 44(7): 20150070.

Kwong JC, Palomo JM, Landers MA, *et al.* Image quality produced by different cone-beam computed tomography settings. Am J Orthod Dentofacial Orthop, 133 (2008), pp. 317–327.

Kobayashi K, Shimoda S, Nakagawa Y, *et al.* Accuracy in measurement of distance using limited cone-beam computerized tomography. Int J Oral Maxillofac Implants. 2004 Mar-Apr;19(2):228-31.

Legan J, Brown C, Andres C. Unusual fracture of a maxillary second premolar. J Endod, 21 (1995), pp. 285–286.

Lertchirakarn V, Palamara J, Messer H. Load and strain during lateral condensation and vertical root fracture. J Endod, 25 (1999), pp. 99–104.

Loubele M, Guerrero M, Jacobs R, *et al.* A comparison of jaw dimensional and quality assessments of bone characteristics with cone-beam CT, spiral tomography, and multi-slice spiral CT. Int J Oral Maxillofac Implants, 22 (2007), pp. 446–454.

Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol 2006;35:219-226.

Ludlow JB, Laster WS, See M, *et al*. Accuracy of measurements of mandibular anatomy in cone beam computed tomography images. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2007;103(4):534-42.

Luebke R.G.. Vertical crown-root fractures in posterior teeth. Dent Clin North Am, 28 (1984), pp. 883–894.

Mah JK, Danforth RA, Bumann A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:508-513.

Majorana A, Pasini S, Bardellini E, et al. Clinical and epidemiological study of traumatic root fractures. Dent Traumatol, 18 (2002), pp. 77–80.

Melo SL, Bortoluzzi EA, Abreu M Jr, *et al*. Diagnostic ability of a cone-beam computed tomography scan to assess longitudinal root fractures inprosthetically treated t eeth. J Endod. 2010 Nov;36(11):1879-82.

Menezes RF, Araújo NC, Santa Rosa JM, *et al*. Detection of vertical root fractures in endodontically treated teeth inthe absence and in the presence of metal post by cone-beam computed tomography. BMC Oral Health. 2016 Apr 14;16:48.

Mischkowski R.A., P. Scherer, L. Ritter, *et al.* Diagnostic quality of multiplanar reformations obtained with a newly developed cone beam device for maxillofacial imaging. Dentomaxillofac Radiol, 37 (2008), pp. 1–9.

Mora MA, Mol A, Tyndall DA, Rivera EM. In vitro assessment of local computed tomography for the detection of longitudinal tooth fractures. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:825-829.

Nair MK, Nair UDP, Grondahl HG, *et al*. Detection of artificially induced vertical radicular fractures using tuned aperture computed tomography. Eur J Oral Sci 2001;109:375-379.

Obermayr G., R.E. Walton, J.M. Leary, *et al.* Vertical root fracture and relative deformation during obturation and post cementation, J Prosthet Dent, 66 (1991), pp. 181–187.

Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam computed tomography in the management of endodontic problems. International Endodontic Journal. 2007;40(10):818-30.

Patel S. New dimensions in endodontic imaging: Part 2. Cone beam computed tomography. Int Endod J 2009;42:463-475.

Rosen H., M. Partida-Rivera. Iatrogenic fracture of roots reinforced with a cervical collar. Oper Dent, 11 (1986), pp. 46–50.

Safi Y, Aghdasi MM, Ezoddini-Ardakani F, *et al*. Effect of Metal Artifacts on Detection of Vertical Root Fractures Using Two Cone Beam Computed Tomography Systems. Iran Endod J. 2015 Summer;10(3):193-8.

Santos AF, Tanaka CB, Lima RG, *et al*. Vertical root fracture in upper premolars with endodontic posts: finite element analysis. J Endod 2009;35:117-120.

Schetritt A., B. Steffensen. Diagnosis and management of vertical root fractures. J Can Dent Assoc, 61 (1995), pp. 607–613.

Spin-Neto R, Gotfredsen E, Wenzel A. Impact of voxel size variation on CBCT-based diagnostic outcome in dentistry: a systematic review. J Digit Imaging. 2013 Aug;26(4):813-20.

Swennen GR, Schutyser F, Barth EL, De Groeve P, De Mey A. A new method of 3-D cephalometry Part I: the anatomic Cartesian 3-D reference system. J Craniofac Surg 2006;17:314-325.

Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006; 72:75-80.

Tamse A. Iatrogenic vertical root fractures in endodontically treated teeth. Endod Dent Traumatol 1988; 4:190-196.

Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. J Endod 1999; 25:506-508.

Tsesis I, Kamburoglu K, Katz A, Tamse A, Kaffe I, Kfir A. Comparison of digital with conventional radiography in detection of vertical root fractures in endodontically treated maxillary premolars: an ex vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 106:124-128.

Tsiklakis K, Donta C, Gavala S, Karayianni K, Kamenopoulou V, Hourdakis CJ. Dose reduction in maxillofacial imaging using low dose Cone Beam CT. Eur J Radiol 2005;56:413-417.

Taylor P. Cotton, DDS, Todd M. Geisler, DDS, David T. Holden, DMD, Scott A. Schwartz, DDS, and William G. Schindler, DDS, MS Endodontic Applications of Cone-Beam Volumetric Tomography. J Endod 2007;33:1121–1132.

Testori T., M. Badino, M. Castagnola. Vertical root fractures in endodontically treated teeth: a clinical survey of 36 cases. J Endod, 19 (1993), pp. 87–91.

Walton RE, Michelich RJ, Smith GN. The histopathogenesis of vertical root fractures. J Endod. 1984;10:48–56.

Wilcox L.R., C. Roskelley, T. Sutton. The relationship of root canal enlargement to finger-spreader induced vertical root fracture. J Endod, 23 (1997), pp. 533–534.

Yang S.F., Rivera E.M., Walton R.E. Vertical root fracture in nonendodontically treated teeth. J Endod, 21 (1995), pp. 337–339.

Yates J.A. Root fractures in permanent teeth: a clinical review. Int Endod J, 25 (1992), pp. 150–157.

Yeh C.J. Fatigue root fracture: a spontaneous root fracture in non-endodontically treated teeth. Br Dent J, 182 (1997 12), pp. 261–266.

Youssefzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. Radiology 1999;210:545-549.

Huang CC, Chang YC, Chuang MC, Lin HJ, Tsai YL, Chang SH, Chen JC, Jeng JH. Analysis of the width of vertical root fracture in endodontically treated teeth by 2 micro-computed tomography systems. J Endod. 2014 May;40(5):698-702. doi: 10.1016/j.joen.2013.12.015. Epub 2014 Feb 15.

Guo XL, Li G, Zheng JQ, Ma RH, Liu FC, Yuan FS, Lyu PJ, Guo YJ, Yin S. Accuracy of detecting vertical root fractures in non root filled teeth using cone beam computed tomography: effect of voxel size and fracture width. Int Endod J. 2019 Jun;52(6):887-898. doi: 10.1111/iej.13076. Epub 2019 Feb 12.

Anexo

Aprovação no Comissão de Etica Em Pesquisa – FO-UFRGS

U F R G S
UNIVERSIDADE FEDERAL
DO RIO GRANDE DO SUL

PRÓ-REITORIA DE PESQUISA
Comitê De Ética Em Pesquisa Da Ufrgs

PROPESQ

CARTA DE APROVAÇÃO

O Comitê De Ética Em Pesquisa Da Ufrgs analisou o projeto:

Número: 17259
Título: Influência do tamanho de voxel e artefato metálico na detecção de fratura radicular vertical in vitro

Pesquisadores:

Equipe UFRGS:

HELOISA EMILIA DIAS DA SILVEIRA - coordenador desde 01/03/2010
HERALDO LUIS DIAS DA SILVEIRA - pesquisador desde 01/03/2010
EDUARDO LUIZ DELAMARE - pesquisador desde 01/03/2010
GABRIELA SALATINO LIEDKE - pesquisador desde 01/03/2010
MARIANA BOESSIO VIZZOTTO - pesquisador desde 01/03/2010
PRISCILA FERNANDA DA SILVEIRA - pesquisador desde 01/03/2010

O mesmo foi aprovado pelo Comitê De Ética Em Pesquisa Da Ufrgs, em reunião realizada em 10/06/2010 - Sala de Reuniões do Gabinete do Reitor (Ex Salão Vermelho) - Prédio Reitoria, 6° andar, por estar adequado ética e metodologicamente e de acordo com a Resolução 196/96 e complementares do Conselho nacional de Saúde.

Porto Alegre, Quinta-Feira, 10 de Junho de 2010

José Artur Chies

JOSE ARTUR BOGO CHIES
Coordenador da comissão de ética

Anexo

Anuência Clínica Intraface para aquisição dos exames de TCFC

INTRAFACE – CENTRO DE RADIOLOGIA ODONTOLÓGICA

São Lourenço do Sul, 19 de Outubro de 2016.

AUTORIZAÇÃO

Eu, Henrique Timm Vieira, autorizo uso do Equipamento OP300 - Instrumentarium para aquisição de Tomografias Computadorizadas Cone Beam para o projeto de pesquisa intitulado: "*Influência de diferentes protocolos de aquisição em diferentes aparelhos de TCFC no diagnóstico de fraturas verticais da raiz dentaria realizado em diferentes resoluções de tela*" sob orientação do Professor Heraldo Luís Dias da Silveira da Faculdade de Odontologia da Universidade do Rio Grande do Sul.

Henrique Timm Vieira

Responsável técnico e administrativo
INTRAFACE – Centro de Radiologia Odontológica

Anexo

Anuência Clínica Imagen para aquisição dos exames de TCFC

CLINICA
IMAGEN

Atlántida, 28 de Octubre ,2016

Clínica imagen-Centro de Radiología Odontológica

AUTORIZACION

Autorizamos el uso del equipamiento ORTHOPHOS SL para la adquisición de tomografía computada CONE BEAM para el proyecto de investigación ¨**Influência de diferentes protocolos de aquisição em diferentes aparelhos de TCFC no diagnóstico de fraturas verticais da raiz dentaria realizado em diferentes resoluções de tela**´´.Proyecto orientado por el profesor Herardo Luis Días da Silveira de la facultad de Odontología Universidad de Rio Grande do Sul

Estela Castro
Por Clínica Imagen
Administración

Calle 7 y 22 | Atlántida | Canelones | Tel: 437 26 871
contacto@clinicaimagen.uy | www.clinicaimagen.uy