



Original Article

Analysis of clinical associated factors of vertical root fracture cases found in endodontic surgery



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KEYWORDS

Clinical associated factors;
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Abstract *Background/purpose:* Early diagnosis of vertical root fracture (VRF) has been a great challenge. Since there is no single specific etiology identified, prevention of VRFs in endodontically treated teeth is quite difficult. The study aimed to evaluate the clinical associated factors of VRFs.

Materials and methods: A retrospective observational study of medical charts was conducted in the Department of Endodontics of Taipei Medical University Hospital in Taiwan from January 2012 to July 2018. Logistic regression model was performed to determine the association between VRF and its clinical associated factors, inclusive of the tooth characteristics (age, gender and tooth type) and iatrogenic risk factors (history of root canal treatment, restoration and post).

Results: A total of 359 teeth were included in the study. The prevalence of VRF on a tooth basis was 18.7%. The result showed that age of more than 50 years (adjusted OR = 3.20, 95% CI: 1.81–5.64, $p < 0.001$) had significant higher risk of VRFs than those of less than 50 years. The subjects of molars (adjusted OR = 4.31; 95%CI = 2.24–8.27; P value < 0.001) and premolars (adjusted OR = 2.61; 95%CI = 1.16–5.86; P value = 0.021) had significant higher risk of VRFs than those of incisors. However, other variables such as gender, history of root canal treatment, restoration and post had no significant association with the VRF.

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Conclusion: Age and tooth type are significant clinical associated factors of VRF. In the presence of these factors as well as predominant diagnostic factors, clinical practitioners should be aware of the possible diagnosis of VRFs.

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Introduction

Vertical root fracture (VRF) is a type of longitudinal tooth fractures. The fracture is initiated from any level in the root and propagates along the long axis of the root. It is usually directed buccolingually and may involve one proximal surface or both proximal surfaces.¹

Failures of endodontic treatments resulted from VRFs are not rare.² Early diagnosis of VRFs may be difficult since the clinical and radiographic characteristics of VRFs are often similar to other commonly seen pathosis, such as periodontal diseases or true endodontic failures.³ Although cone-beam computed tomography (CBCT) has been proposed as a noninvasive diagnostic tool for VRFs, there is still insufficient evidence to show that CBCT is accurate enough in detecting VRFs in endodontically treated teeth.^{4,5} Delay in the detection of VRFs may lead to frustrating situations for both clinical practitioners and patients, as the symptoms persist because of ineffective treatments.

To know VRFs better, many studies were conducted with regard to the possible associated factors of VRFs. Most VRFs occur in endodontically treated teeth and in patients aged over 40 years.^{6–9} Roots with narrower dimension in mesio-distal than buccolingual are more prone to VRFs. The most susceptible teeth are maxillary and mandibular premolars, the mesial roots of the mandibular molars, the mesiobuccal roots of the maxillary molars, and the mandibular incisors.⁶ Other suggested clinical associated factors of VRFs include the loss of tooth structure due to extensive caries or trauma, removal of substantial amounts of root dentin during the endodontic and restorative procedures, excessive force during lateral compaction of gutta-percha and placement of threaded and tapered posts.^{10,11}

Owing to the diagnostic challenges of VRFs, our recent study clarified the clinical diagnostic factors associated with VRFs and showed that radiological image of J-shaped or "halo" radiolucency, periodontal pocket depth ≥ 5 mm, sinus tract and periodontal swelling or abscess are predominant diagnostic factors of VRFs.¹² Apart from these clinical diagnostic factors, clinical associated factors should also be fully assessed. The purpose of this study was to analyze the possible clinical associated factors of teeth with VRF found in endodontic surgery.

Materials and methods

Sample and data collection

A retrospective observational study of medical charts was conducted in the Department of Endodontics of Taipei

Medical University Hospital (TMUH) in Taiwan. The data were collected from the cohort of patients who were surgically treated under the microscope from January 2012 to July 2018. This study was approved by the Institutional Review Board of Taipei Medical University (IRB number: N201905016).

Inclusion and exclusion criteria

Patients were included in the study when they had endodontically treated teeth with persistent signs and symptoms, and received endodontic microsurgery. Teeth with incomplete clinical or radiographic information were excluded from the analysis.

Measurements of variables

According to the criteria described above, a total of 359 teeth from 275 patients were included. All 275 patients were referred from either dental clinics or other divisions of TMUH. During the surgical procedure, the root surface was dyed with methylene blue and inspected with the microscope to identify the exact etiology of treatment failure.

The clinical and radiographic data were obtained from the electronic medical record and digital radiograph database. The following parameters were documented for each subject: (1) age; (2) gender; (3) tooth: tooth type (incisors, canine, premolars or molars) and tooth location (maxillary or mandibular); (4) history of root canal treatment (nonsurgical root canal treatment only or combined with surgical treatment); (5) restoration: presence or absence of restoration, type of the restoration (direct restoration including amalgam and composite resin restorations or cuspal coverage prosthesis including crown and bridge) and the role of the tooth in the restoration (abutment for a single crown, abutment for a fixed partial denture or abutment for a removable partial denture); (6) post: presence or absence of post, type of the post (casting post, screw post, prefabricated metal post or fiber post) and apical extension of the post (coronal, middle or apical portion of the root).

Statistical analysis

Pearson's chi-square test was used to evaluate the relationships between the outcome/dependent variable (the presence of VRF in the teeth) and various independent variable (the demographic factor and clinical factors). The prevalence of VRF in endodontic surgery was used as the key outcome variable. As the dependent variable was dichotomous (having VRF/not having VRF), a binary logistic

regression model was performed to determine the association between VRF and its clinical associated factors such as the tooth characteristics (age, gender and tooth type) and iatrogenic risk factors in dental procedures (history of root canal treatment, restoration and post). A test was considered statistically significant if its two-tailed P-value was <0.05. Odds ratio (OR) and 95% confidence intervals (95%CI) were considered, and the data were analyzed using the IBM SPSS Software Windows version 22.0.

Results

Characteristics of subjects

A total of 359 subjects/teeth from 275 patients were included in the data analysis. There were 215 females (59.9%) and 144 males (40.1%) among the teeth; the mean age of the teeth was 44.8 years (standard deviation: 13.2 years; range: 20–84 years). Sixty-seven teeth with VRF were detected in 62 patients (18.7% of the prevalence of VRFs on a tooth basis and 22.5% on a patient basis).

The determinants of the prevalence of VRF

Age-stratified prevalence of VRFs in relation to gender was presented in Table 1. The highest prevalence of VRFs of all teeth was in the group of 80–89 years (75%), followed with the group of 50–59 years (31.1%), the group of 70–79 years (25%) and the group of 60–69 years (22.9%). The data showed that age group was significant associated with the prevalence of VRFs ($p < 0.001$, Pearson χ^2 Test). Further with a cutoff point of 50 years, it showed the teeth of more than 51 years had much higher significant prevalence of VRFs than those of less than 50 years (31.9% and 12.6% respectively, $p < 0.001$, Pearson χ^2 Test, Table 2).

There was no significant distribution difference in the prevalence of VRFs between female and male (17.2% and 20.8% respectively, p value = 0.388, Pearson χ^2 Test, Table 2). Further age-stratified analysis, the highest prevalence of VRFs of female was in the group of 50–59 years (39.0%), followed with the group of 70–79 years (28.6%), and the group of 60–69 years (20.0%). The most susceptible age of VRFs of male was in the group of 80–89 years (100.0%), followed with the group of 60–69 years (26.7%), and the group of 50–59 years (21.2%) (Table 1).

In terms of tooth type, the most susceptible one to VRFs was the molars (33.7%), followed with premolars (25.0%), canine (23.8%) and incisors (10.6%) (Table 1). The data showed the factor of tooth type was highly statistic significant associated with the prevalence of VRFs ($p < 0.001$, Pearson χ^2 Test, Table 2).

Associations between the presence of VRFs and several interested independent variables were further analyzed using a binary logistic regression model (Table 3). In univariate analysis, the subjects of older than 51 years (crude OR = 3.24, 95% CI: 1.88–5.60, $p < 0.001$) had significantly higher risk of VRFs than those of less than 50 years. The subjects of molars (crude OR = 4.28, 95% CI: 2.27–8.07, $p < 0.001$) and premolars (crude OR = 2.80, 95% CI: 1.27–6.17, $p = 0.010$) had significantly higher risk of VRFs than those of incisors. In addition, other variables such as gender, tooth location (maxillary/mandibular), history of root canal treatment, type of the restoration and type of the post were not significantly associated with the presence of VRFs. These significantly independent variables in the univariate model were further considered and included in the multivariable model.

The result showed that age of more than 50 years (adjusted OR = 3.20, 95% CI: 1.81–5.64, $p < 0.001$) had significant higher risk of VRFs than those of less than 50 years. As well as the subjects of molars (adjusted OR = 4.31; 95% CI = 2.24–8.27; P value < 0.001) and premolars (adjusted OR = 2.61; 95%CI = 1.16–5.86; P value = 0.021) had significant higher risk of VRFs than those of incisors, whereas canines (adjusted OR = 2.28; 95%CI = 0.74–7.05; P value = 0.154) had no significant higher risk of VRFs.

The study further evaluated the susceptible root sites of VRFs in molars (Table 4). In 28 molars with VRFs, one tooth had fracture in both mesiobuccal and distobuccal roots of maxillary molar. Therefore, 29 root sites were included into calculation. The result indicated that the most susceptible sites of VRFs in molars were mesiobuccal roots of maxillary molars (15/16, 93.7%) and mesial roots of mandibular molars (9/13, 69.2%).

Discussion

Due to the difficulties of case collection, most published literature regarding VRFs were case reports in the 1970s.^{13,14} In recent years, various quantitative studies

Table 1 Age-stratified Prevalence (%) of Vertical Root Fractures in relation to Gender and Tooth type (N = 359).

VRF teeth (%)	Total	Age							Pearson χ^2 Test
		20–29	30–39	40–49	50–59	60–69	70–79	80–89	
All	67/359 (18.7)	1/35 (2.9)	17/112 (15.2)	12/87 (13.8)	23/74 (31.1)	8/35 (22.9)	3/12 (25.0)	3/4 (75.0)	<0.001 ^a
Female	37/215 (17.2)	0/23 (0.0)	9/68 (13.2)	6/55 (10.9)	16/41 (39.0)	4/20 (20.0)	2/7 (28.6)	0/1 (0.0)	0.001 ^a
Male	30/144 (20.8)	1/12 (8.3)	8/44 (18.2)	6/32 (18.8)	7/33 (21.2)	4/15 (26.7)	1/5 (20.0)	3/3 (100.0)	0.041 ^a
Tooth type									
Incisors	22/207 (10.6)	1/24 (4.2)	6/67 (9.0)	4/53 (7.5)	9/38 (23.7)	2/17 (11.8)	0/7 (0.0)	0/1 (0.0)	0.144
Canine	5/21 (23.8)	–	1/3 (33.3)	1/9 (11.1)	1/3 (33.3)	1/4 (25.0)	0/1 (0.0)	1/1 (100.0)	0.465
Premolars	12/48 (25.0)	0/5 (0.0)	2/9 (22.2)	3/15 (20.0)	4/9 (44.4)	1/8 (12.5)	2/2 (100.0)	–	0.065
Molars	28/83 (33.7)	0/6 (0.0)	8/33 (24.2)	4/10 (40.0)	9/24 (37.5)	4/6 (66.7)	1/2 (50.0)	2/2 (100.0)	0.067

^a A test was considered statistically significant if its two-tailed P-value was <0.05.

Table 2 Prevalence distribution of the vertical root fractures in relation to the independent variables (N = 359).

	Total (%)	Prevalence of VRF (%)	P Value (Pearson χ^2 Test)
All teeth	359 (100.0)	67/359 (18.7)	—
Age			
≤50	246 (68.5)	31/246 (12.6)	<0.001 ^a
≥51	113 (31.5)	36/113 (31.9)	
Gender			
Female	215 (59.9)	37/215 (17.2)	0.388
Male	144 (40.1)	30/144 (20.8)	
Tooth type			
Incisors	207 (57.7)	22/207 (10.6)	<0.001 ^a
Canine	21 (5.8)	5/21 (23.8)	
Premolars	48 (13.4)	12/48 (25.0)	
Molars	83 (23.1)	28/83 (33.7)	
Tooth location			
Maxillary	269 (74.9)	46/269 (17.1)	0.189
Mandibular	90 (25.1)	21/90 (23.3)	
History of root canal treatment			
Non-surgical	336 (93.6)	60/336 (17.9)	0.134
Non-surgical + surgical	23 (6.4)	7/23 (30.4)	
Type of the restoration			
Direct restoration	100 (27.9)	13/100 (13.0)	0.087
Cuspal coverage prosthesis	259 (72.1)	54/259 (20.8)	
Role of tooth in the prosthesis			
Abutment for a single crown	192 (74.1)	41/192 (21.4)	0.841
Abutment for a splinted fixed partial denture	66 (25.5)	13/66 (19.7)	
Abutment for a removable partial denture	1 (0.4)	0/1 (0.0)	
Presence or absence of post			
Presence	181 (50.4)	32/181 (17.7)	0.630
Absence	178 (49.6)	35/178 (19.7)	
Type of the post			
Casting post	124 (68.5)	20/124 (16.1)	0.079
Screw post	21 (11.6)	7/21 (33.3)	
Prefabricated metal post	23 (12.7)	5/23 (21.7)	
Fiber post	13 (7.2)	0/13 (0.0)	
Apical extension of the post			
Coronal third	47 (26.0)	10/47 (21.3)	0.685
Middle third	118 (65.2)	20/118 (16.9)	
Apical third	16 (8.8)	2/16 (12.5)	

^a A test was considered statistically significant if its two-tailed P-value was <0.05.

were conducted to evaluate the prevalence and associated factors of VRFs.^{6,10,15,16} Owing to the diagnostic challenge, our recent quantitative research clarified the associated clinical diagnostic factors of VRFs by means of inferential statistics and the clinical associated factors of VRFs were further investigated in this successive study.¹²

Previous studies have shown that the prevalence of VRFs in endodontically treated teeth ranged from 7.2% to 20%.^{17–20} In our cases, the prevalence of VRFs was 18.7%, which was a little bit higher among these studies. This result may be explained by the fact that other common reasons for tooth extraction in endodontically treated teeth, e.g., nonrestorable caries, orthodontic and prosthetic considerations, were already excluded because most patients in our study were referred for further treatment of endodontically treated teeth with persistent signs and

symptoms. Moreover, the use of the dental operating microscope can aid the detection of VRFs. However, it was unable to demonstrate the overall prevalence of VRFs by this retrospective study because of the relatively small sample size and exclusion of nonendodontically treated teeth and those which were extracted without surgical exploration.

Patients older than 50 years were 3.2 times more risky to suffer from VRFs than their younger counterparts. The result seems to be consistent with other retrospective studies which found VRFs occur more frequently in patients aged over 40 years.^{6–9} Possible explanations for this phenomenon may be loss of tooth structure due to previous restorative or endodontic procedures, a longer period of loading, and the reduction in fracture toughness of dentin.^{21,22}

Table 3 The main parameters considered and significance for association with the prevalence of vertical root fractures via a binomial logistic regression model (N = 359).

	Univariate model		Multivariate model	
	Crude OR (95%CI)	P value	Adjusted OR (95%CI)	P value
Age				
≤50	Ref.	<0.001	Ref.	<0.001 ^a
≥51	3.24 (1.88–5.60)		3.20 (1.81–5.64)	
Gender				
Female	Ref.	0.388	–	–
Male	1.27 (0.74–2.16)			
Tooth type				
Incisors	Ref.		Ref.	
Canine	2.63 (0.88–7.87)	0.084	2.28 (0.74–7.05)	0.154
Premolars	2.80 (1.27–6.17)	0.010 ^a	2.61 (1.16–5.86)	0.021 ^a
Molars	4.28 (2.27–8.07)	<0.001 ^a	4.31 (2.24–8.27)	<0.001 ^a
Tooth location				
Maxillary	Ref.		–	–
Mandibular	1.48 (0.82–2.64)	0.191		
History of root canal treatment				
Non-surgical	Ref.			
Non-surgical + Surgical	2.01 (0.79–5.11)	0.141	–	–
Type of the restoration				
Direct restoration	Ref.			
Cuspal coverage prosthesis	1.76 (0.92–3.40)	0.090	–	–
Presence or absence of post				
Absence	Ref.	0.630	–	–
Presence	0.88 (0.52–1.49)			

^a A test was considered statistically significant if its two-tailed P-value was <0.05.

Table 4 Sites of vertical root fractures in molars (N = 29).^a

Molars	Sites	Total (%)
Maxillary	Mesiobuccal root	15 (93.7)
	Distobuccal root	1 (6.3)
	Subtotals	16 (100)
Mandibular	Mesial root	9 (69.2)
	Distal root	4 (30.8)
	Subtotals	13 (100)

^a One tooth had fracture in both mesiobuccal and distobuccal roots.

Our results also showed that the association between gender and VRFs was not significant. A few studies have demonstrated a higher prevalence of VRFs in endodontically treated teeth of females.^{7,9,23} In contrast, males have been more frequently reported VRFs in nonendodontically treated teeth.^{15,16}

García-Guerrero et al. found that the teeth subjected to endodontic retreatment had higher risks of VRFs compared to those subjected to primary root canal treatment.²⁴ Karygianni et al. reported a higher prevalence of VRFs in the teeth subjected to the combination of conventional root canal retreatment and apical surgery.²³ Riis et al. showed no significant difference in long-term teeth survival

between surgical or nonsurgical retreated cases, but with the presence of posts in teeth, nonsurgical retreated cases seemed to be more prone to VRFs than surgically treated ones.²⁵ However, no significant association was found between the history of root canal treatment and VRFs in this study. Although some studies showed retreatment procedures may cause defects on root canal walls or crack initiation in apical dentin and result in VRFs,^{26–28} it is difficult to determine whether VRFs occurred before or after the retreatment procedures in this study because most teeth were subjected to conventional root canal retreatment prior to endodontic microsurgery not long ago. With the advancement of endodontic instruments and the aid of the microscope, the association between the history of root canal treatment and VRFs may need further investigation.

In accordance with previous studies, no correlation was found between the type of restorations and VRFs in this study.^{8,10} However, Seo et al. stated that the type of restoration materials rather than the size of the restorations or the classification of the cavity may play an important role in the occurrence of VRFs and recommended the use of bonded material such as resin or porcelain.²⁹

Biomechanical experiments revealed that high tensile stresses and regions of stress concentrations in the remaining dentin structure result in increased predilection of VRFs in teeth with the post.³⁰ However, the presence of the post, the type of the post and the apical extension of the post were not significantly associated with VRFs in this

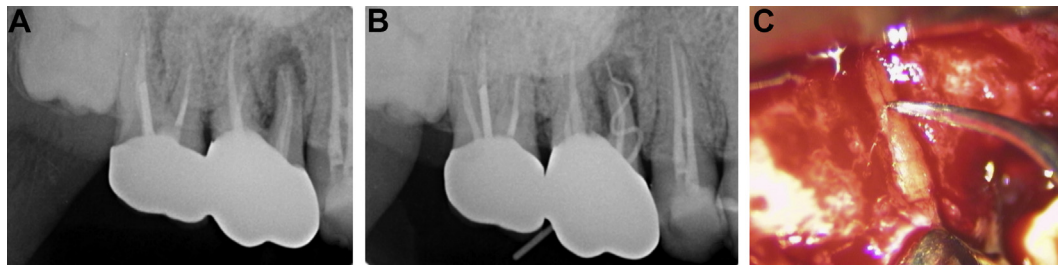


Figure 1 (A) Periapical radiograph of a maxillary right first molar with a 9 mm periodontal pocket at mesiobuccal site and a sinus tract at buccal gingiva. Vertical root fracture was highly suspected. (B) Gutta-percha point tracing the sinus tract to the periapical region of the mesiobuccal root of the maxillary right first molar. (C) A fracture line was identified on the mesiobuccal root of the maxillary right first molar during the exploratory surgery and therefore verified the diagnosis of vertical root fracture.

study. Liao et al. and García-Guerrero et al. also reported no significant association between the presence of post and VRFs.^{16,24} The relationship between post and VRFs were investigated in numerous *ex vivo* studies. Fiber posts were shown to have better fracture resistance than metal posts because of its similar modulus of elastic to dentin.^{11,31,32} In this study, 13 (7.2%) fiber posts were observed in the root canals and none of these teeth, all of which were incisors, were found VRFs. Some *ex vivo* studies have shown that the apical extension of the post does not affect the fracture resistance of the restored teeth,^{33,34} while some other studies suggested that the length of the post extension at least equal to that of the clinical crown and the post should not extend beyond two-thirds of the root length to avoid stress concentration in the apical region.^{35,36} Other factors, such as post diameter, post design, post fitting, core material, luting cement and direction of masticatory forces were also discussed in a variety of *ex vivo* and *in vitro* studies. Due to the limited number of *in vivo* studies and long-term randomized clinical trials, there are still controversies regarding the optimal choice of the post in endodontically treated teeth.

It is of interest to note that the anatomical characteristics of the root seem to play a more important role in VRFs than the presence of the post. Consistent with previous studies, the highest prevalence of VRFs was in molars and followed by premolars.^{7,9,15} In molars, the most susceptible roots were mesiobuccal roots of maxillary molars (Fig. 1) and mesial roots of mandibular molars (Table 4), which were in agreement with previous observations.^{6,15,16} Finite element analysis models have indicated that the canal shape was the most important factor of tensile-stress distribution.³⁷ A reduced radius of curvature presented in the buccal and lingual aspects of the oval root canal leads to higher stress concentration, and is therefore predisposed to VRFs. Also, the heavier occlusal force of premolars and molars may be another predisposing factor. Ferrario et al. showed significantly larger bite forces were found in molars and premolars, while the bite forces increased along the arch from incisors to molars.³⁸

In conclusion, VRFs occurred more often in patients older than 50 years and in molars and premolars. In the presence of these associated factors as well as predominant diagnostic factors mentioned in our recent study,¹² clinicians should be aware that VRFs may be the possible cause of endodontic treatment failures. Still, other clinical

associated factors remained undetermined and more studies need to be carried out for us to understand VRFs better.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jds.2019.09.003>.

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