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CRACKED TEETH – CLINICAL AND RADIOLOGICAL DIAGNOSTIC ASPECTS

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Abstract: (1) *Background*: Cracked teeth manifestations are variate from craze lines to vertical root fractures. Vertical root fractures of endodontic treated teeth are often a cause of tooth extraction. The aim of the study was to evaluate the clinical and radiological features of tooth fractures in adult patients presented for dental treatment in a faculty clinic (2) *Methods*: In the retrospective study all dental charts of patients presented for dental treatment in the Oral Rehabilitation clinic between October 2019 and October 2020 were included. Data collected included number of fractured teeth, types of fractures, types of dental restorations, incidence of tooth fractures and their correlation with contributing factors; (3) *Results*: A total of 73 of dental patients were included; The most important factor associated with tooth fractures was endodontic treatment (43% from endodontic treated teeth had crown fractures and 29% had root fractures). Other factors associated with tooth fractures were dental posts, bruxism and full coverage crowns. (4) *Conclusions*: Common factors associated with tooth fractures were endodontic treatment, extensive carious destruction and dental posts. The core of prevention for destructive tooth fractures is a better diagnostic and prognostic of tooth fracture before the endodontic treatment and a cuspal protection through full crown coverage of all endodontic treated teeth.

Keywords: cracked teeth, crown tooth fracture, vertical root fracture, endodontic treatment, bruxism

1. Introduction

Fatigue tooth fractures have multiple aspects, from cervical V-shaped lesions named abfractions to tooth fractures of cusps, crown, or root that occur unexpectedly, without a traumatic factor. Cracked teeth are defined as fine disruptions of enamel, dentine, or cementum surfaces, of unknown depth or extension [1]. The incidence of cracked teeth has increased significantly in the last decade [2,3,4]. A study on the incidence of root fractures published in 2017 showed that in the endodontic clinic, the frequency of fractured teeth was much higher than in a general dentistry office [5]. The American Endodontic Association (AAE) confirmed this trend, through the 49% of 941 endodontists reporting an increase in cracked teeth and vertical root fractures compared to previous decades [6].

The etiological factors considered by AAE for cracked teeth were deficient occlusion, bruxism and parafunctional habits, and the wedge effect combined with repetitive occlusal forces. After the appearance of incipient fissures, these develop and turn into cracks. If left untreated, these larger cracks can propagate into fractures that lead to catastrophic failures and tooth loss, such as in the case of a vertical root dental fracture [7,8]. An increase in the incidence of these fractures in the context of the COVID-19 pandemic stress was noticed [9,10], but also in the context of the stress of war and the economic crises that are spreading around the world. At the beginning of the COVID-19 pandemic in 2020, an article in USA Today reported that endodontists were seeing twice as many cracked teeth as in the previous year [9]. Besides that, the ADA Huddle reported in 2021 an increase in dental injuries caused by pandemic-related stress [10]. Another article compared the frequency of fractured teeth in a private endodontic practice over three years (2019, 2020, and 2021), showing a significant increase in the incidence of cracked teeth in 2020 and 2021 compared to 2019 for people older than 40 years [11]. Regardless of the direct or indirect causes, the diagnosis of cracked teeth was already widespread before the pandemic and has subsequently increased since then. Dentistry is in a timeframe when cracked teeth and catastrophic root fractures should be part of almost every differential diagnosis of toothache.

The factors considered for the assessment of fatigue fractures presented in 2024 by Popescu et al 2024 [4] combine the criteria used by Ellis et al. [12] and Bhanderi et al [13]. These factors imply an increase in the value of occlusal overload, such as prolonged unilateral chewing, reduction in the number of teeth, rotation and inclination of the fractured tooth, isolated tooth, and finally, sleep or awake bruxism. Other factors reduce the resistance of the tooth to occlusal forces, such as non-iatrogenic ones that refer to the tooth changes produced with age (increased fatigue of the dental tissues, loss of dentin elasticity, and an increase in the number of restored teeth). The iatrogenic factors considered are excessive removal of dental hard tissues during root canal treatment, the use of a high concentration of hypochlorite during root canal treatment, the presence of large dental restorations without cuspidal protection, and the use of materials with coefficients of thermal expansion and mechanical properties different from those of teeth [4].

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Clinical diagnostic techniques used for the identification of cracked teeth are inspection, palpation, percussion, biting tests on each cusp of the tooth, and periodontal probing [6]. Vitality tests through electric pulp testing and cold testing, dye staining performed before or after restoration removal and transillumination to identify disruptions in light transmission through enamel and dentine are other clinical techniques to diagnose cracked teeth. Radiological exams to use are periapical exposure of the tooth on film or radiovisiography and cone beam computer tomography (CBCT) [6].

Clinical signs of cracked teeth are pain triggered on biting, swelling, sinus tract presence, sensibility to percussion, palpation tenderness, increased tooth mobility, and periodontal narrow isolated probing of 6 mm or higher [6,8]. Radiological signs of the cracked teeth and fractured roots visible on periapical radiographs are visible fracture or root separation, J-shaped defects, extensive radiolucency of 5mm or more, lateral radiolucency with a widened periodontal space, and a furcal radiolucency that could extend to the middle 1/3 or entire root length [6,8]. On CBCT images, the bone loss near the tooth is associated with an isolated periodontal defect in the absence of periodontal disease [14]. Also, cortical bone loss is considered a sign of root fracture [15]. A CBCT with a small field of view (FoV) can help identify isolated bone loss near a tooth, but raising a surgical flap to visualize the fracture with an operating microscope is considered the gold standard [6].

Treatment options for cracked teeth depend on the moment of diagnosis. The earlier a diagnosis is made and a fracture found, the higher the treatment success. A fractured tooth without separate fragments could remain in the mouth, but it will always need a crown [16]. Cracked teeth with reversible pulpitis and without periapical inflammation had a high likelihood of survival as vital teeth if crowned at once. Also, treated teeth with onlays had lower survival rates than those with full coverage crowns after 5 years from fracture [16]. Early crown placement on endodontically treated, non-cracked teeth was associated with a higher survival rate than non-crowned teeth restored only with a filling [17].

The study aimed to find the clinical and radiological features of tooth fractures in adult patients presenting for dental treatment at a dental faculty clinic over 1 year.

2. Materials and method

The retrospective study was conducted between October 2024 and June 2025 and included data on patients presented at the Oral Rehabilitation Clinic of UMF Craiova between October 2019 and October 2020. The results were collected in a physical format by analyzing data from the patient dental charts as anamnesis, clinical examination, paraclinical examinations, radiographs, orthopantomography, periapical radiography, and clinical photographs of the patients' oral cavity.

The study followed the Declaration of Helsinki, all dental charts included in the study having the signed informed consent of the patients for dental exams and for dental treatments. The study was approved by the Ethics Committee of the University of Medicine and Pharmacy of Craiova, no. 63/29.01.2024.

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Inclusion criteria:

- Adult dental patients aged 18-75 years;
- Healthy patients or patients with systemic diseases that classify them in terms of risk ASA I or ASA II;
- Patients with/without bruxism.
- Exclusion criteria:
- Pediatric dental patients;
- Patients with systemic diseases of ASA III or higher;
- Pregnant or lactating patients.

The variables included in this study were:

- demographic data: age, gender,
- presence of bruxism,
- number of fractured teeth,
- number of restored teeth,
- type of restoration: filling, crown, DCR with crown, bridge.

Statistical analysis

All data were included in Microsoft Excel, and a simple statistical analysis was used accordingly (Microsoft Excel 2019, Microsoft, Redmond, Washington, USA).

3. Results

A group of 73 patients with a mean age of 49 ± 11.7 years participated in the retrospective study. Of these, 45 patients (62%) were female, aged 22-67 years, and 28 patients (38%) were male, aged 20-62 years. Of the total number of female patients examined, 30 (66%) were from urban areas, and the remaining 15 (33%) were from rural areas. Similar percentages were also observed among male patients, of whom 64% were from urban areas and 36% from rural areas (Table 1).

In the study group, 53% of patients presented for periodic check-ups, 27% for treatment of carious lesions, and the remaining 20% for prosthetic treatment. In the examined study group, the presence of simple caries was found in 82% of the patients, complicated caries in 66% of women and 64% of men, a total of 67% of the patients. Crown fractures were present in 44% of women and 35% of men, 41% of the total number of the examined patients. And root fractures were found in a percentage of 15% in women and 25% in men, a total of 19% of the total number of the examined patients.

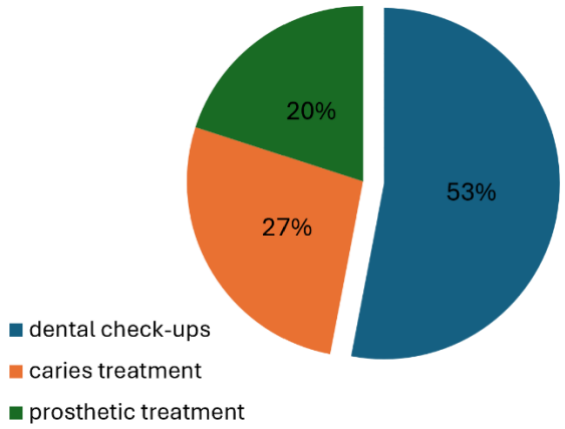

Figure 1. Motivating factors for dental visits in the study group.

Bruxism was present in 20% women and 21.43% men (Table 1).

Depending on the age group, in the group of patients, 6 fractures were observed in the 20-29 age group, 18 fractures in the 30-39 age group, 13 fractures in the 40-49 age group, 9 fractures in the 50-59 age group and 7 fractures at the age greater than or equal to 60 years. Of the total number of teeth with coronal caries, only 36% were fracture-free; the remaining 44% also had coronal fractures, and 20% had root fractures. Extensive coronal fillings are an important risk factor for fractures. Of the total number of teeth in the

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group of patients with coronal fillings, 76% were fracture-free; the remaining 24% had coronal fractures.

Factors favoring fracture development are common among the group of patients. In the first place is endodontic treatment, which is found in 55% of women and 64% of men, in total 59% of the examined patients. Crowns are found in 43% of patients, 37% of women and 50% of men. The crown-root reconstruction was found in only 22% of women and 21% of men, in a total of 22% of the examined patients. Of the total number of patients, 43 patients (59%) received endodontic treatment, 16 patients (22%) received a crown-root reconstruction, and 31 patients (43%) received crowns (Table 1).

Table 1. Demographic and clinical data.

Parameter	Category	W	M	Total
No		45 (62%)	28 (38%)	73 (100%)
Residence	Urban	30 (66.67%)	18 (64%)	48 (65%)
	Rural	15 (33.33%)	10 (36%)	25 (35%)
Bruxism	Present	9 (20%)	6 (21.43)	15 (20.55)
	Absent	36 (80%)	22 (78.57%)	58 (79.45%)
Tooth fractures	Crown fractures	20 (44%)	10 (35%)	30 (41%)
	Root fractures	7 (15%)	7 (25%)	14 (19%)
Treatments	Endodontic treatment	25 (55%)	18 (64%)	43 (59%)
	Metallic crown-root reconstruction	10 (22%)	6 (21%)	16 (22%)
	Full coverage crown	17 (37%)	14 (50%)	31 (43%)

Among the patients examined, 53 tooth fractures were present in the group, from which 30 simple crown fractures, 11 complicated crown fractures, and 12 complicated root fractures. In total, 13 horizontal, 15 oblique, and 25 vertical fractures were found, for a total of 53 fractures. Of the total crown fractures (41), 47% were vertical, 19% were horizontal, and 34% were oblique. Of the total root fractures (12), the vertical ones represented 50%, the horizontal fractures 42% and the oblique fractures 8%. Of the total of 12 root fractures, 3 fractures were located in the cervical third (25%), 4 fractures located in the middle third (33%) and 5 fractures in the apical third (42%). Of the total number of patients with endodontic treatment in the patient group, it was observed that 43% had cervical fractures, 29% had root fractures and only 28% were teeth free of fracture (Table 2).

Table 2. The direction of the fracture line in the fractured teeth.

Fractures	Horizontal	Oblique	Vertical	Total
Crown	8	14	19	41
Root	5	1	6	12
Total	13	15	25	53

Of the total number of patients presenting with crown-root metal reconstruction, only 56% were fractures free; the remaining patients presented root fractures. The presence

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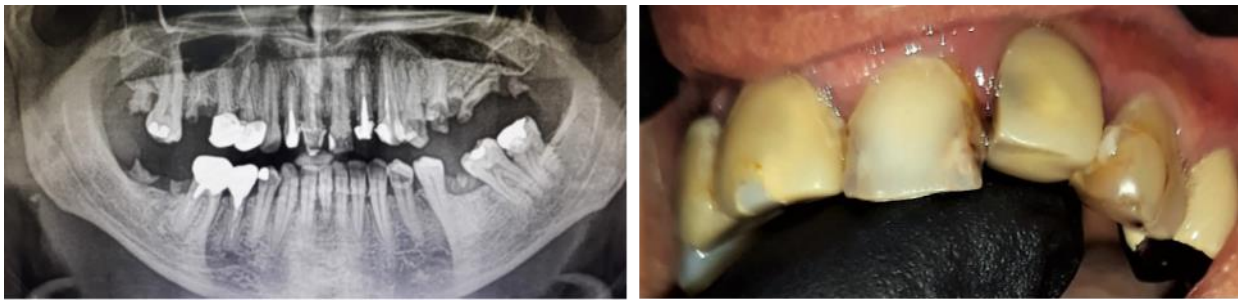
of the full coverage crown represented a protective factor for fractures compared to dental post. However, 34% of patients wearing crowns presented root fractures, while 37% presented fractures of the esthetic part of the crown and only 29% had fracture-free teeth. The presence of the dental post is a factor favoring the development of fractures (Figure 2).



(a) (b)

Figure 2. A patient with a vertical root fracture tooth (22) with a dental post and a porcelain fused to metal crown. (a) orthopantomography with visible 22 tooth; (b) clinical image of the mobile tooth with porcelain fused to metal crown.

(a) (b)

Figure 3. A patient with a vertical root fracture tooth (22) with a dental post and a porcelain fused to metal crown. (a) clinical image of the remaining root; (b) The extracted fractured tooth and the dental post cemented to porcelain fused to metal crown.

After tooth extraction and visual examination of the root fragments, it was found that the tooth in question had suffered a vertical root fracture, with an oblique cervico-apical direction (Figure 3).

The cause of the fracture was:

- the presence of caries recurrence that undermined the resistance of the already undermined tooth structure and produced a vertical root fracture;
- a 20-year-old porcelain fused to metal crown, which, due to the existing caries recurrence, no longer presented a good marginal fit.

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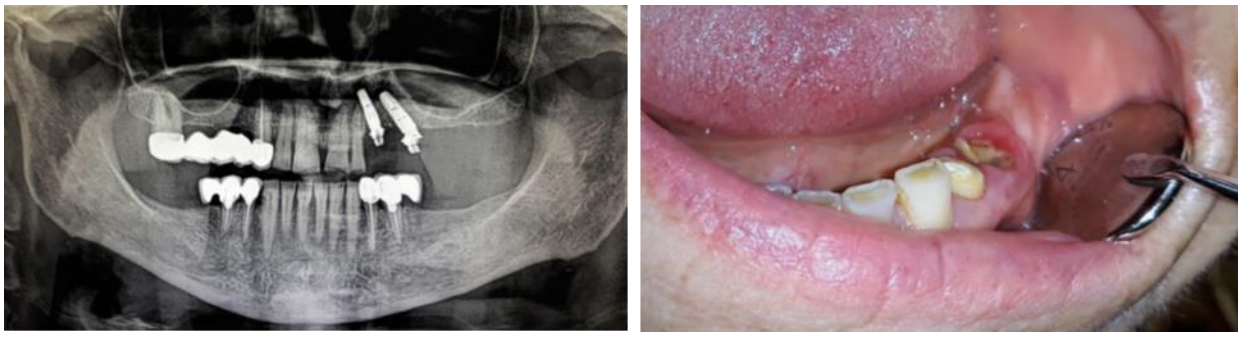

(a) (b)

Figure 4. Teeth fractured because of a higher occlusal force produced by an implant bridge in maxillary arch (a) Bridge in quadrant 3 with abutment teeth 3.4 and 3.5 and extension replacing tooth 3.6. (b) Following the root fracture of tooth 3.5 and removal of the bridge, a coronal fracture of tooth 3.4 was also found, which produced the bridge mobilization.

Rigid occlusal contacts as in implant bridge visible in figure 3 produced fractures in the teeth sustaining the opposing bridge in the lower jaw. The bridge in quadrant 3 had as abutment teeth 3.4 and 3.5 with an extension replacing tooth 3.6, forcing the post teeth to sustain the higher occlusal forces from missing first molar. Following the root fracture of tooth 3.5 and removal of the bridge, a coronal fracture of tooth 3.4 was also found, which determined the mobilization of the bridge. Since the two abutment teeth of the bridge with extension, 3.4 and 3.5, were fractured and the patient wanted a quick rehabilitation, the decision was made to extract both teeth and insert two post-extraction implants with immediate prosthetics. Following the anamnesis, clinical and radiological examination, the following aspects were found: widening of the peri-radicular space indicating occlusal overloading of tooth 3.5, vertical root fracture of tooth 3.5 and horizontal coronal fracture of 3.4 (Figure 4).

A tipical cone beam computer tomography image of a maxillary premolar fractured that includes the radiological characteristics of the root fractures (isolated bone loss adjacent to root) is presented in Figure 5.

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Figure 5. A vertical root fracture with a mesio-buccal bone loss in a maxillary first premolar of an adult man of 49 years old.

4. Discussion

The retrospective study focused on the presence of tooth fractures and on contributing factors that favor the occurrence and development of coronal, radicular, and coronoradicular fractures. This study involved adult patients who presented to a dental faculty clinic over 1 year. Motivating factors for patients to present to the dentist were not always linked to their real problems. Approximately half of the patients presented for periodic control, while other reasons were treatment of carious lesions and prosthetic treatment. However, no one presented for treatment of tooth fractures, even though they were present in the majority of patients in the study. Motivating factors to visit a dentist are current complaints such as a toothache or an esthetic problem, but also a preferance for minimal invasive treatment as laser, a cost bonus and the trust in dentist [18].

Of the factors favoring the initiation and development of fractures, only three were found: endodontic treatment, crown coating, and the dental post, regardless of the material used or the correctness of the marginal fit. The presence of factors favoring a high incidence of fractures was consistent with the results regarding the total number of fractures in the patient group. The decision to restore a tooth with a full coverage crown after endodontic treatment is very important in tooth survival. Also, for cracked endodontic treated teeth that could be recovered, this decision is mandatory [19].

Observation without restorative treatment may be appropriate for asymptomatic cracked teeth. In cracked teeth with vital dental pulp, direct restorations without cuspal coverage may substantially increase the risk of pulpal complications and tooth loss compared with full-crown restorations. For cracked teeth that have undergone root canal treatment, full-

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crown restoration is strongly recommended [20].

Endodontic treatment was the most common contributing factor encountered in the patient group since it was encountered in more than half patients. A study on the long-term outcomes of endodontic treatment reported high tooth survival and sustained symptom-free function. The main prognostic factors associated with extraction were deep periodontal pockets (> 6 mm), preoperative apical radiolucency, and lack of occlusal protection, such as not using a night guard [21]. Since a lot of patients are stressed and have bruxism [22], using an occlusal appliance is important to preserve the endodontic treated teeth as well as the cuspal coverage by full crown [23]. The favorable long-term prognosis of endodontically treated teeth should encourage clinicians to consider primary root canal treatment when deciding whether a tooth with pulpal and/or periapical disease should be preserved or extracted and replaced with an implant [21].

Teeth treated with dental posts and full coverage crowns presented a high percentage of coronal and root fractures. Possible explanation should be the association of dental posts and crowns with endodontic treatment. Also, most of the time, the crowns either have a poor marginal adaptation or their occlusal adaptation is not optimal, which leads to overloading of the tooth and eventually to its fracture. In a clinical study on endodontic treated teeth outcome with matched control, vertical root fractures were strongly associated with unilateral chewing, hard-food consumption, metal posts, and protrusive occlusal interferences. In endodontically treated teeth, evaluating occlusal patterns, chewing habits, and post type is essential. Early detection and management of these factors may lower the risk of root fractures and improve long-term outcomes [24].

In patients in whom voluminous coronal caries cavities were identified, the fracture percentage was similar to that of patients who presented voluminous coronal fillings. This percentage is due to the presence of voluminous carious processes that can be the starting point for a coronal and/or root fracture, because the carious process undermines the resistance of the remaining dental hard tissue, which becomes overloaded [25]. The probability that a tooth with a carious process will develop a fracture increases with the increase in the depth of the carious process, the increase in the process on the surface and the decrease in the amount of remaining healthy dental tissue. For reasons similar to those mentioned above, a high percentage for the occurrence of fractures in teeth with voluminous fillings is also explained. The deficient marginal closure of voluminous fillings, the increase in porosity with the increase in their age, secondary caries and caries recurrences occurring under the voluminous filling are added [25]. Large cavities like MOD (mesial-occlusal-distal) in molars resulted from voluminous caries can reduce cuspal stiffness by up to 63%, increasing the risk of cuspal fracture. An in vitro study on extracted molars evaluated the fracture resistance of MOD cavities restored with direct composite resin. Their results showed that cavities 3 mm deep or less can be restored to near-physiological fracture strength with direct composite restorations, whereas cavities 5 mm deep or more cannot. Cusp thickness did not significantly affect

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fracture resistance in molars restored with direct composite [26].

During the clinical and paraclinical examination of the patients, data were also recorded regarding the direction of the coronal fracture line. Coronal fractures with an oblique direction (mainly at the cusps of the lateral teeth and the incisal angles of the upper front teeth) were the most encountered, while vertical direction (mainly at the front teeth represented by enamel cracks) and horizontal fractures (during accidents or direct blows) were fewer. At the root level, half of the fractures that occurred were horizontal (apical fractures, treated by apical resection), almost half vertical and very few were oblique. The latter two were treated by extraction, the teeth being irretrievable. These percentages suggest that the vast majority of root fractures result in tooth loss because the affected teeth are very difficult to treat and become irretrievable [25].

Vertical root fracture can originate at any root level, but most commonly originate at the apex and can progress to the rest of the root [7]. If the starting point is other than the apical one, for example in the middle or coronary third of the root, then the fracture can propagate in any direction, either towards the coronary or the apex. Vertical root fractures originating in the apical region of the tooth propagate most often in the buccal-oral direction, compared to fractures originating in the cervical region of the root that can propagate in different directions [27]. In the transverse plane, the fracture originates at the level of the root canal and over time extends to the external wall of the root, on the buccal/oral surface (incomplete fracture) or on both sides (complete fracture). Both types of fractures, in general, have a buccal-oral direction. The mesio-distal orientation of the vertical fracture line is rare. The fracture lines most often have a longitudinal direction, parallel to the long axis of the root, but in some cases the direction may differ, being influenced by the root convexities and the direction of action of the occlusal forces [28].

The increased number of fractures recorded in the study group may be due to the fact that the study was conducted during the Covid 19 virus pandemic. During this period, the stress that patients felt associated with the closure of dental offices and the postponement of medical check-ups caused an increase in the number of coronal-radicular fractures [2-4]. The Sars-Cov2 pandemic has doubled the number of cases of crown-root fractures presented to the dental office for diagnosis and treatment [4].

In a recent review about vertical root fractures in root filled teeth, the etiological factors included predisposing and contributory factors [28]. Between predisposing factors, most are related to tooth properties like structural integrity, the existance of cracks and fractures before the treatment, anatomy and root canal morphology and changes in biomechanical properties of dentine as in aged teeth. Besides these factors, diet, parafunction, an unfavorable occlusal arrangement of teeth in the arch and tooth location predispose also to the development of vertical root fractures. There are also some iatrogenic factors that contribute to the vertical root fractures. These are the root canal treatment with excessive removal of dentine, or with a prolonged time for disinfectants like hypochlorite, or with a poor execution of the final restoration of the root canal treated tooth [28].

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Vertical root fractures occur most often in root-filled premolars and molars [29]. Although several etiological and predisposing factors have been proposed, the most important contributors remain unclear. Early-stage symptoms and clinical signs are often subtle, making diagnosis difficult. CBCT may help identify the radiographic pattern of periradicular bone loss characteristic of vertical root fractures [30,31]. It is important to note that diagnosing vertical root fractures by computed tomography is challenging because these lesions usually occur in devitalized, root-filled teeth, often restored with posts. Root-filling materials, sealers, posts, coronal restorations, and full-coverage crowns can interfere with the X-ray beam and create imaging artifacts that obscure root fractures [30]. For a better interpretation of images, artificial intelligence is used now in diagnosing root fractures [32].

Since a vertical root fracture could be prevented if the cracks in the tooth are identified before endodontic treatment, modern techniques could be used to diagnose cracked teeth, especially enamel cracks. Among these are magnification with a clinical microscope (ideal 16X), transillumination (FOTI, DiFOTI systems), quantitative light-induced fluorescence with blue light of wavelength 405 nm (QLF), near-infrared laser (for example diode laser with 810 nm wavelength), SSOCT (swept source optical coherence tomography) with an intraoral end and near infrared wavelength of 1300 nm, near-infrared fluorescence (ICG-NIRF), infrared thermography, ultrasonic imaging systems [33,34]. All types of images, but especially radiological ones, could be interpreted by advanced artificial intelligence systems with object detection-based algorithms like RCNN, YOLO, FCN or Seg-Net [35]. Another clinical diagnostic method called InnerView, based on quantitative percussion diagnostics (QPD) turns gentle percussion taps into measurable data about structure of the tooth and quantify the internal mobility in the tooth [36].

Several measures during endodontic treatment can reduce the risk of vertical root fracture. Before treatment, the clinician should carefully assess factors that influence fracture resistance, including the remaining tooth structure, number of residual walls, presence of pre-existing cracks, and root canal morphology [37]. Occlusion should also be evaluated, especially parafunctional habits such as bruxism, occlusal interferences, and the overall occlusal scheme. When parafunction is present, patient education, an occlusal splint, and, when indicated, re-establishment of canine guidance may help reduce excessive biomechanical stress on the teeth [28]. For cuspal coverage of root-filled teeth, cast gold and modern monolithic all-ceramic materials, combined with a carefully executed bonding protocol, allow minimal preparation of the remaining tooth structure. Depending on the number of residual walls and the amount of tooth tissue remaining, an onlay may be the preferred option because it improves stress distribution and preserves bonding substrate after endodontic treatment. Root-filled teeth should also be avoided as bridge or denture abutments whenever possible to limit additional functional loads and stress [28].

5. Conclusions

Vertical root fractures are a complication of root canal treatment that may lead to tooth

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extraction. Common factors associated with crown and/or root fractures included endodontic treatment, full-coverage crowns, extensive carious lesions, large restorations, and dental posts. Patients with these factors showed a higher number of tooth fractures. The increased fracture rate observed in this group may be related to the COVID-19 pandemic, when stress associated with dental office closures and delayed check-ups may have contributed to more vertical root fractures.

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Define data availability restrictions.

Ethics statement

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