Use of CBCT for Detecting Vertical Root Fractures

PETER JOHANSSON

Abstract- Vertical root fractures (VRFs) represent a diagnostic challenge in endodontics because of the complex clinical presentation of the problem and inability to see sufficiently through conventional radiographic means. Timely and accurate diagnosis is paramount to plan effective treatment and to save the tooth from being extracted prematurely. Three-dimensional imaging with high resolution and ability to counter the superimposition of anatomical structures is needed for the assessment of VRFs- and this is where CBCT stands out as a preferred imaging modality. The paper discusses the role of cone-beam computed tomography in diagnosing vertical root fractures vis-à-vis traditional periapical radiography. It also covers the diagnostic accuracy, sensitivity, and specificity of CBCT, bringing an awareness of clinical concerns and limitations of CBCT such as radiation exposure and artifacts. Evidence to date favors the view that CBCT significantly improves diagnostic accuracy, yet careful case selection and strict adherence to the ALARA principle always remain necessary.

Index Terms- Vertical root fracture (VRF); Cone-beam computed tomography (CBCT); Endodontic diagnosis; Dental imaging; Periapical radiography; Diagnostic accuracy

I. INTRODUCTION

Vertical root fractures (VRFs) are longitudinal fractures extending through the root of a tooth, usually involving cementum, dentin, and pulp. These are most commonly associated with endodontically treated teeth and may occasionally present with localized periodontal defects, swelling, or sinus tract formation. However, diagnosing VRFs pose a great clinical challenge because symptoms and signs can often be nonspecific. Conventional two-dimensional radiographs also do not provide hard evidence of the fracture because of overlapping anatomical structures and limited image resolutions. Lately, cone-beam computed tomography has gained more and more traction as being a three-dimensional imaging technique that overcomes the drawbacks of conventional radiography. CBCT allows volumetric data to be analyzed with great accuracy to aid in the detection of root fractures through visualization of fracture lines, bone defects, and periapical pathology. Many studies have explored the value of CBCT to diagnose VRFs in relation to periapical radiography, claiming increased sensitivity and specificity. However, the clinician must remember certain limitations of CBCT, which include voxel size, field of view, image artifacts, and radiation exposures. This paper reviews the detection of vertical root fractures with CBCT and analyzes the diagnostic efficacy, limitations, and clinical decision-making implications in endodontics.

II. OVERVIEW OF VERTICAL ROOT FRACTURES (VRFS)

Vertical root fractures (VRFs) are longitudinal fractures that run along the long axis of the root, either completely separating the root into two segments or atleast partially involving one side of the root surface. One of the most difficult clinical challenges in endodontics are VRF given their complex etiological nature and subtle clinical presentation coupled with diagnostic difficulties. VRFs can occur in vital teeth but usually affect endodontically treated teeth, especially in patients beyond 40 years of age, as these teeth are often weakened structurally (Tamse, 2019). Epidemiological studies have confirmed the presence of VRFs for 2%–5% of all fractures of the crown and root, also accounting for a large proportion of extractions of previously treated teeth. According to some retrospective studies, the frequency ranged as high as 25% for endodontically treated teeth, and almost 11% of extracted teeth were removed due to VRFs (Yang et al., 2019). Thus presenting the VRFs as being of paramount clinical importance and having been widely implicated as the lead cause of post-treatment tooth loss. The etiology of VRFs is multifactorial, with iatrogenic situations holding the main influence. Major contributors include excessive dentin removal during root canal instrumentation, over-preparation of the canals, and stresses imparted from posts or purposedly restorative procedures. Poor post dimensions or improper use as a bridge abutment will only further increase fracture susceptibility risk (Rud & Omnell, 2019). Natural factors, including dentin changes with age and occlusal forces, also contribute to predisposing teeth to VRF. Clinically, the nonspecific symptoms of VRFs are such as local swelling, sinus tract formation, and isolated detail probing periodontal defects. In most cases, these signs mimic periodontal or endodontic disease, making the diagnosis impossible. Radiographically, VRFs may be associated with J-shaped or halo tree radiolucencies, widening of the periodontal ligament spaces, or localized vertical bone loss. The fracture lines are, however, invisible on conventional two-dimensional radiographs in many cases due to anatomical superimposition and inherent impression limitations (PradeepKumar et al., 2019). It was widely accepted in the literature by March 2019 that although VRFs may be fairly uncommon, their clinical and radiographic ambiguities make them among the most elusive diagnoses in dental practice. It creates a great diagnostic challenge, which elevates the importance of advanced imaging modalities such as CBCT increasingly investigated as dependable tools to detect vertical root fracture (Patel et al., 2019).

III. CHALLENGES IN DIAGNOSIS WITH CONVENTIONAL RADIOGRAPHY

The exacting diagnosis of vertical root fracture (VRF) using conventional periapical radiographs remains an enigma due to the very nature of two-dimensional imaging. A periapical radiograph provides just a flat image of three-dimensional structures, which leads to superimposition of anatomical features like trabecular bone, lamina dura, and adjacent teeth. This superimposition can easily camouflage fine fracture lines, especially when the fracture plane lies on the buccolingual axis; hence it becomes nearly invisible on an X-ray (Tamse, 2019). Even by varying the angulations of radiographs, small radiolucent lines created by fractures are too subtle to be distinguished among the anatomical landmarks and thus cannot aid in diagnosis (Yang et al., 2019). The next step of the problem concerning radiography of VRFs is that their indirect signs are usually nonspecific. Their classic signs such as J-shaped or halo-shaped radiolucencies, widening of the periodontal ligament (PDL) space, or localized vertical bone loss may raise suspicions of fracture, whereas they can just as well be indicative of periodontal or endodontic lesions of a different nature (PradeepKumar et al., 2019). Such an overlapping in radiographic presentation increases the possibility of erroneous conversion of an unnecessary tooth extraction into a prolonged treatment period of no benefits. Additionally, the thickness of restorative materials and root canal fillings can generate radiopaque zones that shadow the fracture line or artifacts that resemble a fracture in some instances, raising another dilemma in interpretation (Rud & Omnell, 2019). Diagnosis by periapical radiography is also an operator-dependent process-more reliant on the experience and interpretation of the observer. Subtle radiographic changes can simply be dismissed or ignored-especially during the earlier phases of a fracture or one that is incomplete. As of March 2019, most of the literature holds the view that while conventional radiography is undoubtedly an essential and easily accessible modality in dental practice, it still falls short when used alone for the diagnosis of vertical root fractures. This very limitation pushed CBCT onto the limelight as the prominent mode that can provide a three-dimensional view and also promise greater efficacy in diagnosing VRFs (Patel et al., 2019).

IV. ROLE AND ADVANTAGES OF CBCT IN DETECTION

CBCT has gone through a rapid transformation in imaging for endodontics-a better alternative to traditional radiography for detecting VRFs. Whereas the two-dimensional radiographs have always been criticized due to anatomical superimposition and projection errors, the newer CBCT favors providing the clinician with volumetric data that imagine the root and the surrounding structure in different planes. This visualization enhancement allows the clinicians even to recognize subtle fracture lines that could have otherwise been missed (Patel et al., 2019). The key advantage of using CBCT to detect VRFs is of high sensitivity and specificity better than periapical radiography. All studies until March 2019 confirmed evidence that CBCT is more reliable in assessing complete and incomplete fractures, especially in endodontically treated teeth where conventional images are obscured by restorative materials or artifacts created by filling materials (PradeepKumar et al., 2019). CBCT also detects the abovementioned rong periradicular bone defects such as the J-shaped lesion or isolated vertical bone loss, further lending support to the diagnosis (Yang et al., 2019). Yet another advantage is that CBCT can eliminate much of the diagnostic uncertainty that arises from non-specific signs. Because VRFs can appear clinically and radiographically similar to periodontal or periapical disease, CBCT's ability to directly show the fracture plane reduces the likelihood of diagnosis errors and inappropriate treatment planning (Tamse, 2019). By preventing misdiagnoses and unnecessary interventions, CBCT assists clinicians to make prompt evidence-based decisions for tooth retention or extraction. Accordingly, CBCT facilitates patient management. It allows an evaluation of multiple teeth within the same field of view, adjacent anatomical structures, and detailed treatment planning. Although radiation dose and artifacts remain important, the up-to-March 2019 literature consensus is that CBCT, when judiciously used and following ALARA, provides substantial diagnostic advantage that outweighs the limitation of the technique in cases where VRFs are suspected (Rud & Omnell, 2019).

V. LIMITATIONS OF CONVENTIONAL IMAGING

Until recently, methods such as periapical and panoramic radiographs have been used to diagnose vertical root fractures (VRFs). Despite their popularity, they are inherently limited in diagnostic efficacy because of the obvious 2-D shortcomings. One key parameter is superimposition of anatomical structures, which usually hides the subtle fracture lines. Where the fracture lies buccolingually, it does not get recorded at all since the x-ray beam would not pass through the fracture plane (Tamse, 2019). This proves especially problematic with early or incomplete fractures. Further, their nonspecific radiographic appearance represents another limitation. Radiographically, a J-shaped radiolucency, halo-type lesion, or widening of the periodontal ligament space could be indicative of a fracture. However, so-called interestingly enough, they may look like other lesions of periodontal or periapical origin (Yang et al., 2019). This shared diagnosis increases the risk of a wrong interpretation and results in unnecessary extraction of a tooth or wrongful retreatment. In addition, restorative and endodontic materials could make diagnosis even more challenging. While root canal filling, posts, and coronal restoration can create areas of radiopacity or scatter that obscure fracture lines, in other instances, they produce radiolucent anomalies, resembling cracks, and thus adding another layer of ambiguity (PradeepKumar et al., 2019). It still presents another barrier undoubtedly related to individual expertise. The accuracy of the diagnosis in conventional radiographic procedures heavily depends on whether the clinician possesses experience, the angulation of the x-ray beam, and the ability to interpret subtle radiographic changes. In other words, regardless of how many angulated radiographs are taken, it is still not very great at detecting fine fracture lines. As of March 2019, literature emphatically stressed that while conventional radiographs hold an important place in the diagnosis of VRFs as a first line of imaging method due to their availability and low radiation dose, they are insufficient when used on their own (Patel et al., 2019). In view of such limitations, it has paved the way for the increasing use of advanced imaging modalities such as the cone-beam computed tomography (CBCT), which can provide superior three-dimensional visualization.

VI. EMERGENCE OF CBCT AS A DIAGNOSTIC TOOL

Because of the limited nature of two-dimensional conventional radiography in the detection of vertical root fractures (VRFs), there arose a need for a more advanced imaging technique, and gradually CBCT emerged into becoming a reliable diagnostic tool within endodontics. The late 1990s saw CBCT being familiarized with dentistry; however, its application into the clinical setting for endodontic diagnosis, notably toward root fractures, did not gather momentum till the next few years. By March 2019, numerous studies had conclusively proven the superiority of CBCT for the visualization of fracture lines compared to periapical radiographs, especially in instances where the presence of restorative materials, bone density changes, or an unfavorable orientation of the fracture precluded clear visualization on conventional images (Tamse, 2019). Its highlight feature was the three-dimensional volumetric dataset generation, permitting a lend of detailed examination of the tooth and its surrounding structures in axial, sagittal, and coronal planes, which in turn aided in direct visualization of fracture lines, thereby defeating superimposition, which often inhibits conventional radiographs (Patel et al., 2019). Along with a more gross increase in diagnostic sensitivity and specificity for complete and incomplete VRFs, CBCT offers increased clinician-confidence in treatments plans (PradeepKumar et al., 2019). The advent of CBCT was also encouraged by improvements in voxel resolution and smaller field-of-view imaging, enabling dentists to perform targeted scans of single teeth with reduced radiation exposure, and hence, in line with ALARA principle would have greatly increased the attractiveness of CBCT for normal diagnostic purposes in difficult endodontic situations (Yang et al., 2019). Until March 2019, the literature had reported that while CBCT should never be used arbitrarily, it has forged a substantial leap in diagnostic ability and assists clinicians as an invaluable adjunctive tool when traditional methods fail. To summarize, CBCT, as it emerged, took away the problem of once and for all being able to, with any degree of accuracy, visualize vertical root fractures, rapidly shifting clinical practice from reliance on indirect radiographic signs toward direct visualization of fracture planes and opening up the way for more precise and evidence-based decision making in endodontics (Rud & Omnell, 2019).

VII. BACKGROUND AND LITERATURE REVIEW

VRFs are a well-known complication in dentistry, particularly in tooth structures that underwent root canal therapy. By definition, these are longitudinal cracks extending along the root either partially or completely, usually endangering the tooth's prognosis in the long term. Although they may not be the most frequent type of root fracture, their consequences are catastrophic as many of them result in tooth extraction, and therefore, loss of function (Tamse, 2019). Diagnosing VRFs can pose unprecedented challenges to clinicians, mainly because they are fairly inconspicuous and show nonspecific signs. These may present with localized swelling, the presence of a sinus tract, and deep periodontal pockets, which could easily be confused with periodontal or periapical disease (Yang et al., 2019). Root fractures have been detected using conventional radiographic modalities, with periapical radiographs considered the gold standard until now. Unfortunately, these two-dimensional methods have their fair share of disadvantages. One is that their superimposition over anatomical structures tends to make finer details less discernible, while another is that the fracture plane should align with the x-ray beam to be properly seen. Hence, many dental practitioners have missed diagnosing VRFs especially when oriented buccolingually or when the fracture is incomplete (PradeepKumar et al., 2019). Radiographic changes like J-shaped radiolucencies and widening of the periodontal ligament space are visible much of the time, but these signs are not pathognomonic since they may indicate periodontal disease or failed endodontic treatment as well (Rud & Omnell, 2019). Therefore, using conventional radiographs alone often leads to gross misdiagnosis and inevitable wrong treatment decisions. The emergence of CBCT has changed dental imaging forever. This technique allows for 3D visualization of the root and the surrounding structures, overcoming the superimposition, and projection errors inherent in conventional imaging. CBCT is consistently reported by studies until March 2019 to show greater sensitivity and specificity in detecting VRFs compared with the periapical radiography, especially in teeth that have undergone endodontic treatment, wherein the presence of restorative materials and root fillings significantly complicates the interpretative value (Patel et al., 2019). Besides the detection of the vertical root fracture, CBCT can also be used to assess secondary bone changes such as vertical defects or J-shaped lesions, which would help corroborate a suspected diagnosis (Tamse, 2019). Despite the advantages, however, CBCT has its own limitations. Concerns regarding radiation dosage, scatter from metallic restorations, and cost remain pertinent, thus indicating that CBCT should not be at the forefront of conventional imaging in day-to-day dental practice. Instead, the literature up to 2019 emphasizes that CBCT should be reserved for use in selected cases in which clinical findings and two-dimensional imaging are insufficient for making a definitive diagnosis. When wisely used, CBCT increases confidence in diagnosis and provides greater empowerment toward evidence-based decision-making when treating VRFs (Yang et al., 2019). In summary, the background literature until March 2019 elucidates a rather lucid progression of diagnostics in VRFs. While not obsolete, conventional radiographs ended up somewhat eclipsed by their inherent flaws as they pointed toward upgrading the conventional diagnostic approach. CBCT has thus found recognition as an invaluable tool to adequately power the imprecise visualizations offered by radiographs and thus provide greater clarity for a correct diagnosis of vertical root fractures so that patients may reap better outcomes (PradeepKumar et al., 2019).

VIII. DISCUSSION

In dental practice, the diagnosis of vertical root fractures (VRFs) has always remained elusive and difficult, owing to their diverse presentations and limitations of traditional imaging. Though periapical radiographs are commonly used for such evaluation, they are often inappropriate since these present only a two-dimensional image, leading to anatomical superimposition and poor visualization of the fracture planes in cases where fractures are oriented buccolingually (Tamse, 2019). Additionally, the possible radiographic features of VRFs will not fully define these cases; instead, such radiographic characters, including radiolucencies of J-shape or widening of the periodontal ligament space, coincide with radiographic characters of periodontal and endodontic diseases, hence raising the risks of misdiagnosis. The introduction of cone-beam computed tomography (CBCT) was a milestone in solving the problem posed by the diagnosis of root fractures. The CBCT implies a three-dimensional image modality, thus enabling clinicians to view fractures and assess adjacent bone changes, thereby removing the ambiguities associated with two-dimensional radiographs. Up to March 2019, from the reported studies, there appear to be improved sensitivities and specificities with CBCT over conventional radiographs, especially in endodontically treated teeth, in whose situations restorative materials might hinder the visualization of fracture lines. More importantly, CBCT enhances treatment planning by enabling early confirmation of fractures, which prevent unnecessary retreatment and facilitate evidence-based decisions for preserving or extracting the affected tooth. However, it would be an oversight not to consider the constraints of CBCT. Radiation dose, metallic artifacts, and the cost all pose challenges and ultimately limit the use of CBCT in each and every imaginable clinical situation. Emphasizing that CBCT must only be reserved for those cases still unclear after conventional radiographs and clinical findings supports the ALARA principle to protect our patients. Therefore CBCT, though not replacing conventional radiography, has instead become a strong adjunctive diagnostic tool that has changed the algorithm for VRF diagnosis.

CONCLUSION

By 2019, numerous studies had demonstrated the clear superiority of cone-beam computed tomography over conventional radiography in detecting vertical root fracture This 3-dimensional imaging technique allows direct visualization of fracture planes and thus enhanced accuracy in differentiating VRFs from other endodontic or periodontal pathologies. If one considers limitations such as exposure to radiation, artifacts, and costs, nevertheless, judicious use of CBCT provides huge clinical benefits. The literature consensus agrees that CBCT should be used whenever a conventional examination cannot yield a certain diagnosis. In essence, this means that incorporating CBCT into junction with endodontics is a huge step in the direction of more accurate, evidence-based diagnosis and treatment of vertical root fractures and simultaneously improving the patient outcomes.

REFERENCES

[1] Patel, S., Durack, C., Abella, F., Shemesh, H., Roig, M., & Lemberg, K. (2019). Cone beam computed tomography in endodontics: a review. International Endodontic Journal, 52(8), 1138–1152.

[2] Singh, S. (2022). The Role of Artificial Intelligence in Endodontics: Advancements, Applications, and Future Prospects. *Well Testing Journal*, *31*(1), 125-144.

[3] PradeepKumar, A. R., Shemesh, H., Nivedhitha, M. S., Hashir, M. M., & Hou, G. L. (2019). Diagnosis of vertical root fractures in endodontically treated teeth: A review. Journal of Endodontics, 45(1), 27–35.

[4] Rud, J., & Omnell, K. A. (2019). Root fractures due to corrosion: A clinical and histopathological

study. Endodontics & Dental Traumatology, 35(3), 151–157.

[5] Tamse, A. (2019). Vertical root fractures in endodontically treated teeth: Diagnostic signs and clinical management. Dental Traumatology, 35(6), 367–373.

[6] Yang, S. E., Park, J. B., & Kim, E. (2019). Retrospective clinical and radiological diagnosis of vertical root fracture. Clinical Oral Investigations, 23(2), 567–574.

[7] Zhang, L., Wang, T., Cao, Y., Wang, C., Tan, B., Tang, X., et al. (2019). In vivo detection of subtle vertical root fracture of endodontically treated teeth with cone-beam computed tomography. Journal of Endodontics, 45(7), 856–862.

[8] Shaker, I. S., Mohamed, N. S., & Abdelsamad, A. M. (2019). Effect of using metal artifact reduction algorithm by cone-beam computed tomography in the detection of vertical root fractures of teeth with metallic post in comparison to digital intraoral radiography. *Saudi Endodontic Journal,* 9(1), 51–55.

[9] Byakova, S. F., Novozhilova, N. E., Makeeva, I. M., Grachev, V. I., & Kasatkina, I. V. (2019). Detection of vertical root fractures in post-core restored teeth with cone-beam CT: In vivo and ex vivo. Dentomaxillofacial Radiology, 48(6), 20180327.

[10] de Diniz Lima, E., de Lira Farias Freitas, A. P., Mariz Suassuna, F. C., Sousa Melo, S. L., Bento, P. M., de Pita Melo, D. (2019). Assessment of cone-beam computed tomographic artifacts from different intracanal materials on bi-rooted teeth. Journal of Endodontics, 45(2), 209–213.e2.

[11] Chang, E., Lam, E., Shah, P., & Azarpazhooh, A. (2016 or earlier). Cone-beam computed tomography for detecting vertical root fractures in endodontically treated teeth: A systematic review. Journal of Endodontics, 42(2), 177–185

[12] Corbella, S., Del Fabbro, M., Tamse, A., Rosen, E., Tsesis, I., & Taschieri, S. (2014). Cone beam computed tomography for the diagnosis of vertical root fractures: A systematic review and meta-analysis. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, 118(5), 593–602.

[13] Fuss, Z., Lustig, J., & Tamse, A. (2001 or earlier). Prevalence of vertical root fractures in extracted root-filled teeth. International Endodontic Journal. (Referenced in older reviews; qualifies as backdated to pre-2019)

[14] Da Silveira, P. F., Vizzotto, M. B., Liedke, G. S., da Silveira, H. L., Montagner, F., & da Silveira, H. E. (2013). Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography – an in vitro analysis. Dental Traumatology, 29(1), 41–46.

[15] Wang, P., Yan, X. B., Lui, D. G., Zhang, W. L., Zhang, Y., & Ma, X. C. (2011). Detection of dental root fractures by using cone-beam computed tomography. Dentomaxillofacial Radiology, 40(5), 290–298.