Universitas
ODONTOLOGICA

Vol. 40
Rolling volume, January-December
2021

ISSN: 2027-3444 (online) | ISSN: 0120-4319 (print)

Clinical Practice

Cone Beam Tomography and Periapical Radiographs for Early Vertical Root Fracture Diagnosis. Systematic Review*

Tomografía de rayo cónico y radiografías periapicales para diagnosticar tempranamente fracturas verticales radiculares. Revisión sistemática

Tomografia de feixe cônico e radiografias periapicais para diagnosticar precocemente fraturas radiculares verticais. Revisão sistemática

DOI: https://doi.org/10.11144/Javeriana.uo40.cbtp
Submission Date: 12 March 2021
Acceptance Date: 3 July 2021
Date: 7 December 2021

Elizabeth Hernández Hernández [a]
Universidad Santo Tomas, Bogotá, Colombia.
ely1712@yahoo.com
https://orcid.org/0000-0002-1641-4078

Catalina Méndez de la Espriella [a]
Pontificia Universidad Javeriana. Bogotá, Colombia.
catalina.mendez@javeriana.edu.co
https://orcid.org/0000-0002-4653-3799

Oscar Mauricio Jiménez-Peña [a]
Universidad Santo Tomas, Bogotá, Colombia.
Institución Universitaria Colegios de Colombia UniCOC, Bogotá, Colombia.
maurimenez@gmail.com
https://orcid.org/0000-0002-9759-5164

ABSTRACT

Background: Determining the position, direction, and size of the fracture in early stages is of great value in choosing the appropriate treatment. **Purpose:** To compare the diagnostic accuracy of conventional periapical radiographs (PR) with cone beam computerized tomography (CBCT) to identify vertical root fractures (VRF) in root treated teeth. **Methods:** This review used the Cochrane Handbook and the recommendations given by SIGN 50 as a guide. Meta DiSc 1.4 software was used to calculate the operative characteristics of sensitivity, specificity, positive, and negative values. **Results:** Initially 651 articles were obtained; after completing the review 4 articles were chosen: 2 studies had a sensitivity of 60-61 % using conventional PR and 80 % CBCT; specificity 70-71 % using conventional RP and 69 % CBCT; there were no significant differences between the two (p >0.05). Digital dental radiography (DDR) had a specificity of 78 % compared to 70 % of the conventional RP. **Conclusions:** Based on the results and the information published, both tools, digital dental radiograph (DDR) and CBCT are useful to diagnose VRF. There were no significant differences between the CBCT and conventional (PR) (p >0.05) either in advanced or early stages of VRF. To answer research the question more studies are required. To make an early VRF diagnosis on initial stages, the current imaging tools, clinical methods, and patient's symptoms must be considered. As a final option, a surgical exploration is required to confirm its presence.

Keywords: cone beam computed tomography; cracked tooth syndrome; diagnostics; endodontics; periapical radiographs; root canal therapy; tooth fracture

Author's note: [a] **Correspondence:** ely1712@yahoo.com; catalina.mendez@javeriana.edu.co; maurimenez@gmail.com

RESUMEN

Antecedentes: Determinar la posición, dirección y tamaño de una fractura en etapas iniciales es de gran valor para elegir el plan de tratamiento adecuado. **Objetivo:** Comparar la precisión diagnóstica de las radiografías periapicales (RP) convencionales con la tomografía computarizada de rayo cónico (TCRC) para identificar fracturas radiculares verticales (FRV) en dientes con raíces tratadas. **Métodos:** Se tomaron el manual Cochrane y recomendaciones de SIGN 50 como guía para la revisión. Se utilizó el software Meta DiSc 1.4 para calcular las características operativas de sensibilidad, especificidad, valores positivos y negativos. **Resultados**: Se obtuvieron inicialmente 651 artículos y después de la revisión completa se eligieron 4: 2 estudios tuvieron una sensibilidad del 60-61 % usando RP convencional y 80 % TCRC; especificidad 70-71 % usando RP convencional y 69 % TCRC; no hubo diferencias significativas entre los dos (p> 0,05). La radiografía dental digital (RDD) tuvo una especificidad del 78 % frente al 70 % de la RP convencional. **Conclusiones:** Con base en los hallazgos y la información publicada, ambas herramientas, la RDD y la TCRC son útiles para el diagnóstico de FRV. No hubo diferencias significativas entre TCRC y RP convencional (p> 0,05), ni en etapas avanzadas ni en tempranas de VRF. Para responder a la pregunta de investigación se requieren más estudios. Para hacer un diagnóstico temprano de VRF en las etapas iniciales, se deben considerar las herramientas de imagen actuales, los métodos clínicos y los síntomas del paciente. Como última opción, se requiere una exploración quirúrgica para confirmar su presencia.
Palabras clave: diagnóstico; endodoncia; fractura de diente; fractura dental; radiografías periapicales; síndrome del diente agrietado; terapia de conducto radicular; tomografía computarizada de rayo de cono

RESUMO

Antecedentes: A determinação da posição, direção e tamanho da fratura em estágios iniciais é de grande valia na escolha do tratamento adequado. **Objetivo:** Comparar a acurácia diagnóstica de radiografias periapicais convencionais (RP) com tomografia computadorizada de feixe cônico (TCFC) para identificar fraturas radiculares verticais (FRV) em dentes tratados com raízes. **Métodos:** Esta revisão utilizou o Manual de Cochrane e as recomendações dadas pelo SIGN 50 como guia. O software Meta DiSc 1.4 foi usado para calcular as características operatórias de sensibilidade, especificidade, valores positivos e negativos. **Resultados:** Inicialmente foram obtidos 651 artigos; após a conclusão da revisão 4 artigos foram escolhidos: 2 estudos tiveram uma sensibilidade de 60-61 % usando RP convencional e 80 % TCFC; especificidade 70-71 % usando RP convencional e 69% TCFC; não houve diferenças significativas entre os dois (p > 0,05). A radiografia dental digital (RDD) teve uma especificidade de 78 % em comparação com 70 % da RP convencional. **Conclusões:** Com base nos resultados e nas informações publicadas, ambas as ferramentas, RDD e TCFC são úteis para diagnosticar FRV. Não houve diferenças significativas entre a TCFC e a RP convencional (p > 0,05) tanto em estágios avançados ou precoces de FRV. Para responder à pergunta de pesquisa são necessários mais estudos. Para fazer um diagnóstico precoce de FRV nos estágios iniciais, as ferramentas de imagem atuais, os métodos clínicos e os sintomas do paciente devem ser considerados. Como opção final, é necessária uma exploração cirúrgica para confirmar sua presença.
Palavras-chave: endodontia; fratura de dente; radiografias periapicais; síndrome do dente rachado; diagnósticos; terapia do canal radicular; tomografia computadorizada de feixe cônico

INTRODUCTION

A vertical root fracture (VRF) is defined as a complete or incomplete fracture that begins at the root at any level, usually in the buccolingual direction (1). A prevalence of 2-5 % of VRF in endodontically treated teeth has been reported, compared to VRF in endodontically treated teeth that were extracted and had a prevalence of 11-20 % (2). In the clinical examination, some methods to diagnose VRF can be used, such as transillumination and dye test, radiographic projection, bite test, periodontal probing, presence of fistulous tracts, and exploratory surgery, if necessary (3,4). Yoshino *et al*. (5) found that 31.7 % teeth were extracted because of VRF and 93.6 % had endodontic treatment.

On the other hand, Fuss *et al*. (6) reported a 10.9 % prevalence of extractions due to VRF in endodontically treated teeth. Chang *et al.* (2), in a systematic review, investigated the diagnostic ability of cone beam computerized tomography (CBCT) to detect VRFs in endodontically treated teeth and found a prevalence of 40-90 %, with a sensitivity of 84-100 % and a specificity of 64-100 %. Diagnostic aids to identify VRF are conventional periapical radiographs (PR), with the limitation they show a two-dimensional image that does not allow to visualize all the surfaces of the dental structure.

There are other sensitive mechanisms such as the CBCT that has better results compared to conventional PR to identify VRF. The initial or early stage of a VRF and the overlapping of anatomical structures adjacent to the tooth may complicate the visualization of fracture lines in conventional PR, although they can only be observed when the fracture line and cone of the X-ray equipment are in the same plane or almost 4° apart (2). Tsesis *et al.* (7) conducted a systematic review in which they found there is a lack of evidence regarding the accuracy in the diagnostic evaluation in clinical and radiographic effectiveness to identify VRF in endodontically treated teeth.

Moreover, Eskandarloo *et al.* (8) reported a sensitivity of 74 %, a specificity of 62.2 %, and an accuracy of 67.2 % of CBCT for the detection of VRF. Unfortunately, the most traditional methods have limited reliability because many signs and symptoms are not specific to VRF. Therefore, distinguishing the difference between a VRF from a pulpal necrosis, an endodontic treatment failure, or periodontal disease is challenging (9). As previously mentioned, to visualize a VRF with a conventional PR, a good angulation of the X-ray cone is required; also, considering that the superposition of surrounding anatomical structures could make it even more difficult to visualize. For this reason, the plane of fracture is only observed in a third of the cases in conventional PR (10). Once the diagnosis is established, the prognosis of a VRF is poor; because there are currently no reliable methods to treat VRF and usually the affected tooth is removed (3). The presence of this pathology in an endodontically treated teeth has a great impact on the prognosis of the treatment.

Therefore, an early diagnosis of VRF is of great importance to avoid overtreatment and extensive bone loss (10). In this stage of clinical assessment, it must be considered that forces developed during endodontic treatment, such as root canal over-preparation, or the strength of gutta-percha obturation can result in dentinal fatigue or cracks causing VRF that will induce inflammation to the adjacent periodontium. Consequently, fractures can be found in the buccolingual direction, which extend from cervical to apical (11). It is worth mentioning that in a conventional PR a root fracture may not be seen because the intact segment can be superimposed over the fractured segment. In these cases, the diagnosis could be difficult clinically (3,4,12). With the CBCT, the images are in three dimensions (3D) with high resolution that allow to improve the diagnosis; however, there are few studies regarding the value of CBCT to identify root fractures (13-15).

Undoubtedly, being able to determine the position, direction, and size of a fracture is important to choose a treatment plan (4). The aim of this review was to determine if CBCT or conventional PR can help to identify a VRF to make a diagnose in its initial or early stage. There were no other reviews found at the time to add more information that can help to draw more accurate conclusions. For this reason, the purpose was to perform this search in four databases and to be able to make an analysis of the findings found. The research question was: Which diagnostic tool allows the initial identification of a VRF between CBCT and conventional PR in the endodontic practice?

MATERIALS AND METHODS

A systematic review of the literature (SRL) of the years 2009-2018 was conducted through the PubMed, Scopus, Cochrane, and Web of Science databases. The CONSORT Statement was used to guide methodology decisions (16). The research question, "which diagnostic tool allows the initial identification of a vertical root fracture between CBCT and conventional PR in the endodontic practice?" was formulated for clarity and precision using the PICO mnemonic as follows: P, teeth with VRF; I, cone beam computerized tomography; C, conventional periapical radiograph; and OR, initial or early diagnosis of VRF; plus, S, experimental studies.

The inclusion and exclusion criteria are listed in Table1. The search strategy was carried out by using combinations of keywords through five formulas: Formula 1, with terms 1, 2, 3, and 5; formula 2, with terms

1, 2, 4, and 5; Formula 3, with terms 1, 2, and 3; Formula 4, with terms 1, 2, and 4; Formula 5, with terms 1, 2, and 5 (table 2). The search filters were human, English, Spanish, and 2009-2018; all connected through the Boolean connector AND.

TABLE 1
Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
Experimental studies	Case series
Study population: human teeth	Case studies
Publication date: last 10 years	Animal research models
Endodontically treated teach	Dental alveolar trauma
VRFs caused by implants located on antagonist or proximal teeth	Insufficient information

TABLE 2
Formula Term Combinations to Perform the Search

Formula Terms	**Combinations**
1	Diagnostic techniques AND procedures OR diagnosis, differential OR diagnosis, oral OR early diagnosis
2	Tooth fracture OR vertical root fracture OR crack OR root fracture OR cracked tooth syndrome
3	Cone-beam computerized tomography OR CBCT OR cone-beam computed tomography
4	Dental digital radiography OR dental radiology OR periapical radiography
5	Endodontics

We performed a search of titles in the four databases to identify relevant or potentially relevant studies. Two reviewers, independently, examined and selected the relevant studies, discarded non-relevant ones, and registered the content of the chosen articles to create table 3. The checklists for quality assessment of the studies followed the Cochrane Handbook for Systematic Reviews of Interventions (17) to analyze the accuracy and diagnosis of each article. This was carried out by two reviewers to reduce biases. Any disagreement between the reviewers was analyzed and resolved by discussing and consulting with all the authors of the study.

The analysis of methodological quality and level of evidence of the selected articles was done independently by the two reviewers. Agreement on recommendations between the two examiners was given by SIGN 50 (Scottish Intercollegiate Guidelines Network, 2012) (18), in which A represents the highest level of evidence and C the lowest. The Meta DiSc 1.4 software was used to calculate the operational characteristics of sensitivity, specificity, positive and negative values to plot the data in the receiver operating characteristics (ROC) plane, which is a sensitivity graph as a function of 1-specificity. 95 % confidence intervals were used, which are influenced by the size of the sample (19).

TABLE 3
Selected Articles and Data Collected

Study	**Queiroz *et al*. 2016 (20)**	**Tofongchiha *et al*. 2011 (21)**	**Metska *et al*. 2012 (22)**	**Huang *et al*. 2014 (23)**
Tooth Characteristics				
Teeth endodontically treated	20 uniradicular teeth	230 uniradicular teeth	39 endodontically treated teeth	37 endodontically treated teeth with VRF
Prevalence of VRF	No investigated	No investigated	No investigated	Not specified
Specificity	(0.85-0.98)	70% (CR), 78% (DDR)	56% (Newtom 3G), 80% (3D Accuitomo 170)	Not reported
Sensibility	(0.47-0.77)	60% (CR), 61% (DDR)	75% (Newtom 3G),100% (3D Accuitmo170)	Not reported
Positive predictive value	Not reported	Not reported	75% (Newtom 3G), 90% (3D Accuitomo 170)	Not reported
Negative predictive value	Not reported	Not reported	55% (Newtom 3G),100% (3D Accuitomo170)	Not reported
Test accuracy	Not reported	* CR - 65% * DDR - 70%	68% (Newtom 3G), 93% (3D Accuitomo170)	Not reported
Bias control	Not reported	Not reported	Three blinded endodontists assessed all the images independently twice	Not reported
Study Characteristics				
Study design	Experimental in-vitro	Experimental in-vitro	Experimental in-vitro	Experimental in-vitro
Study setting	Academic institution	Not specified	Academic institution	Not specified
Inclusion criteria	Not specified	Single rooted human teeth with closed apices.	*Patients from 2009-2011 with clinical and radiographic signs suggesting the presence of VRF in endodontically treated teeth. *Pain on percussion and/or palpation, presence of deep isolated periodontal pocket (bone loss), presence of multiple sinus tracts, and halo or J-type radiolucency around the corresponding tooth on the periapical radiograph (PR).	*Teeth extracted after clinical diagnosis of VRF. *Only extracted teeth without evident root surface damage. *All teeth must have had at least 1VRF line on the root surface confirmed by 2 endodontists.
Exclusion criteria	Not specified	Internal or external fracture and roots with severe curvatures	Not specified	Not specified
Level of evidence	2-	2+	2+	2-
Grade of recommendation	C	B	B	C

Ranking	Q1	Q1	Q2	Q1
Index Test				
CBCT model (Voxel size)	N/A	N/A	* Newtom 3G. 110 kv, 3.90 - 5.6 mA (QR SLR, Verona, Italy). * 3D Accuitomo 170. 90 kv, 5 mA (J. Morita, Kyoto, Japan).	µ - CT (Triumph X-0 Ct System; Gamma medical Ideas, Northridge, California)
Periapical machine model	* GX-770 periapical machine (Gendex Dental Systems, Lake Zurich, IL; 70 Kvp, 7 mA, exposure time 0.08") *DBSWIN software (DüRR Dental, Bietigheim-Bissingen, Germany)	Plameca Dental X-ray unit (Plameca, Finland)	N/A	N/A
Imaging Parameters				
CBCT	N/A	N/A	Voxel size for Newtom 3G – 2 mm Voxel size for 3D Accuitomo - 0.08 mm	80 kv, 90 µA, field of view 29.59 mm Acquisition time 5 minutes y 512 slices.
Periapical radiograph type/parameters	* Radiographs were taken in an orthoradial incidence (0° horizontal and vertical angles indicated by a protractor) with the aid of a custom holder designed to maintain the specimen, the film holding device, and the image receptor in a reproducible relationship.	* 63 kVp, 8 mA *Exposure time: Conventional Radiograph (CR) - 0.16" Direct Digital Radiograph (DDR) - 0.1" * Kodak E speed No. 2 periapical film (Eastman-Kodak Co, Rochester, NY, USA) Processed manually for 15" at 22°C with Teifsaz chemicals (Teifsaz, Tehran, Iran)	N/A	N/A
Examiners				
Interpreters	3 calibrated examiners	2 observers (who had more than 10 years' experience in dental radiography).	3 observers assessed all images twice and independently.	Not defined
Blinding	Not specified	The observers were not aware of the fractured teeth distribution.	The observers did not receive clinical information before examination.	Fisher exact test was used to evaluate fracture width >100 µm y ≤100 µm, fracture line extension within the apical 3mm were associated with the number of fracture lines

Agreement	Intra-observer and inter-observer reproducibility were evaluated by using Kappa test. The scores were compared with the gold standard by use the operating characteristics curve (ROC). Significance level of 5%	* Cohen's kappa statistics. * X² test to compare two observers 'diagnosis.	Intra-observer agreement (Cohen Kappa) was calculated for each observer and for each scanner independently. Used the interclass correlation coefficients (ICCs).	Application of 9-µm CT can be accurately used for early detection of VRF. Fracture characteristics (e.g., number of fracture lines, extension of fracture line) may affect the fracture width. Appropriate use of µ-CT technology can be helpful for early diagnosis of VRF.
Conclusions	Digital subtraction radiography could be considered as an alternative tool or the investigation of VRFs because of its comparable diagnostic accuracy to existing methods.	No significant difference was seen between the two techniques. The specificity of DDR was slightly better than CR, and their accuracy and sensibility showed small differences.	The results of our study support the use of 3D Accuitomo 170 for the detection of VRFs in endodontically treated teeth. They also suggest that the reproducibility and accuracy in VRF detection depend on the CBCT system used.	

651 titles were identified in the Pub Med, Scopus, Cochrane, and Web of Science databases. After applying the filters, the number was reduced to 242 titles. The next step included a review of 212 articles with abstracts through which studies that did not meet the inclusion criteria were eliminated. From this screening there were 25 eligible articles, which were read in full text. At the end, 4 articles met all the search criteria (Figure 1). A critical reading following the CONSORT guidelines was performed to determine the validity and applicability of the research findings described the final sample of 4 articles (20-23).

The study's flow diagram shows the study selection process for the systematic review. The search was conducted August 2018.

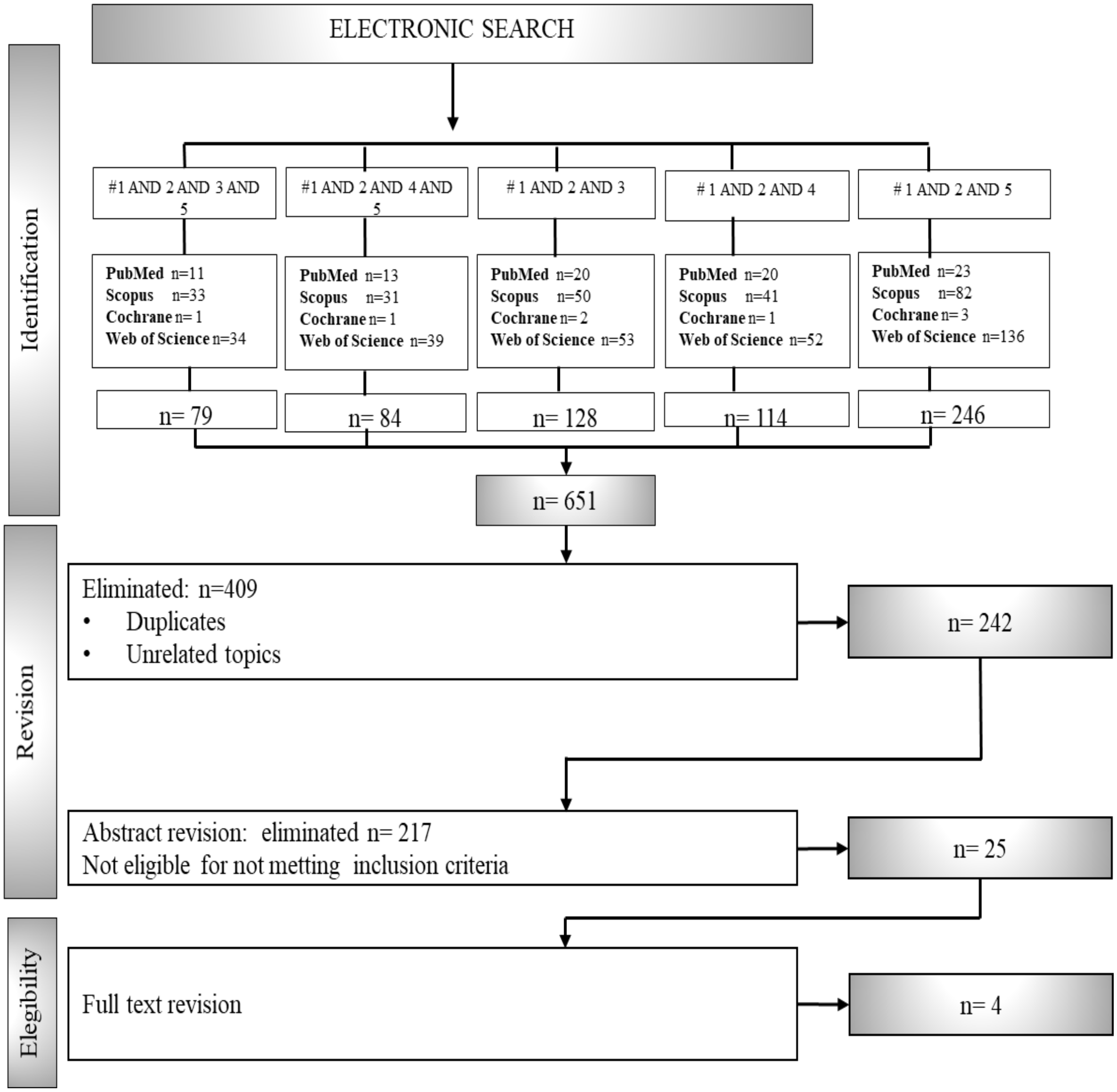
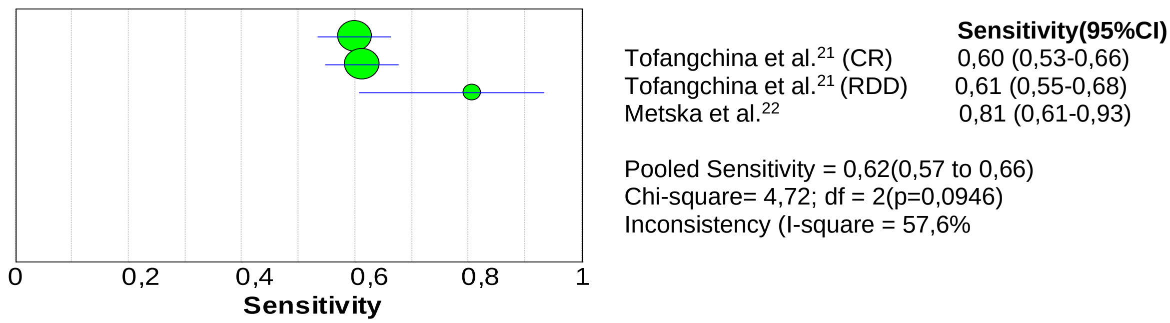


FIGURE 1
Flow Diagram

RESULTS

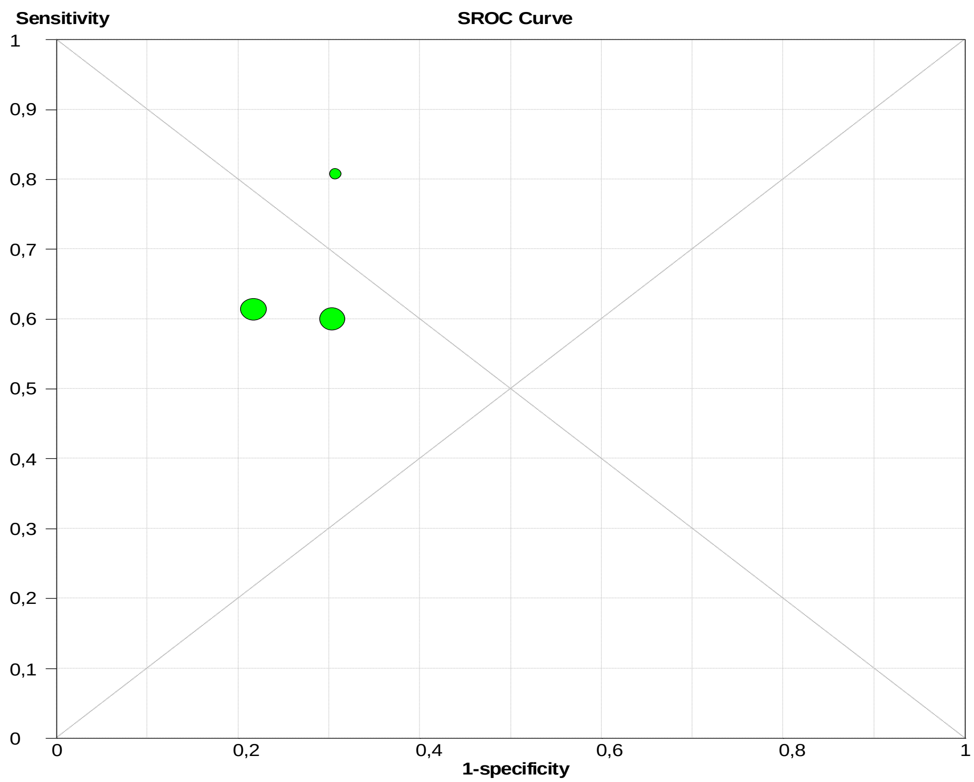
The sample size in the 4 studies ranged from 20 to 230 endodontically treated teeth. As for the reference test, that is, surgical exploration, extraction, or retreatment, it was only reported in one study (21). Sensitivity values were reported in 2 studies and varied between 60-61 % in PR and 80 % in CBCT (20, 22). Specificity values varied between 70-71 % in PR and 69 % in CBCT. A better sensitivity was observed by Metska *et al.* (22) at 81 %, though there were no significant differences between both ($p > 0.05$) (Figure 2). Regarding specificity, it was observed that DDR is more specific to diagnose VRF when compared to conventional PR due to the variety of image tools that let to observe the teeth with different color shades (21). Values were plotted in a plane showing the ROC curve in which both studies are located above the diagonal, indicating acceptable sensitivity and specificity (20,21) (Figure 3). Queiroz *et al*. (20), using PR/digital abduction radiography (DAR), reported a specificity of 85-98 % and a sensitivity of 47-77 %. Huang *et al*. (23) did not report specificity or sensitivity in their study with CBCT.

FIGURE 2
Sensitivity Results



Regarding sensitivity, no statistically significant differences were found between tests (p>0.05). However, from a descriptive viewpoint, the test in Metska *et al.* (23) reports greater sensitivity**.** Regarding the specificity, no statistically significant differences were found between tests (p>0.05). Nevertheless, it can be observed descriptively that the test in Tofangchiha *et al.* (21) (RDD/DDR) showed greater specificity.

FIGURE 3
ROC Plot Results



The ROC plot of the studies shows 3 studies are above the main diagonal, which indicates that the sensitivity and specificity were appropriate.

DISCUSSION

This systematic review sought to determine, according to the literature, which of the two diagnostic tools CBCT and conventional PR is the most accurate to identifying VRF in initial or early stages. Based on the Cochrane Handbook (17), there are reviews that could end up with a few articles to conduct an analysis. Four studies were considered eligible for inclusion. However, all the articles had a high risk of bias due to imprecisions in reporting ranges of diagnostic ability; three studies had a small sample size (21-23), all used different radiographic equipment and CBCT, image parameters, and diagnostic techniques (24). The findings should be viewed with caution because the radiological interpretation is not the same in each situation, which may affect the sensitivity and specificity values (25,26). For example, a more conservative observer might interpret a root fracture as such, only if a bony area that would produce a high specificity value and a low sensitivity value is clearly seen in the image, while a less conservative observer can report the presence of a fracture despite artifacts near the area (27). The difference in training and experience (e.g., oral radiologists v. endodontists) can be a significant variable of the diagnostic source. Therefore, these findings cannot reflect the interpretation capacity of the observers (2). Due to the limited number of studies included in this review, it is not possible to make an objective analysis to determine more accurately the impact of the use of diagnostic tools (CBCT and PR).

However, the interpretations presented in the included studies based on interpretations of endodontists and oral radiologists trained in diagnostic tools. The reproducibility of the four studies is limited because there was no information in two studies on the scores of “agreement between observers” (22,23); it was presented as a limitation. It should also be mentioned that only 2 studies reported the positive and negative predictive values (20,21), which was considered another limitation to make a descriptive analysis of positive and negative predictive values.

Nevertheless, two articles were able to represent in a ROC’s plane, where the sensitivity and specificity were compared. Youssefzadeh *et al.* (28), after an *in vivo* diagnostic study of VRF, reported a sensitivity of (PR)/(CR) of 23 %, which is mentioned in the article as PR. Tofangchiha *et al*. (21) found that although many fractures are not accessible to clinical examination, it is worth mentioning that PR and DDR serve well as diagnostic tools. The intraoral film can provide a resolution of more than (20 lp mm) 1, while current digital systems can provide a resolution of (7 lp mm) 1. Despite this, the level of agreement in this study with digital system and with radiographic film were the same. These studies support the results of Queiroz *et al.* (20), who reported a specificity of 85-98 % and a sensitivity of 47-77 %, considering the use of the subtraction radiograph, used in DDR, as an alternative tool to visualize a VRF due to the diagnostic accuracy comparable with existing methods.

Usually, visualization is difficult due to the superimposition of the fracture line by the sealing material. Even with methods such as CBCT, the presence of gutta-percha decreases the diagnostic accuracy (24,29). The CBCT allows obtaining 3D images of dental arches with high spatial resolution and low radiation compared with the computed tomography (30). Some studies support the use of CBCT to detect VRF in teeth endodontically treated (31,32). However, in those studies fractures were created artificially, which may differ from those that occur “naturally.” Also, when the identification of VRF with CBCT was analyzed, there were always differences in precision between *ex vivo* and *in vivo* (33,34).

Studies of CBCT have shown greater sensitivity and specificity than PR to detect tooth fracture lines (31). In contrast to those studies, Chang *et al*. (2) state that due to the imprecision of reported ranges and biases observed in their systematic review, they determined that there is insufficient evidence to suggest CBCT is reliable to identify VRF in endodontically treated teeth. The resolution of CBCT depends on the size of the voxel, focal point, kV, and CBCT settings (35). The smaller the voxel size, the higher the CBCT resolution (32). Therefore, a higher resolution may be required to detect a longitudinal fracture.

A recent systematic review by Corbella *et al*. (36) evaluated the ability to diagnose teeth with and without endodontic treatment, analyzing separately *in vivo* and *ex vivo* studies. The authors concluded there is a limited number of studies and there is no evidence to suggest CBCT can provide an additional benefit to diagnose VRF in teeth with endodontic treatment. Likewise, Rosen *et al.* (37) examined the efficacy of CBCT in endodontics, concluding there is insufficient evidence to support efficacy in the diagnosis using CBCT, which means that its potential impact to improve patient outcomes and reduce the cost-benefit ratio is questionable. There is concern about an increase in the indiscriminate and unjustified use of CBCT. The principles of "ALARA" (as low as reasonably achievable) should be considered when deciding to take CBCT images because it is now known that any exposure to ionizing radiation it can have potentially harmful effects (38). According to the American Academy of Oral and Maxillofacial Radiology and the American Association of Endodontists, the decision to take CBCT should only be considered "if the intraoral and radiographic 2D clinical examination are inconclusive to detect vertical root fracture" (39). In the European guidelines, described in the Sedentexct project, clinicians should keep in mind that, even if a CBCT image is taken, root fillings limit diagnostic accuracy (40).

As limitations, we found there were only 4 studies with limited data available; even though, we asked the authors for additional information, which could have helped to conduct a complete statistical analysis. Therefore, it is more difficult to draw definitive conclusions. The results could lead to continue a more thorough search on the issue to draw more precise conclusions.

CONCLUSIONS

Based on our findings and the information found in the literature inspected, both tools, DDR and CBCT are useful to diagnose VRF. There were no significant differences between the CBCT and PR ($p>0.05$), though in advanced stages, not in initial or early stages. The research question could not be answered because more and better studies are required. To make an early diagnosis in the initial stages of VRF, current imaging tools, clinical methods, and patient's symptoms must be considered. As a final option, a surgical exploration is required to confirm the presence of a VRF to choose an adequate treatment plan.

RECOMMENDATIONS

Conduct comparative clinical studies and other systematic reviews with more recent literature to provide stronger and more current evidence when comparing CBCT and PR/DDR as a VRF diagnosis tools in initial stages of the endodontic treatment.

ACKNOWLEDGEMENTS

To the Universidad Santo Tomas's Dental School, and Dr. James Gutmann for their support and advice in this study.

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How to cite this article: Hernández-Hernández E, Méndez de la Espriella C, Jimenez-Peña OM. Cone beam tomography and periapical radiographs for early vertical root fractures diagnosis. Systematic review. Univ Odontol. 2021; 40. https://doi.org/10.11144/Javeriana.uo40.cbtp