Title

Comparison of fracture sites and post lengths in longitudinal root fractures

Author list

Tsutomu Sugaya, DDS, PhD*, Megumi Nakatsuka, DDS, PhD*, Kana Inoue, DDS, PhD*, Saori Tanaka, DDS, PhD*, Hirofumi Miyaji, DDS, PhD*, Ryuji Sakagami, DDS, PhD†, Masamitsu Kawamami, DDS, PhD*

*Department of Periodontology and Endodontology, Hokkaido University Graduate School of Dental Medicine

†Department of Periodontology, Fukuoka Dental College

Corresponding author

Tsutomu Sugaya, DDS, PhD

Department of Periodontology and Endodontology

Hokkaido University Graduate School of Dental Medicine

N13 W7 Kita-ku, Sapporo, Hokkaido 060-8586, Japan

E-mail: sugaya@den.hokudai.ac.jp

Tel: +81-11-706-4266

Fax: +81-11-706-4334

Abstract

Introduction

Comparing the epidemiology of fractures originating in the cervical and apical regions may help to understand the causes and risk of vertical root fracture. We aimed to determine the frequency of vertical root fractures in different fracture sites and how the fracture site relates to fracture direction and post length.

Methods

Teeth diagnosed with vertical root fracture were retrospectively surveyed for age and sex of the patient, type of tooth, fracture region in longitudinal axial direction, site of the fracture, and presence of a post. The fracture region in longitudinal axial direction was classified as incomplete fracture, complete fracture, and uncertain. Incomplete fractures were further classified into fracture originating in the cervical region, fracture originating in the mid-region, and fracture originating in the apical region. Posts were evaluated by loss of post and length of post.

Results

Fractures originating in the cervical and apical region were at around the same frequency, while fractures originating in the mid-region were extremely scarce. Of the fractures originating in the cervical region, 36.2% were in a mesial and/or distal site and 57.4% in a buccal and/or lingual site. Of the fractures originating in the apical region, 90.8% were in the buccal and/or lingual site. The number of cases of fracture originating in the apical region decreased with increased post length.

Conclusion

Sites of fracture and post length differed greatly between fracture originating in cervical region and apical region, suggesting that risk factors for fracture originating in cervical and apical region are different.

Keywords: vertical root fracture, fractures originating in the cervical region, fractures originating in the apical region, site of fracture, post length

Introduction

Vertical root fractures cause rapid disruption of the periodontal tissues, and in almost all cases extraction is required. Among patients in the maintenance phase of restorative and periodontal treatment, the cause of tooth loss is reported to be caries in 7% of cases and periodontal disease in no more than 5%, while root fracture accounts for an overwhelming majority of 62% of cases (1). Prevention and treatment of root fracture can therefore greatly increase the lifespan of teeth. There are various causes of vertical root fracture, making it difficult to gain a full understanding of the mechanism. Endodontics and prosthetics show many of the factors associated with root fracture, but there have not been consistent results establishing them as causes.

Enlargement of the root canal is reported to reduce fracture resistance (2). Micro-cracks that form at the time of root canal enlargement have been identified as a possible cause of root fracture. In particular, a number of studies have shown that cracks form more readily with a nickel-titanium rotary file than when a hand instrument is used (3-5). Prolonged irrigation of the root canal with highly concentrated irrigant solutions (6,7) and long-term application of calcium hydroxide to the root canal are reported to decrease the strength of the dentin (8-10). Excessive pressure applied during root canal obturation is also seen as a cause of root fracture (11,12). Cracks caused during root canal preparation can be extended by the pressure of root canal obturation (13,14), thus greatly reducing fracture resistance (3).

Many studies have investigated the role of prosthetics in root fracture occurrence. There are reports that thinning of the root canal wall due to insertion of the post reduces fracture resistance (15), and that bonding the post to the root canal wall (16,17) or the presence of a ferrule (18) increase fracture resistance. There have recently been numerous reports of fiber posts in relation to root fracture, but *in vitro* findings are inconclusive, for example, one study observed that fiber posts increase fracture resistance (19) and another reported deterioration resulting from fiber posts (20). Further clinical studies on the effects of fiber posts on fracture resistance are required (21,22).

Neither the mechanism of vertical root fracture nor the measures to prevent them have been fully clarified yet in clinical studies. It is known that vertical root fractures may originate either from the cervical region or from the apical region (23,24), and it is probable that the two types of fracture are each associated with different factors. Comparison of the epidemiology of fracture in the cervical region and fracture in the apical region may help to understand the causes and risks of vertical root fracture. We aimed to determine the

frequency of vertical root fractures in different fracture sites and how the fracture site relates to fracture direction and post length.

Materials and methods

A retrospective study was carried out in teeth diagnosed with vertical root fracture at the Department of Endodontics and Periodontics, Hokkaido University Hospital between 1994 and 2012. The study was approved by the Institutional Review Board for Clinical Research of Hokkaido University Hospital. The items surveyed were age and sex of the patient, type of tooth, fracture region in longitudinal axial direction, site of the fracture, and presence of a post.

Where complete fracture could not be diagnosed by inspection or radiograph, the post or root canal obturation material was removed and the fracture was checked from inside the root canal with a microscope. Where the fracture was indistinct, it was stained with a caries detector or iodine tincture. Where it was difficult to distinguish root fracture from root morphology such as fins, the root canal was enlarged. If the suspected fracture line disappeared during enlarging, the tooth was excluded from the study; vertical fracture was diagnosed only if it continued as far as the periodontal ligament. Fracture region in longitudinal axial direction was classified as incomplete fracture, complete fracture, and uncertain. Incomplete fractures were further classified into the three subgroups namely, fracture originating in the cervical region, fracture originating in the mid-region, and fracture originating in the apical region. The criteria for the groups and subgroups were as follows. Fracture originating in the cervical region: a fracture in the cementoenamel junction (CEJ) or in the foremost coronal side of the root if the CEJ is indistinguishable that does not extend to within 3 mm of the apical region. Fracture originating in the mid-region: there is no fracture in the CEJ or foremost coronal side of the root, and no fracture within 3 mm of the apical foramen. Fracture originating in the apical region: a fracture in the apical foramen or a fracture line within 3 mm of the apical foramen that extends to two sides (e.g. the buccal and lingual sides), and no fracture in the CEJ or foremost coronal side of the root. Complete fracture: a fracture in the CEJ or in the foremost coronal side of the root if the CEJ is indistinguishable that extends to within 3 mm of the apical foramen or within 3 mm of the apical region. Uncertain: the fracture line cannot be verified satisfactorily because of curvature of the tooth root, etc. The site of fracture was classified into buccal and/or lingual, mesial and/or distal, and other (fracture affecting both buccal/lingual and mesial/distal sites).

Posts were evaluated by loss of post, material of post, and length of post. Posts that were

not present in the canal at the time of visit to the clinic, and posts that were lost only when connected crowns or a fixed partial denture were cut, were classified as lost. Length of the post was classified according to the method of Schei et al. (25) by calculating the ratio of the post length to the root length from the radiograph, and was expressed as 0, ≤2/10, ≤4/10, ≤6/10, and >6/10. The length of the root was taken as the length from the apex to the cementoenamel junction or else to the gingival margin of a crown restoration.

Statistical tests used were χ^2 test and Pearson's correlation, performed with IBM SPSS Statistics Ver. 21 (IBM, USA).

Results

The patients included 76 men and 174 women. The age at diagnosis was 29–84 years (mean 57.5±11.6 years) in men, and 23–77 years (mean 54.9±11.1 years) in women. A total of 304 teeth were studied, 181 from the maxilla and 123 from the mandible. The age group with the highest number of vertical root fractures was 50–59 years for both men and women (Table. 1). The tooth type with the greatest frequency of vertical root fracture was the maxillary second premolar, followed by the maxillary first premolar and mandibular first molar. The lowest frequency was in the mandibular central incisor and mandibular third molar, followed by the mandibular lateral incisor and maxillary third molar (Table 2). Seven of the teeth were vital, two were non-vital but without caries, and 295 had received root canal therapy.

Looking at the fracture region in longitudinal axial direction by tooth type, fracture originating in the cervical region was significantly (p=0.006) more common than fracture originating in the apical region in the maxillary central incisors and canines, with 5–10 times more fracture originating in the cervical than apical region. In the other tooth types, fractures originating in the cervical and apical region were at around the same frequency. Fractures originating in the mid-region were extremely scarce, accounting for only five of the 304 cases (Table 2). There were no teeth with both fractures originating in the cervical and apical regions.

The overwhelming majority of fractures originating in the apical region were in buccal/lingual sites, whereas fractures originating in the cervical region occurred in both buccal/lingual and mesial/distal sites (Table 3). The site of fracture was statistically different between fractures originating in the cervical and apical regions (p<0.001).

The number of teeth to have lost a post was 87 out of 304, while 126 teeth had a post, 63 teeth had no post or were vital, and in 29 teeth the status was unknown because root canal therapy had been carried out at a different clinic or for some other reason. The rate of post

loss was significantly greater with fracture originating in the cervical region than apical region ($p<0.001$) (Table 4).

When the ratio of post length to root length is sorted by fracture site (Fig. 1), with fracture originating in the cervical region, most post length/root length ratios were in the range 2/10–6/10 and there was no correlation between post length and number of fractured tooth roots ($p=0.934$). With fracture originating in the apical region, most teeth did not have a post. The number of fracture cases decreased with increasing post length, with a negative correlation found ($p=0.005$). The ratio of post length to root length was significantly greater with fracture originating in the cervical region than with apical region ($p=0.001$).

Discussion

The teeth studied here presented a range of symptoms and conditions. Some showed no symptoms and the root fracture was discovered by chance during endodontic treatment, others formed deep pockets or abscesses, and in others the fracture was discovered in the root canal wall because a post was lost. Diagnosis of vertical fracture cannot be made only on the basis of clinical condition or radiographic examination; the fracture line must also be confirmed. Particularly, in cases in which the fracture occurs locally only in the apex, the diagnostic accuracy decreases markedly unless a microscope is used. In the present study, the site of the fracture and fracture region in longitudinal axial direction were confirmed using a dental microscope in all cases where complete fracture was not detected by inspection or dental radiograph. Also, if a fracture line is found following extraction, the possibility that the force applied during extraction caused the fracture or lengthened the fracture line cannot be excluded. Consequently, in the present study the classification was completed prior to extraction. Root curvature and other factors sometimes prevent sufficient observation of the fracture line with a microscope in the root canal; however, only about 10 teeth were excluded from the present study for this reason, and the remaining 304 were included in the analysis. Therefore, including other diagnostic methods, such as surgical exposure of the root, may not significantly alter the results. It is possible that fractures may be extended during removal of posts or root canal fillings. However, even if a minute number of cracks are extended during post or root canal filling removal, the fracture site would not change, and the presence of such crack extensions would not have a significant effect on the finding that the location of fracture sites differs greatly depending on whether they originate in the cervical or apical region.

In the present study, vertical root fracture was most common among the 50–59 years age group in both men and women, which largely agrees with the results of Chan et al. (26).

Although it is unclear why root fractures were most common in the 50-59 years age group, one possible reason may be that a growing number of non-vital teeth with age is offset by the loss of teeth in older age groups, resulting in fewer teeth in general in later age groups. Vertical root fracture occurred with the greatest frequency in the maxillary premolars, followed by the mandibular molars and mandibular premolars, which is in agreement with the results of Testori et al. (27) and Chan et al. (26). One reason may be that these teeth are subjected to a strong occlusal force. Further studies are needed to elucidate the relationship between vertical root fracture and factors such as age and type of tooth.

In the case of complete fracture, it is unclear whether the fracture occurred in one go as a result of a strong external force, or whether a tiny crack gradually progressed over time. In the case of incomplete fracture, fracture originating in the mid-region of the root accounted for only 1.6% of cases (5/304). It is therefore likely that there are very few cases in which tiny cracks first occur in the mid-region of the root and subsequently extend to the cervical or apical regions. Consequently, it may be surmised that most vertical root fractures start in either the cervical or apical regions, from where they then extend, and that fractures occur at the same level of frequency in both these regions. Fractures originating in the cervical region were found in both the mesial/distal and the buccal/lingual sites. In contrast, the majority of fractures originating in the apical region were in the buccal/lingual sites. This indicates that the distribution of stress is different in fractures originating in the cervical and apical region, which in turn suggests that the different types of fractures have different causes. Lertchirakarn et al. (28) and Chai et al. (29) report the results of finite element studies in which many of the fractures caused by pressure from a spreader were in the buccal/lingual site. Pressure from the spreader may perhaps be a major cause of fracture originating in the apical region. At the same time, in the present study fracture originating in the apical region was seen in teeth that were not root canal treated, although only at a low frequency of 4.08% (4/98).This type of fracture had occurred in only two maxillary first premolars and two mandibular first premolars, all in buccal/lingual sites. This indicates that factors other than endodontic problems such as excessive pressure when using a spreader during root canal obturation or micro-cracks during root canal enlargement are also involved in root fracture. Finite element analysis has shown that occlusal force is uniformly distributed around the wall in the case of circular root canals, whereas with oval root canals the stress is concentrated at the buccal and lingual sides of the canal (30,31). As most roots are oval-shaped with greater width in the buccal/lingual site than the mesial/distal site, fracture originating in the apical region may perhaps be readily influenced by the shape of the root.

The loss of a post was more common in cases of fracture originating in the cervical region than apical region. It is not possible to distinguish which occurred first, root fracture or loss of post. However, Ona et al. (32) found higher risk of root fracture as a result of debonding of the post in a finite element study. Debonding of the post may possibly have been a major risk factor for fracture originating in the cervical region in the present study.

Büttel et al. (33) and Cecchin et al. (34) report that post length has no effect on fracture resistance in vitro studies. In this study, no association was seen between post length and fracture originating in the cervical region, and there were fewer fractures originating in the apical region with longer posts, so longer posts may possibly be preferable for preventing vertical fracture. Bonding a long post to the tooth to create a monoblock, as proposed by Tay et al. (35) may be effective in preventing fracture in particular from the apical region. It may be possible to reduce fractures both from the cervical region and the apical region by using a long post made of fiber with elasticity similar to dentin rather than a cast material, and bonding the post to the wall of the root canal.

We hereby demonstrated that the frequency of vertical root fractures originating in cervical and apical regions was the same, and that such fractures were extremely scarce in the mid-region. While fractures originating in the cervical region occurred in both buccal/lingual and mesial/distal sites, 90.8% of fractures originating in the apical region were in buccal/lingual sites, indicating that fracture direction differs greatly with the region of fracture. Post length had no association with fractures originating in the cervical region, but fractures originating in the apical region occurred less frequently with increasing post length. This indicates that the different types of fractures have different causes. However, the causes of vertical root fracture are complex, and further research is needed in this field to prevent vertical root fracture.

Acknowledgements

The authors deny any conflicts of interest related to this study.

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Figure Legends

Figure 1. Post length and number of vertical root fractures

Table 1. Number of tooth root fractures by age at diagnosis and sex

Table 2. Number of vertical root fractures originating in each region in longitudinal axial direction and type of tooth

Table 3. Fracture site in longitudinal axial direction of fractures originating in the cervical and apical regions

Table 4. Fracture originating in each region in longitudinal axial direction and number of posts lost

Figure 1. Post length and number of vertical root fractures

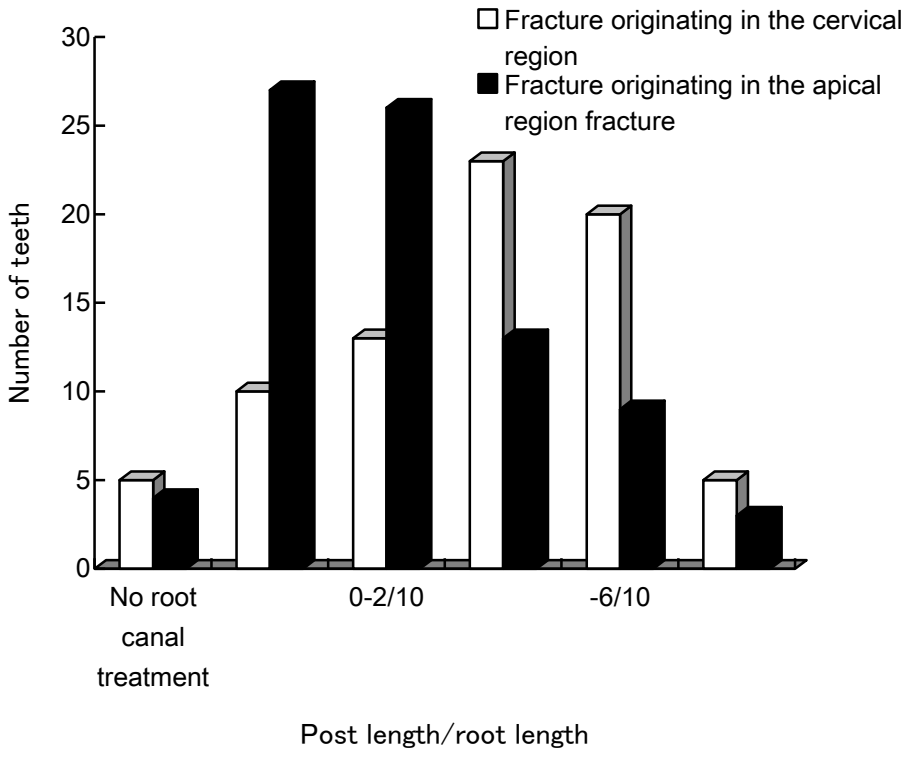

Table 1. Number of tooth root fractures by age at diagnosis and sex

	20-29 y	30-39 y	40-49 y	50-59 y	60-69 y	70-79 y	80- y	Total
Female	2(0.7%)	16(5.3)	47(15.5)	69(22.7)	58(19.1)	15(4.9)	0(0)	207(68.1)
Male	1(0.3)	9(3.0)	13(4.3)	33(10.9)	26(8.6)	14(4.6)	1(0.3)	96(31.9)
Subtotal	3(1.0%)	25(8.2)	60(19.7)	102(33.6)	84(27.6)	29(9.5)	1(0.3)	304(100)

Table 2. Number of vertical root fractures originating in each region in longitudinal axial direction and type of tooth

	Tooth type	Cervical region	Mid-region	Apical region	Complete fracture	Total
Maxillary	Central incisor	10 (5.5%)	1 (0.6)	1 (0.6)	5 (2.8)	17 (9.4)
	Lateral incisor	5 (2.8)	0 (0)	5 (2.8)	2 (1.1)	12 (6.6)
	Canine	10 (5.5)	0 (0)	2 (1.1)	9 (5.0)	21 (11.6)
	First premolar	8 (4.4)	3 (1.7)	14 (7.7)	15 (8.3)	40 (22.1)
	Second premolar	12 (6.6)	0 (0)	19 (10.5)	29 (16.0)	60 (33.1)
	First molar	6 (3.3)	1 (0.6)	8 (4.4)	2 (1.1)	17 (9.4)
	Second molar	2 (1.1)	0 (0)	6 (3.3)	5 (2.8)	13 (7.2)
	Third molar	0 (0)	0 (0)	1 (0.6)	0 (0)	1 (0.6)
	Subtotals	53 (29.3%)	5 (2.8)	56 (30.9)	67 (37.0)	181 (100)
Mandibular	Central incisor	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Lateral incisor	0 (0)	0 (0)	1 (0.8)	0 (0)	1 (0.8)
	Canine	3 (2.4)	0 (0)	2 (1.6)	3 (2.4)	8 (6.5)
	First premolar	6 (4.9)	0 (0)	4 (3.3)	8 (6.5)	18 (14.6)
	Second premolar	15 (12.2)	0 (0)	5 (4.1)	13 (10.6)	33 (26.8)
	First molar	7 (5.7)	0 (0)	16 (13.0)	10 (8.1)	33 (26.8)
	Second molar	10 (8.1)	0 (0)	14 (11.4)	6 (4.9)	30 (24.4)
	Third molar	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Subtotals	41 (33.3%)	0 (0)	42 (34.1)	40 (32.5)	123 (100)
	Total	94 (30.9%)	5 (1.6)	98 (32.2)	107 (35.1)	304 (100)

Table 3. Fracture site in longitudinal axial direction of fractures originating in the cervical and apical regions

	Tooth type	Fracture originating in the cervical region			Fracture originating in the apical region		
		Mesial/distal	Buccal/ lingual	Other	Mesial/distal	Buccal/ lingual	Other
Maxillary	Central incisor	6 (11.3%)	3 (5.7)	1 (1.9)	0 (0%)	1 (1.8)	0 (0)
	Lateral incisor	2 (3.8)	3 (5.7)	0 (0)	2 (3.6)	3 (5.4)	0 (0)
	Canine	3 (5.7)	7 (13.2)	0 (0)	1 (1.8)	1 (1.8)	0 (0)
	First premolar	2 (3.8)	6 (11.3)	0 (0)	0 (0)	14 (25.0)	0 (0)
	Second premolar	4 (7.5)	8 (15.1)	0 (0)	2 (3.6)	16 (28.4)	1 (1.8)
	First molar	3 (5.7)	3 (5.7)	0 (0)	0 (0)	8 (14.3)	0 (0)
	Second molar	1 (1.9)	1 (1.9)	0 (0)	1 (1.8)	5 (8.9)	0 (0)
	Third molar	0 (0)	0 (0)	0 (0)	0 (0)	1 (1.8)	0 (0)
	Subtotals	21 (39.6%)	31 (58.5)	1 (1.9)	6 (10.7)	49 (87.5)	1 (1.8)
Mandibular	Central incisor	0 (0%)	0 (0)	0 (0)	0 (0%)	0 (0)	0 (0)
	Lateral incisor	0 (0)	0 (0)	0 (0)	0 (0)	1 (2.4)	0 (0)
	Canine	0 (0)	3 (7.3)	0 (0)	0 (0)	2 (4.8)	0 (0)
	First premolar	1 (2.4)	4 (9.8)	1 (2.4)	0 (0)	4 (9.5)	0 (0)
	Second premolar	5 (12.2)	8 (19.5)	2 (4.9)	0 (0)	5 (11.9)	0 (0)
	First molar	1 (2.4)	6 (14.6)	0 (0)	0 (0)	15 (35.7)	1 (2.4)
	Second molar	6 (14.6)	2 (4.9)	2 (4.9)	1 (2.4)	13 (31.0)	0 (0)
	Third molar	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Subtotals	13 (31.7%)	23 (56.1)	5 (12.2)	1 (2.4)	40 (95.2)	1 (2.4)
	Total	34/94 (36.2%)	54/94 (57.4)	6/94 (6.4)	7/96 (7.1)	89/96 (90.8)	2/96 (2.0)

Table 4. Fracture originating in each region in longitudinal axial direction and number of posts lost

	Tooth type	Fracture originating in the cervical region	Fracture originating in the apical region
Maxillary	Central incisor	5	1
	Lateral incisor	4	2
	Canine	2	0
	First premolar	2	0
	Second premolar	5	1
	First Molar	0	1
	Second Molar	0	0
	Third Molar	0	0
	Subtotals	18 (34.0%)	5 (8.9%)
Mandibular	Central incisor	0	0
	Lateral incisor	0	0
	Canine	3	1
	First premolar	2	0
	Second premolar	6	0
	First Molar	2	1
	Second Molar	4	1
	Third Molar	0	0
	Subtotals	17 (41.5%)	3 (7.1%)
	Total	35/94 (37.2%)	8/98 (8.2)