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Review Article

Horizontal root fracture in posterior teeth without dental trauma: A diseased condition with special characteristics

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Horizontal root fractures (HRF) were observed mostly in the anterior teeth of young adults due to dental injury. However, HRFs in posterior teeth (PHRF) without dental trauma cannot be neglected. The etiology and risk factors of PHRF were unclear. Lower premolars and palatal root of maxillary molars were particularly affected, indicating the specificity of this diseased entity. PHRF were mainly reported in Asian population, suggesting possible racial difference. Whereas most PHRF teeth showed symptoms mimicking endodontic and periodontal lesions, some affected teeth were asymptomatic. Periodontal pocket, soft tissue swelling, chronic pain or discomfort during mastication were commonly noted. Diagnosis of PHRF depended on thorough clinical examination, radiographic images or exploratory surgery. Intracanal bleeding and electronic apex locator confirmation during endodontic treatment were also useful for diagnosis. Flexible splinting, endodontic/periodontal treatment or root amputation were treatment strategies to preserve the fractured teeth. The aim of this narrative review is to summarize the demography, tooth and root distribution, diagnostic methods, etiology and

Abbreviations: Horizontal root fracture, HRF; Posteior horizontal root fracture, PHRF; Vertical root fracture, VRF; Cone-beam computed tomography, CBCT; Field of view, FOV.

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possible related factors, clinical features, radiographic characteristics, and the treatment schemes of PHRF without dental trauma. A better understanding and identification of this particular root fracture could be achieved. The diagnostic tools and practical management are useful for clinical guides.

Introduction

Tooth and root fractures could be categorized into different diagnosis based on the origin, direction and the extending area of the fractures. Cracked tooth is featured by the crack, which originated from the crown portion and may propagate into root structure.[1,2] Vertical root fracture is characterized by the fracture line parallel to the long axis of root.[3,4] Horizontal root fracture (HRF) is defined as the fracture line which extends transversely or obliquely across the long axis of the root.[5] HRF in traumatized teeth occurred predominantly in the anterior teeth of young adults due to dental injuries.[6,7] HRF in posterior teeth (PHRF) were not uncommon and some of them may still be related to severe impact trauma. However, several reports illustrated HRF in posterior teeth without accidental events.[5,8–16] The patients were not aware of a clear causative incident that may lead to the PHRF. PHRF were also reported and followed during the maintenance phase of periodontal therapy.[17] Thus, not only endodontists, but also periodontists or general dentists may encounter this particular type of root fracture. Misdiagnosis may potentially lead to medical legal issues or the progression and extraction of affected teeth.

The common clinical symptoms and signs of PHRF were soft tissue swelling, tenderness to percussion, periodontal pocket, chronic and intermittent pain during mastication.[8,11–13,15] Some of the root-fractured teeth could be asymptomatic and existed even without the patients' awareness.[9,10,16] PHRF were not easy to diagnose and treat in the early stage, due to no history of traumatic dental injuries or asymptomatic. The symptoms and signs may mimic periodontal or endodontic diseases.[11,13] Accurate diagnosis of root fractures would depend on the knowledge of dentists and thorough examinations.

Most of the publications focused on the description of HRF in anterior teeth due to traumatic fractures. However, PHRF without dental trauma appeared to be a new diseased entity with clinical challenge. Only a few case reports or case series had been published.[5,8–13,15,16] The subject was scarcely summarized and discussed. The actual causes and prognosis of PHRF were still unclear. Thus, the aim of this article was to review the demography, tooth and root distribution, diagnostic methods, etiology and possible related factors, clinical features, radiographic characteristics, and the treatment schemes of PHRF without dental trauma, which were described in the past and latest studies. The recognition and better understanding of this peculiar entity are quite urgent. The value of this article was to provide an informative narrative review and the detection of this specific and unique type of root fracture.

An electronic search was undertaken for English language articles published from 1994 until 2021. The search terms for each aspect of PHRF were entered into the following databases: MEDLINE, PubMed, and Google Scholar. The inclusion criteria were systematic reviews, retrospective cohort studies, demographic research, clinical studies, case reports, and case series written in English. The exclusion criteria were in vitro, ex vivo, and animal model studies. The literature retrieved was screened independently by two researchers. All titles, abstracts, and full texts were reviewed for the inclusion and exclusion criteria. Disagreements regarding the inclusion or exclusion of the retrieved studies were resolved following discussion between the 2 researchers. The data collection from patients with PHRF at the Dental Department of the National Taiwan University Hospital was approved by the Ethics Committee of the National Taiwan University Hospital, Taipei, Taiwan. Some relevant cases are shown in the figures of this article.

Demography

Gender and racial

Most of the literatures related to PHRF without dental trauma were case reports and only provided limited information.[8–12,14–16] A case series collected 5 male and 7 female patients with HRF in posterior teeth.[13] Another study presented 13 male and 11 female patients during a 10-year period.[5] Due to the small case numbers, it seems no gender preference was discovered so far. Racial (mainly Chinese) is also another possible influencing factor and should be further addressed in different countries.

Age at diagnosis

Most of the patients were older than 40 years old when they were diagnosed with PHRF without dental trauma.[5,9–15] The relationship between the patient's age and the risk of root fracture had been highlighted.[11] The dentition of the elder patient may be predisposed to root fractures due to the changes in dentin elasticity, increased restorations and the effect of long-term occlusal forces during mastication.[18,19] The demographic data reported by the past literatures were presented in Table 1, with the patients' age ranging from 41 to 78 years old. Only 1 case of a 16 year-old patient was reported.

Table 1 Demography, tooth and root type and diagnostic methods of horizontal root fracture in the posterior teeth (PHRF) without dental trauma reported by the past literatures.

Literature	Gender	Age at diagnosis	Racial	Tooth and root type	Diagnostic methods
Jerome, 1994[8]	Male	38	Caucasian	Mesiobuccal root of a maxillary left first molar	Periapical radiograph and during endodontic retreatment
Legan et al., 1995[9]	Female	66	NA	Maxillary second premolar	Periapical radiograph
Borelli et al., 1999[10]	Female	56	NA	2 Maxillary molars	Periapical radiograph
Lin et al., 2008[11]	Female	48	Chinese	Palatal root of a maxillary left first molar	Periapical radiograph, during endodontic treatment and eventually confirmed through surgical intervention
	Female	75	Chinese	Palatal root of a maxillary left second molar	Clinical examination
Wang et al., 2011[13]	5 males and 7 females	41～70	Chinese	8 maxillary first molars (7 palatal roots and 1 distobuccal root), 1 maxillary second molar, 1 mandibular first premolar and 4 mandibular second premolars	Clinical examination and periapical radiograph
Wang et al., 2011[12]	Male	59	NA	Palatal root of a maxillary left first molar	CBCT
	Male	50	NA	Palatal root of a maxillary right first molar	CBCT
	Female	62	NA	Palatal root of a maxillary right first molar	CBCT
Clarkson et al., 2015[14]	Female	55	NA	Palatal root of a maxillary left first premolar	Periapical radiograph and CBCT
Tsai et al., 2017[5]	13 males and 11 females	45～78	Chinese	5 maxillary premolars, 15 maxillary molars, 5 mandibular premolars and 3 mandibular molars	Clinical examination, periapical radiograph, CBCT or exploratory surgery
Badar et al., 2018[15]	Male	58	NA	Palatal root of a maxillary right first premolar	Periapical radiograph
Da Silva et al., 2018[16]	NA	16	NA	Mesial root of a mandibular right second molar	Periapical radiograph

NA: no data available.

Tooth and root distribution

PHRF without dental trauma primarily occurred in the palatal roots of maxillary molars.[5,11–13,20] A case series report presented 12 patients with PHRF in non-endodontically treated teeth. The fractures were observed in 8 maxillary first molars, 1 maxillary second molar, 1 mandibular first premolar and 4 mandibular second premolars. Eight fractures of the maxillary molars occurred in the palatal roots and 1 was observed in the distobuccal root.[13] Another study collected 28 PHRF without dental trauma and also found that most of the affected teeth were maxillary molars. First molars and second molars have shown similar predilection.[5]

Several ideas regarding the occurrence of PHRF in the maxillary molars had been proposed. Clarkson et al. (2015) suggested that bone structure over the buccal root of the maxillary posterior teeth is quite thin and even fenestrated in some area. Thus, the buccal bone may provide only a little resistance to the buccal movement of the affected tooth. In the meantime, the palatal root sustained most of the forces and could result in HRF eventually,[14] especially when the teeth were suffered from lateral traumatic occlusal force. The morphology of roots or the presence of the temporomandibular joint were described as other possible related factors. The thickness of roots in the mandibular molars may provide the resistance to fracture forces and the existence of the temporomandibular joints may contribute some degree of elasticity to the area.[10] Thus, more HRF in the posterior teeth were found in the maxilla instead of the mandible. PHRF in lower premolars showed another special clinical feature. Perhaps due to the

differences in cusp inclination and force distribution upon crown and cervical area of the root. Cracked and VRFs were commonly discovered in the upper premolars while HRFs were identified more in the lower premolars.

The different anatomic configuration of the root structure may act as another factor in PHRF. PHRF without dental trauma were discovered mostly in the palatal roots of the maxillary molar.[13] The distobuccal and palatal roots of the maxillary molars usually showed circular shape in the cross section. The mesiobuccal root exhibited wider buccopalatal dimension than the distobuccal root. This kind of deep oval or flattened-shaped root texture may predispose to VRFs.[21,22] Thus, particular root structure may play an important role in the occurrence of HRF or VRF. The actual mechanism whether the specific root anatomic structure was more susceptible to HRF in posterior teeth without dental trauma need further investigation. The information regarding the tooth and root distribution of HRF was presented in Table 1.

Diagnostic methods

Clinical examination

Occasionally, a PHRF could be diagnosed clinically if the root-fractured line existed above the marginal gingiva.[11,13] Most of the fractured teeth did not exhibit an inflamed gingiva.[13] The elicitation of pain when the file passed through the root-fractured line, bleeding from the root canal during endodontic treatment, and confirmation through the application of an electronic apex locator were helpful in the differential diagnosis of horizontal root fracture.[11] PHRF could sometimes be diagnosed and suspected clinically (Fig. 1). However, VRF was usually hard to detect by the electronic apex locator, if no displacement of fracture roots had occurred.

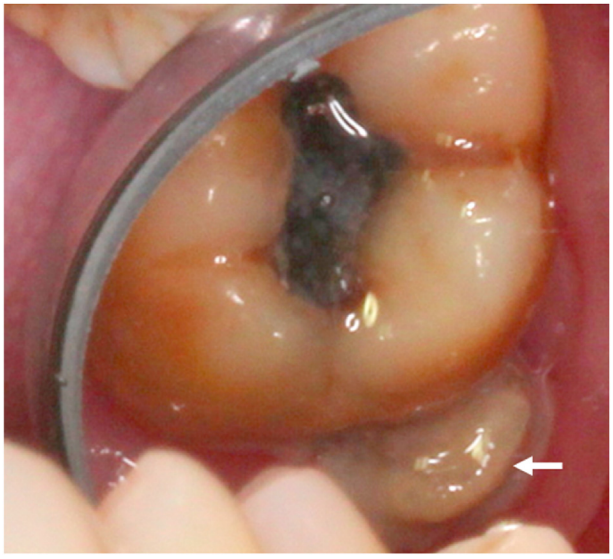

Figure 1 One representative case of horizontal root fracture in posterior teeth (PHRF). Horizontal root fracture (HRF) of the distobuccal root in a maxillary left second molar was detected clinically (white arrow). The root-fractured line occurred above the marginal gingiva.

Radiographic examination

Most of the PHRF were diagnosed through radiographic images.[9–11,13–16] The radiolucent fracture line may be detected on the film surprisingly during routine examination, but the patient was without any symptom and sign (Fig. 2). Radiographic examination with multiple shifting angled x-rays was suggested. If the x-ray beam does not pass directly through the fracture line, it usually does not show on the radiographic image.[23] In other cases, radiographic images may reveal bony destruction surrounding the fracture line of roots with HRF and provide some clues.[13]

Conventional radiography sometimes could only provide limited information. The adjacent anatomic structures could superimpose and interfere the detection of the fractured line.[13] Maxillary sinus or zygomatic process may disguise the fractured lines which occurred in the upper posterior teeth. Cone beam computed tomography (CBCT) provides helpful 3-dimensional images and is a non-invasive tool for detecting HRF.[12,14,24] Three PHRF cases which were diagnosed via the combination of conventional radiographs and CBCT to detect fractured lines in the maxillary first molars were published in 2011. More detailed information could be displayed by CBCT than the conventional radiographs (Fig. 3). CBCT images are able to show the presence or absence, as well as the location, extent, level, and direction of the HRF.[24] Several articles also depicted the potential of CBCT image in diagnosing, treatment planning, and outcome evaluation of HRF.[14,25–32]

In order to reduce the radiation dosage, CBCT with a limited field of view (FOV) was recommended. A study applied 3 different CBCT units in detecting simulated HRF. The authors concluded that limited FOV CBCT could be used in observing HRF with the advantage of reducing radiation dosage.[33] Another study elucidated that a limited CBCT with 30 mm $\times$ 40 mm FOV and a voxel size of 0.125 mm showed better results in detecting simulated HRF when compared with conventional intraoral radiographs.[34] CBCT images usually revealed a clear radiolucent fractured line or displacement of the fracture fragment in observing HRF, whereas VRF were sometimes difficult to detect even after taking a CBCT. Thus, if conventional radiograph is inconclusive in a suspicious case of PHRF, CBCT should be arranged due to its usefulness and outstanding performance in the diagnosis of HRF.

Exploratory surgery

Exploratory surgery is another option for diagnosis and treatment in some uncertain cases.[5,11] Especially in teeth associated with deep periodontal pocket, swelling, abscess, and pus discharge. After flap elevation, horizontal fractured line could be directly observed (Fig. 4). The removal of the fractured root could be performed simultaneously during the surgery.[11] The diagnostic methods recommended by the literatures were listed in Table 1.

Etiology and possible related factors

PHRF could occur without the patients' awareness of a clear causative event or any prior accidental injuries. Thus, the researchers tried to find the other possible causes of

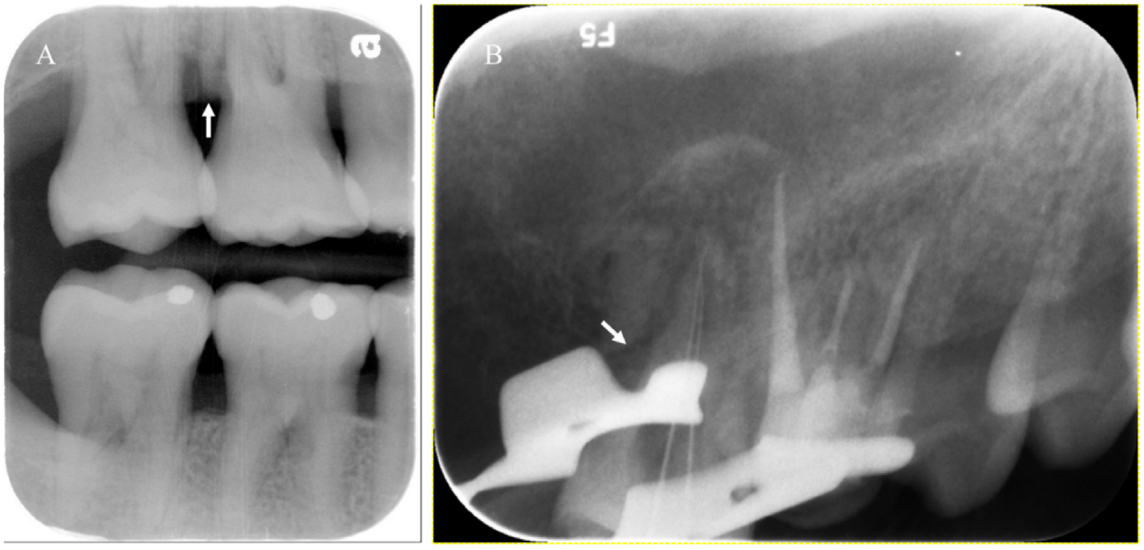

Figure 2 PHRF in the palatal root of maxillary molars. HRFs of the palatal roots in (A) a maxillary right first molar (white arrow) and (B) a maxillary right second molar (white arrow).

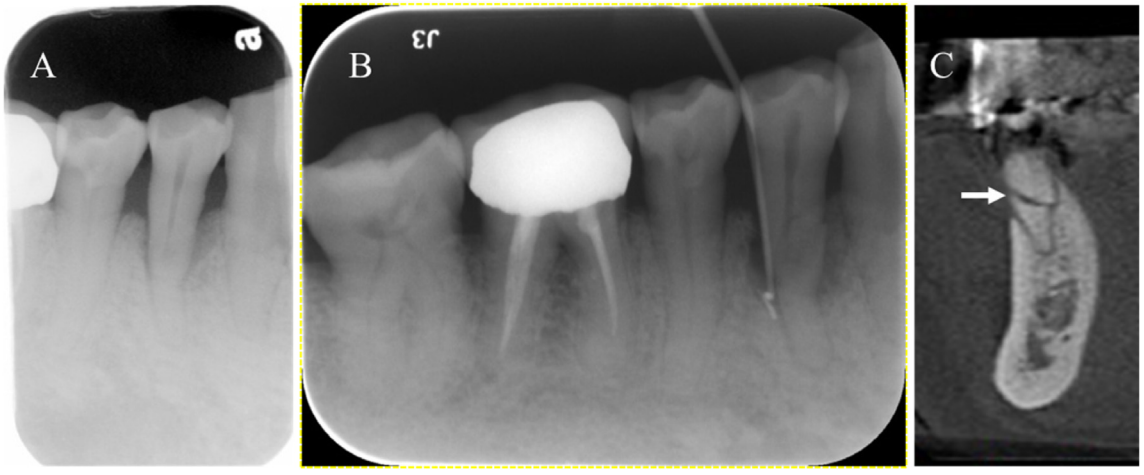

Figure 3 Radiographic characteristics of PHRF. (A) The periapical radiograph of a mandibular right first premolar with vertical bony destruction. (B) The periapical radiograph with gutta-percha tracing from the sinus tract of the mandibular right first premolar. (C) The cone beam computed tomography image of the mandibular right first premolar presented a clear diagnosis of HRF (white arrow).

the PHRF. The actual etiology of PHRF without dental trauma was quite difficult to establish.[14] The etiology and possible related factors could be further divided into 2 categories: iatrogenic factor and occlusal forces-related factor based on the past literatures.

In iatrogenic situations, PHRF may occur as a damage during Caldwell-Luc procedures and curettage of the sinus membrane in treating chronic sinusitis.[8] It is also suggested that overzealous horizontal force applied during the seating of an over-contoured complete crown restoration of 1st molar may possibly induce root stress and lead to horizontal root fracture of adjacent upper 2nd premolar.[9] However the actual reason is not clarified, because the authors have not provided the occlusion of left side posterior teeth in this case. PHRF of the 2nd molar can be also generated during the extraction of an impacted third molar.[16]

For occlusal forces-related factors, occlusal or lateral trauma had been proposed to be the causes of these fractures.[10] Weak tooth structure, severe attrition or incidentally biting on hard object may predispose the teeth to root fracture,[11,15] especially when missing teeth and occlusal disharmony were presented. The damaging chewing habits exhibited by the Chinese population, such as excessively and repetitively chewing food that could not be sheared easily may initiate or further lead to root fractures.[3,13,35] Those teeth may show evident occlusal wear or facets on the remaining occluding surfaces.[5,13,14] This may explain why some of the PHRF without dental trauma occurred and were reported more in the Chinese patients. Bruxism had also been suggested to be a possible cause.[14] Thus, taking a complete dental history was important in detecting the possible causative factors of PHRF.[8] The etiology and possible related factors of the PHRF without dental trauma were collected in Table 2.

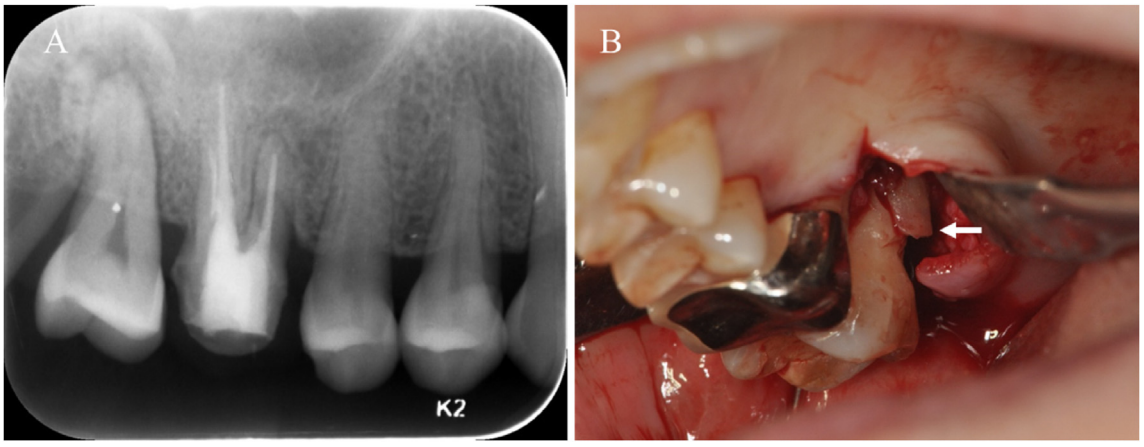

Figure 4 HRF in palatal root of a maxillary second molar. (A) The periapical radiograph of a maxillary right second molar. (B) A HRF was diagnosed in the palatal root of the maxillary right second molar during exploratory surgery (white arrow).

Table 2 Etiology and possible related factors of HRF in the posterior teeth without dental trauma reported by the past literatures.

Literature	Category	Etiology and possible related factors
Jerome, 1994[8]	Iatrogenic factor	Patient received 2 Caldwell-Luc procedures and curettage of the sinus membrane in treating chronic sinusitis. A polyp and mucoid mass were removed from the left maxillary sinus.
Legan et al., 1995[9]	Iatrogenic factor	HRF was probably caused by the overzealous force applied while seating an over-contoured prosthesis on the adjacent tooth and due to iatrogenic nature.
Borelli et al., 1999[10]	Occlusal forces related factor	Patient presented neurotic and anxious character. She also reported a teeth-clenching habit. Occlusal or lateral trauma were suspected to be the cause of HRFs.
Lin et al., 2008[11]	Occlusal forces related factor	Case 1: Large access cavity and relatively weak tooth structure may predispose the tooth to HRF. Case 2: Severe attrition may predispose the tooth to HRF.
Wang et al., 2011[12]	Occlusal forces related factor	The root-fractured teeth showed attrition. Imply that the teeth sustained heavy, repeated and prolonged stress.
Wang et al., 2011[13]	Occlusal forces related factor	Patients habitually chewed hard foods. Excessive, repetitive, and heavy masticatory stress may lead to root fractures.
Clarkson et al., 2015[14]	Occlusal forces related factor	Occlusal trauma, vertical or lateral force exerted on the tooth or bruxism habit that caused the HRF.
Tsai et al., 2017[5]	Occlusal forces related factor	Full mouth periodontal condition, occlusal wear and patients' age at diagnosis (older population).
Badar et al., 2018[15]	Occlusal forces related factor	Patient had incident of biting hard object.
Da Silva et al., 2018[16]	Iatrogenic factor	HRF happened during the procedures of removing an impacted third molar.

Clinical features

Pain

The common symptoms and signs of PHRF were mild and intermittent biting pain with sensitivity to percussion.[8,11–13,15] The patients may complain of chronic pain even for several years.[8] However, some of the fractured teeth may probably remain symptomless.[9,10,14,16]

Periodontal status

The onset of root fractures may be slow or abrupt, but the root displacement may not be evident at the early stage. In some cases, the PHRF teeth showed normal periodontal probing depth.[9] If progression and exacerbation of the root fractures were initiated, the symptoms and signs may become more evident and usually accompany with pulpal or periodontal lesions. Deep periodontal pocket or even combined

Table 3 Clinical and radiographic features of HRF in the posterior teeth without dental trauma reported by the past literatures.

Literature	Pain	Abscess or sinus tract	Percussion pain	Periodontal pocket	Tooth mobility	Vitality test	Tooth status	Occlusal feature and chewing habits	Radiolucent root-fractured line	Associated bony destruction
Jerome, 1994[8]	Yes	NA	Yes	NA	NA	Endodontically treated	Previously treated	NA	Yes	No
Legan et al., 1995[9]	No	NA	NA	No	Yes	Positive response	Without restorations and dental caries	NA	Yes	Yes
Borelli et al., 1999[10]	No	No	No	Yes	Yes	Positive response	With minimal or no restoration	Clenching and grinding habit	Yes	NA
Lin et al., 2008 [11]	Yes	NA	Yes	Yes	Yes	Endodontically treated	Prepared abutment tooth without prosthesis	NA	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	NA	Occlusal attrition, intact tooth, no restoration.	Occlusal attrition	No	Yes
Wang et al., 2011[13]	Yes (11/12)	No	Yes	NA	NA	Five responded positively to electric pulp tester and 4 were non-responsive	Moderate to severe attrition, intact crowns	Six patients habitually chewed hard foods	Yes	Yes
Wang et al., 2011[12]	Yes	Yes	Yes	Yes	Yes	No response	Intact tooth with minimal or no restoration	Patient habitually chewed hard foods	No	Yes
	Yes	No	Yes	No	No	Positive response	Intact tooth with minimal or no restoration	Patient habitually chewed hard foods	No	Yes
	Yes	No	NA	No	Yes	Positive response	Intact tooth with minimal or no restoration	Patient habitually chewed hard foods	Yes	No
Clarkson et al., 2015[14]	No	NA	No	NA	Yes	Responded positively to electric pulp test but was	Intact tooth without restorations	Faceting and substantial erosion of the occluding	Yes	No

(*continued on next page*)

Table 3 (*continued*)

Literature	Pain	Abscess or sinus tract	Percussion pain	Periodontal pocket	Tooth mobility	Vitality test	Tooth status	Occlusal feature and chewing habits	Radiolucent root-fractured line	Associated bony destruction
						unresponsive to cold		surfaces		
Tsai et al., 2017[5]	NA	NA	NA	Yes (87%)	NA	NA	82% without crowns and bridges restorations	All of the occlusal surfaces with tooth wear	Yes	Yes
Badar et al., 2018[15]	Yes	NA	Yes	NA	Yes	Responded positively to electric pulp test	Intact tooth with minimal or no restoration	Patient had incident of biting hard object	Yes	No
Da Silva et al., 2018[16]	No	No	NA	NA	No	NA	Intact tooth with no restoration	NA	Yes	No

NA: no data available.

periodontal-endodontic lesions may be generated at later stage.[10–12] The chronic inflammation may further lead to the periodontal breakdown and worsen the prognosis.[5] Occasional bleeding from the gingival sulcus had also been observed.[10]

A study illustrated that 22 out of 24 patients with PHRF without dental trauma exhibited generalized chronic periodontitis.[5] It was speculated that full mouth chronic periodontitis with variable bony destruction may lead to insufficient bone support and a lower fulcrum of the surrounding tooth. So even under a normal occlusal force, the tooth may endure occlusal trauma due to the increasing torque.[5] Lateral traumatic occlusal force may also lead to PHRF especially when multiple missing teeth and occlusal discrepancy were presented. Another case series report proposed that there was no relationship identified between the patients' periodontal status and the likelihood of root fracture.[13] Thus, the actual mechanism of this feature needed further verification.

Tooth mobility

PHRF could exist without tooth mobility. Thus, the patients may not be aware of the situation. After a time period, the fractured tooth may exhibit mild to moderate or even severe tooth mobility when the pulpal or periodontal tissues were progressively involved.[9–12,14,15]

Pulpal status

The pulp may remain vital and respond positively to sensibility test even years after PHRF had happened.[9,10,12,15] It has been reported that 20–40% of the nonendodontically treated teeth with PHRF would undergo pulpal necrosis eventually.[10] A small proportion of the PHRF teeth were endodontically treated or did not respond to vitality test.[8,11–13] The pulpal reaction may be related to the exacerbating status of the root-fractured teeth. Thus, confirming the pulpal status is important before performing any further treatment.

Tooth status and occlusal features

Most of the PHRF cases were found in relatively intact teeth with only minimal or no restorations and did not receive any endodontic or prosthodontic therapy.[5,9–16] Widespread of tooth wear, attrition or faceting of the occlusal surfaces were also common findings in PHRF.[5,11,13] Occlusal wear may imply long-term and repeated heavy occlusal forces applied on the teeth that may serve as a factor in root fractures.[3,13,35,36] Multiple root fractures may occur in the same patient, suggesting that individual or genetic parameters may also play an important role in PHRF.[5,13]

Displacement of the fracture fragment

The fractured fragment may separate or displace for a distance from the original root portion at the later stage.[11] If the root-fractured level existed above the marginal gingiva, then HRF could be detected clinically.[11,13] The clinical features of PHRF without dental trauma reported by the past literatures were presented in Table 3.

Table 4 Treatment schemes and prognosis of HRF in the posterior teeth without dental trauma reported by the past literatures.

Literature	Treatment	Prognosis
Jerome, 1994[8]	Root amputation	The chronic pain was resolved and the tooth was uneventful at 2 years follow-up.
Borelli et al., 1999[10]	Patient refused any dental treatment including endodontic treatment or extraction, except for routine periodontal maintenance.	Maxillary right first molar showed hopeless prognosis with abscess formation after 9 years. Although the maxillary left molar was asymptomatic and in good function after 11 years, pulp necrosis was suspected.
Lin et al., 2008[11]	Case 1: Endodontic treatment and root amputation	The tooth was preserved in the short term and early healing uneventfully. The radiolucent lesion decreased in size and tooth mobility improved at 2-month follow-up.
	Case 2: Endodontic treatment and root amputation	The tooth was preserved in the short term and early healing uneventfully. Tooth mobility improved at 4-month follow-up.
Wang et al., 2011[12]	Case 1: Endodontic treatment with calcium hydroxide/ iodoform paste placing into the root-fractured canal to induce hard tissue formation.	NA
	Case 2: Endodontic treatment with calcium hydroxide/ iodoform paste placing into the root-fractured canal to induce hard tissue formation.	NA
	Case 3: Patient did not accept any treatment.	Patient did not accept any treatment.
Clarkson et al., 2015[14]	No treatment was performed	The fracture line healed with the ingrowth of connective tissue spontaneously.
Badar et al., 2018[15]	Flexible splinting for 4 weeks	The fracture line healed with interproximal connective tissue and no signs of pathology after 2.5 years.
Da Silva et al., 2018[16]	No treatment was performed	The fracture line healed with a small callus after 7 months.

NA: no data available.

Radiographic characteristics

Radiolucent root-fractured line

HRFs are not always discernible in conventional/periapical radiographs. Apply different shifting angle of the x-ray cone may be helpful in order to move the superimposition structure away. If the fracture fragment was separated or displaced from the original root portion, then a definitive diagnosis of PHRF could be observed from the radiographs. However, there is another more important reason to do this examination. The fracture line will be visible only when the central X-ray beam must pass within the range of 15°—20° of the fracture plane.[37] Hence, there is a high possibility of missing the horizontal fracture on traditional radiographs. Recently HRFs were shown to be detected by CBCT image analysis.[5,8–16]

Associated bony destruction

Periodontal or periapical bony destructions beside the fractured roots had been reported to be associated with PHRF teeth.[5,11,13] After progression of root fracture, the development of pulpal or periodontal lesions may become evident. Surprisingly, some of the asymptomatic PHRF teeth healed spontaneously without bony defect formation.[14–16] The radiographic features of PHRF teeth without dental trauma reported by the past literatures were presented in Table 3.

Treatment of horizontal root fracture in posterior teeth

Spontaneous healing of the HRF teeth with or without receiving initial treatment had been reported to occur even in posterior teeth.[14,16] The healing outcome of HRF had been classified into 4 groups: healing with calcified tissue, healing with interproximal connective tissue, healing with interproximal bone and connective tissue or interproximal inflammatory tissue without healing.[38] If the root-fractured line was located below the alveolar crest, the tooth showed a good chance of survival even if it was untreated. Better prognosis was shown to be associated with no or only mild displacement of the fracture fragment.[39]

If the HRF tooth showed mobility without any symptoms of pulpalgia, then a flexible splinting was suggested before further evaluation for endodontic intervention.[15] Root canal treatment and/or root amputation were suggested in

PHRF of molars with pulpal or periodontal lesions.[8,11,12] Placement of the calcium hydroxide/iodoform paste into the root-fractured canal in order to induce hard tissue formation had been proposed with limited success.[12] A 4-year survival rate of maxillary molars after root amputation was reported to be 93%, and the long-term survival rate of teeth after root amputation ranged from 87% to 95%.[40–42] However, when the fracture line allowed communication with the oral cavity, microbial contamination of the pulp and pulp necrosis were expected. The fractured tooth may exhibit a poorer prognosis.[43]

Treatment alternatives for teeth with HRF may depend upon the location and extent of the fracture, the status of pulp tissue, occlusion, the severity of dislocation of the root fragments, and the surrounding bony support.[8,23] Additional factors included the remaining structure of the fracture tooth, root morphology, and distribution of occlusal forces for the final reconstruction.[41,44] The treatment schemes and prognosis of the PHRF without dental trauma reported by the past literatures were displayed in Table 4.

Several suggestions were proposed for the prevention of PHRF without dental trauma. Excessive forces and pressures should be avoided when placing a single or multiple unit restorations to prevent further damage to the prepared teeth and the adjacent teeth.[9] A night guard appliance was strongly suggested for patients who showed the habits of clenching and grinding.[10] If the patient presented evident attrited dentition, the clinicians could remind them to be aware of certain chewing habits and the entity of PHRF. The above described considerations may assist in preventing and raising the awareness of PHRF without dental trauma.

Conclusions

HRF could occur in posterior teeth and without any traumatic events. Most of them were nonendodontically and nonprosthodontically treated. Diagnosis of the PHRF depended on the clinical examination, radiographic images or through exploratory surgery. Limited FOV and high-resolution CBCT were useful in diagnosing PHRF with the advantage of reducing the radiation dosage. PHRF teeth may be asymptomatic and healed spontaneously without patients' awareness. If the fractured teeth exhibited pulpal or periodontal symptoms, treatment options included endodontic treatment, flexible splinting and/or root amputation.

More cases should be collected to clarify the relationship between the fracture tooth and root distribution, patients' chewing habits, and the delivery of the occlusal forces. Besides, most of the HRF studies were investigated in anterior teeth. Experimental models using posterior teeth should be conducted. The clinical significance of different treatment strategies and the long-term prognosis of PHRF without dental trauma should be further addressed to provide a better comprehension of this particular disease entity.

Declaration of competing interest

The authors declare no conflict of interest.

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