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Vertical root fractures of endodontically treated posterior teeth

A histologic analysis with clinical and radiographic correlates

In memory of Barbara Bosshardt

KEYWORDS
vertical root fracture
premolar
molar
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radiography

SUMMARY

Vertical root fractures (VRFs) usually develop slowly, unnoticed by the patient until clinical signs and symptoms become apparent. In endodontically treated teeth, a VRF is a typical cause for extraction. The objective of the present study was the histologic analysis of VRFs in extracted, endodontically treated premolars and molars. In addition, clinical and radiographic findings of these VRF-affected teeth were retrospectively evaluated. Thirty extracted teeth with a clinically diagnosed VRF were embedded in methylmethacrylate. Serial ground sections (perpendicular to the longitudinal axis of the root) were stained with toluidine blue and basic fuchsin. The specimens were photographed and assessed with regard to the vertical and horizontal extent as well as to the course of the VRF. Most VRFs ran from the cervical to the apical region (81.3%). In the axial plane, 50% of VRFs traversed the root completely from buccal to oral. Another 40.6% of VRFs were limited to the buccal root portion. 84.4% of the evaluated roots presented an isthmus. Overall, the VRF was associated with the isthmus in 56.3%, but bypassed the isthmus in 28.1%. The most frequently observed clinical findings included pain (in 60% of the evaluated cases), presence of a fistula (46.7%) and an isolated periodontal pocket with ≥6 mm probing depth (40%). A periapical radiolucency (53.3%) was the most frequent radiographic finding in VRFs. "J-shape" lesions were seen in eight cases (26.7%).

Introduction

A vertical root fracture (VRF) is defined as a longitudinally oriented fracture that is confined to the tooth root (Chang et al. 2016). According to the American Association of Endodontists, a VRF is a fracture in the root whereby the fractured segments are incompletely separated (AAE 2016). VRFs of endodontically treated teeth are annoying for the patient as well as for the health care professional. VRFs usually develop slowly, unnoticed by the patient until clinical signs and symptoms become apparent. Several issues have been associated with the development of VRFs: oversized root canal therapy, pressure transmission to canal walls during mechanical shaping and obturation of root canals, presence of a post or screw, presence of an isthmus, and occlusal overload by masticatory forces (Barreto et al. 2012, Corbella et al. 2014, Chai & Tamse 2015, Rivera & Walton 2015).

The frequency of VRFs in extracted endodontically treated teeth was reported to be 10.9% (Fuss et al. 1990). In contrast, Yoshino et al. (2015) found VRFs as the reason of tooth extraction in 31.7%, with 93.6% of those teeth presenting endodontic treatment. The same authors also reported the highest percentage of extractions due to a VRF in lower first molars (51.8%) and lower second premolars (51.0%). In a landmark study, Axelsson et al. (2004) recruited patients in 1971/72 for a long-term study regarding tooth maintenance. A total of 173 teeth in 257 subjects who returned for the 30-year examination were lost in that period. Root fractures of endodontically treated teeth were by far the most frequent reason (in 62.4%) for tooth extraction.

VRFs may originate from the cervical or apical root regions. Sugaya et al. (2015) demonstrated that VRFs originating from the apical region had a predilection of axial location in the bucco-oral direction (90.8%) whereas VRFs originating from the cervical region demonstrated a more diverse pattern of axial locations (57.4% bucco-oral, 36.2% mesio-distal, 6.4% other).

VRFs with pulpal communication allow bacterial contamination of the periodontium. Generally, this periodontal destruction and the accompanying signs and symptoms bring the fracture to the attention of the patient or dentist (Rivera & Walton 2015). Since the infection may drain along the periodontium or via a sinus tract (fistula), symptoms are usually mild and pain is often absent. Typical clinical findings of VRFs include isolated deep pocket probing on buccal and/or oral aspects of the affected root. Periapical radiographs may exhibit "halo" or "J-shape" radiolucencies along the fractured root (Tamse et al. 2006). However, many clinical and radiographic signs are not specific for the diagnosis of VRFs. A recent systematic review concluded that there is no substantial evidence regarding the accuracy of clinical and radiographic indices for the diagnosis of VRFs in endodontically treated teeth (Tsesis et al. 2010). Three-dimensional radiography (CBCT) is currently not recommended as a reliable method of VRF detection in endodontically treated teeth (Corbella et al. 2014, Chang et al. 2016).

The primary objective of the present study was the histologic assessment of VRFs in extracted, endodontically treated teeth. Secondary outcome measures included clinical and radiographic correlates of these VRF-affected teeth.

Material and methods

All cases included in this study were collected by the same clinician over a period of 12 years. Thirty extracted maxillary or mandibular posterior teeth (premolars and molars) with a preoperatively presumed VRF based on clinical (fistula located close to gingival margin, isolated deep probing depth) and/or radiographic findings ("halo" or "J-shape" radiolucencies) were stained with 1% methylene blue (Dr. G. Bichsel AG, Laboratory and Pharmacy, Interlaken, Switzerland) for clinical, post-extraction verification of the VRF. Roots that fractured during the extraction procedure into (multiple) fragments were excluded from further histological analysis.

The extracted teeth, or only the affected root(s) in case of crown damage during extraction, were subjected to histologic analysis. The specimens were placed in 10% neutral buffered formalin combined with 1% $CaCl_2$ for two weeks. After washing in water and dehydration in ethanol, the samples were embedded in methylmethacrylate. Using a low-speed diamond saw with copious water cooling, all teeth or roots were horizontally sectioned yielding serial ground sections of approximately 500 µm thickness. The sections were mounted on Plexiglas with acrylic glue and ground to a final thickness of around 100 µm. Finally, the sections were superficially stained with toluidine blue and basic fuchsin. Digital photography was performed using a digital camera (AxioCam MRc; Carl Zeiss, Göttingen, Germany) connected to a microscope (Axio Imager M2; Carl Zeiss).

The following histologic parameters with respect to the VRF were evaluated:

- Vertical extent of fracture (Fig. 1)
- Horizontal extent of fracture (Fig. 2)

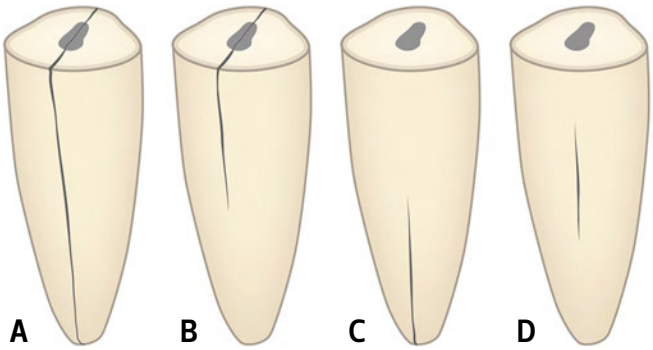

Fig. 1 Illustrations of the vertical extent of VRF (longitudinal plane): (A) complete, (B) cervical, (C) apical, (D) mid-root

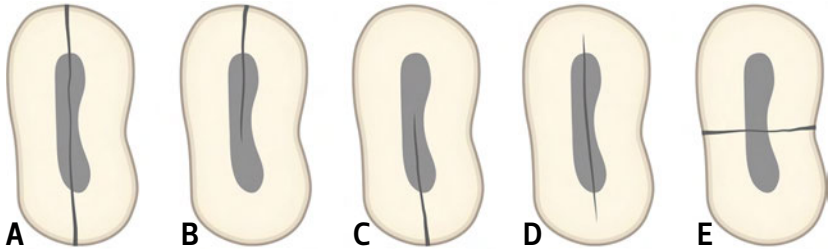

Fig. 2 Illustrations of the horizontal extent of VRF (axial plane, buccal at top): (A) complete, (B) buccal-central, (C) oral-central, (D) central, (E) mesio-distal

- Course of fracture in the axial plane (Fig. 3)
- Affected root portions by fracture in the axial plane (Fig. 4)
- Association of fracture and isthmus (Fig. 5)

The following clinical and radiographic data were retrospectively collected from these 30 cases:

- Patient-related data: gender, age
- Tooth-related data: type of tooth/root
- Symptoms and signs: pain, swelling, fistula, isolated periodontal pocket
- Treatment-related data: presence of post/screw, type of restoration/reconstruction
- Periapical radiography (PA) and cone beam computed tomography (CBCT) findings: type and location of radiolucency

Results

A total of 32 VRFs in 30 teeth were assessed. The patients included 16 females (53.3%) and 14 males (46.7%). The mean age of the patients was 58.7 years (range 39 to 86 years). The most frequently affected tooth was the lower first molar (Tab. I). The events of VRF diagnosis are presented in Table II. In the present study, the majority of VRFs were detected upon initial examination of teeth referred for apical surgery (60%). In ten cases (33.3%), the diagnosis of VRF was ensured during elevation of a flap.

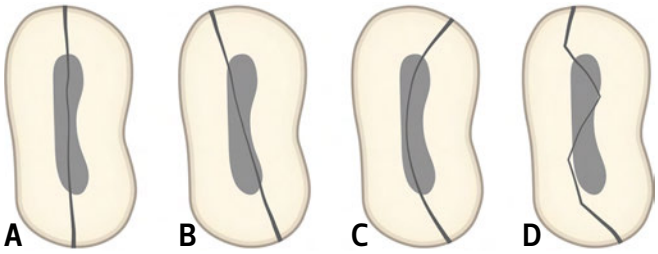

Fig. 3 Illustrations of the course of VRF (axial plane): (A) straight, (B) oblique, (C) curved, (D) zigzag

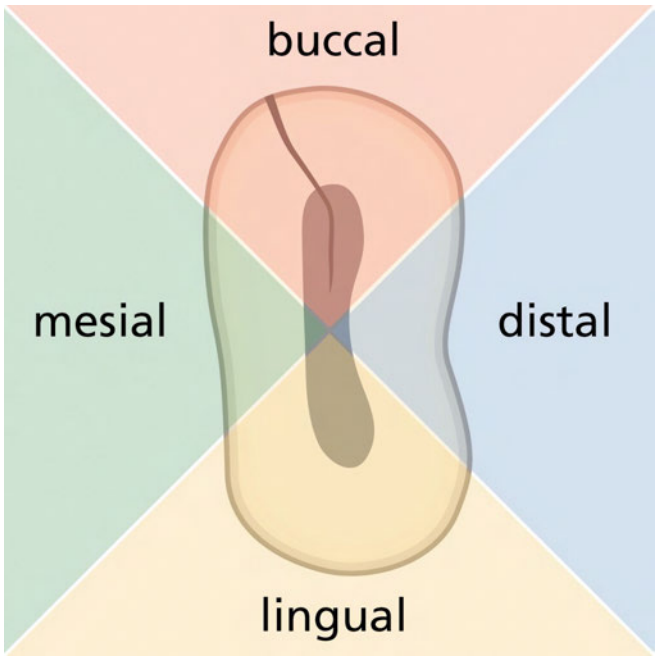

Fig. 4 Illustration of definitions of the affected root portions (axial plane): in the example, the VRF affects only the buccal root portion.

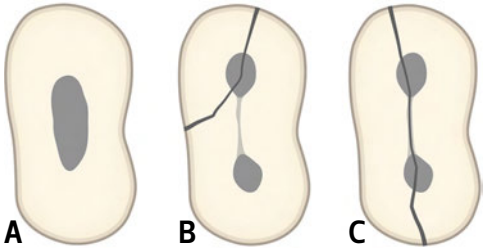

Fig. 5 Illustrations of the association of VRF and isthmus: (A) no isthmus present, (B) isthmus present with VRF bypassing the isthmus, (C) isthmus present with VRF involving the isthmus

Tab. I Evaluated teeth (N=30) and roots (N=32)

	Tooth	N	Root	N
Maxilla	1st premolar	6	–	6
	2nd premolar	8	–	8
	1st molar	2	1× mesiobuccal, 1× fused mesiobuccal-palatal	2
Mandible	1st premolar	1	–	1
	1st molar	13	10× mesial, 1× distal, 2× mesial and distal	15
Total		**30**		**32**

Tab. II Events of diagnosis of the VRF (N=30)

Event		N	%
Initial examination of tooth referred for apical surgery		18	60
5-year follow-up examination after "in-house" apical surgery		4	13.33
Self-referral after "in-house" apical surgery because of pain and/or fistula	1× 9 months after surgery 2× 2 years after surgery 1× 6 years after surgery 1× 9 years after surgery	5	16.66
Self-referral after endodontic treatment *alio loco* because of pain and/or fistula		2	6.66
Implant site evaluation adjacent to endodontically treated tooth		1	3.33
Total		**30**	**100**

Histological findings

The histological assessment of the VRFs is summarized in Table III. In the majority of the cases (81.3%), the VRF extended from the cervical region to the apex (Fig. 6). With regard to the horizontal plane, 50% of VRFs traversed the root completely from buccal to oral. However, many VRFs were also limited to the buccal root portion (40.6%). The course of VRFs was evenly distributed among the four categories (21.9–28.1%). Buccal and oral root portions were affected by VRFs in 93.8% and 65.6%, respectively. An isthmus was present in 84.4% of the evaluated roots. Overall, the VRFs were associated with an isthmus in 56.3%, but bypassed the isthmus in 28.1% (Fig. 7).

Tab. III Histological findings of the VRFs (N=32)

Variable	Subgroups	N	%
Vertical extension	Complete	26	81.25
	Cervical	5	15.625
	Apical	0	–
	Mid-root	1	3.125
Horizontal extension	Complete	16	50
	Buccal only	13	40.625
	Oral only	1	3.125
	Central	1	3.125
	Mesio-distal	1	3.125
Course	Straight	8	25
	Oblique	8	25
	Curved	7	21.875
	Zigzag	9	28.125
Affected root portions*	Buccal	30	93.75
	Mesial	2	6.25
	Oral	21	65.625
	Distal	1	3.125
Isthmus	Present (VRF is associated with Isthmus)	18	56.25
	Present (VRF is not associated with Isthmus)	9	28.125
	Absent	5	15.625

*Multiple portions possible per case (N>32)

Clinical and radiographic findings

The most frequently observed clinical findings included pain (60% of the cases), presence of a fistula (46.7%) and an isolated periodontal pocket with ≥6 mm probing depth (40%) (Tab. IV, Fig. 8). All fistulae (except one) were found on the buccal aspect of the affected roots. Furthermore, fistulae were located closer to the gingival margin than to the apical region. Two buccal fis-

Fig. 6 Three histologic sections of VRF in a maxillary second premolar with complete vertical and horizontal extent: (A) cervical area, (B) mid-root area, (C) apical area

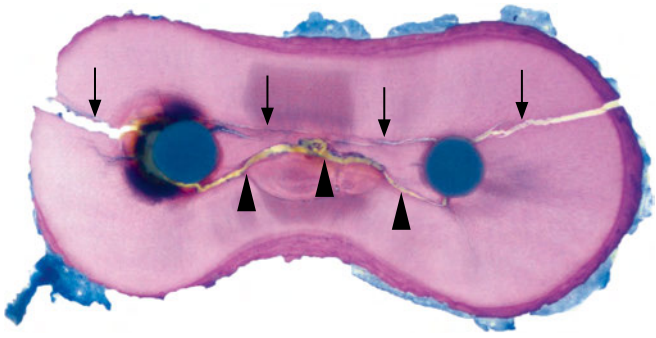

Fig. 7 Histologic mid-root section of VRF in the mesial root of a first mandibular molar. A complete VRF is visible (arrows) that, however, bypasses the isthmus (arrowheads).

Tab. IV Clinical findings (N=30)

Clinical findings		N	%
Symptoms*	Pain	18	60
	Percussion sensitivity	2	6.66
	Palpation sensitivity	2	6.66
Clinical signs*	Fistula	14	46.66
	Isolated periodontal pocket ≥6 mm	12	40
	Localized swelling	7	23.33
	Pus from fistula	2	6.66
	Pus from sulcus	1	3.33
	Increased tooth mobility	1	3.33

*Cases could demonstrate multiple findings

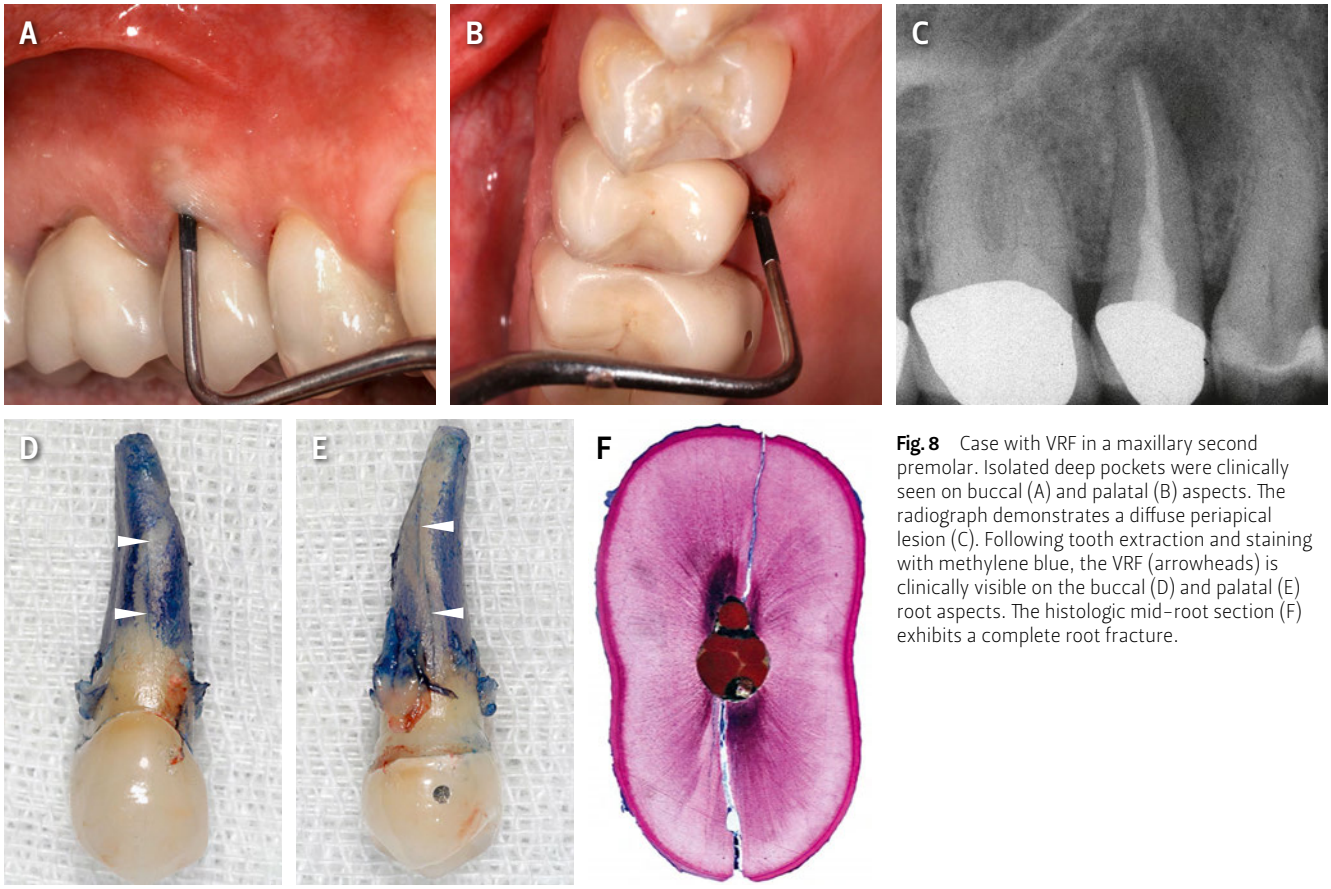

Fig. 8 Case with VRF in a maxillary second premolar. Isolated deep pockets were clinically seen on buccal (A) and palatal (B) aspects. The radiograph demonstrates a diffuse periapical lesion (C). Following tooth extraction and staining with methylene blue, the VRF (arrowheads) is clinically visible on the buccal (D) and palatal (E) root aspects. The histologic mid-root section (F) exhibits a complete root fracture.

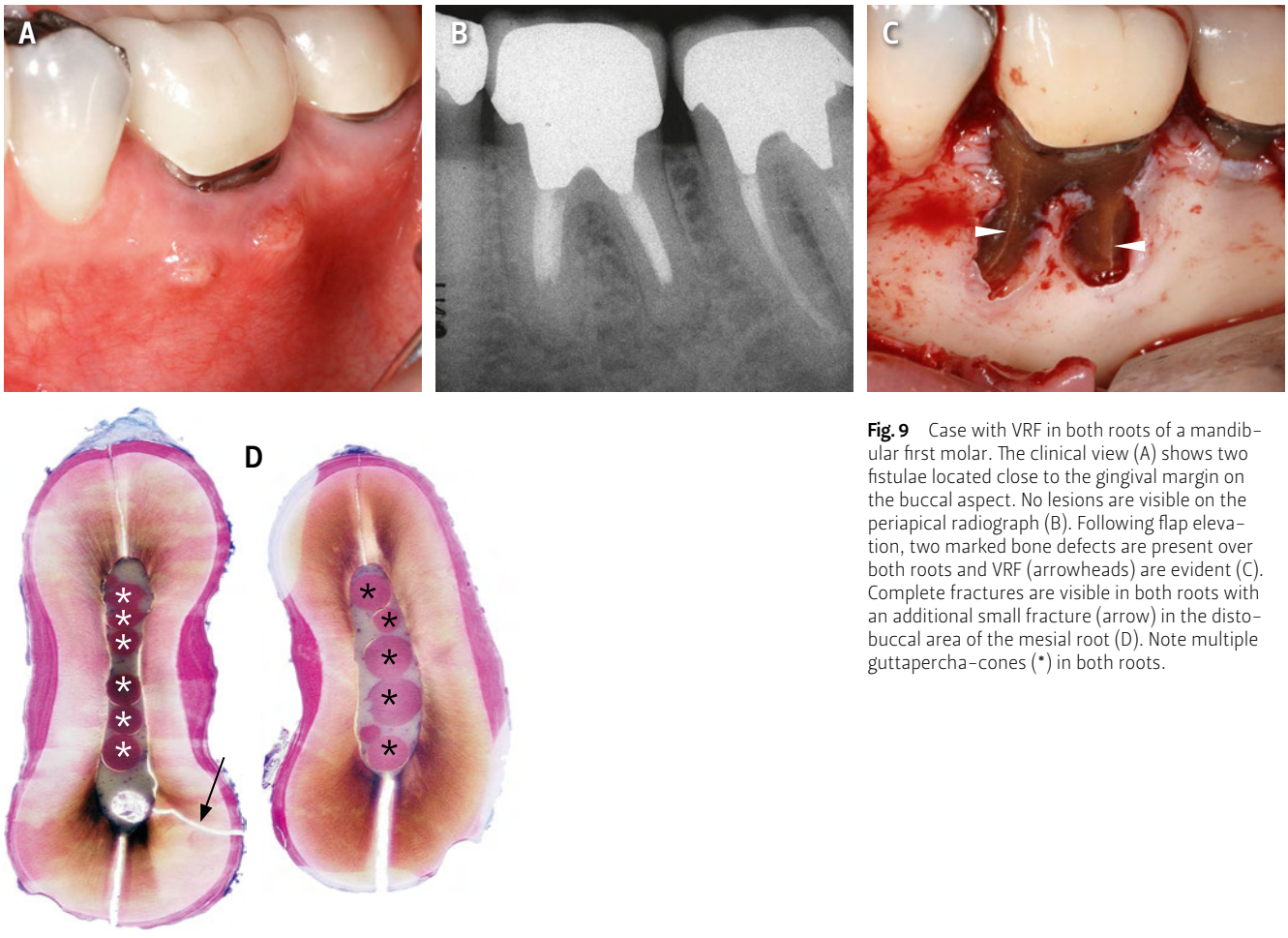

Fig. 9 Case with VRF in both roots of a mandibular first molar. The clinical view (A) shows two fistulae located close to the gingival margin on the buccal aspect. No lesions are visible on the periapical radiograph (B). Following flap elevation, two marked bone defects are present over both roots and VRF (arrowheads) are evident (C). Complete fractures are visible in both roots with an additional small fracture (arrow) in the distobuccal area of the mesial root (D). Note multiple guttapercha-cones (*) in both roots.

Tab. V Radiographic findings (N=30)

Radiographic findings	Type/location of radiolucency	N	%
PA (N=30)	Periapical	16	53.33
	J-shape	5	16.66
	Periradicular	4	13.33
	Apical and interradicular	2	6.66
	No radiolucency	3	10
CBCT (N=10)*	Periapical	4	13.33
	+J-shape	3	10
	+Bone dehiscence over root	2	6.66
	+Bone fenestration over root	2	6.66
	Periradicular	1	3.33
	Apical and interradicular	1	3.33

* Cases could demonstrate multiple findings
\+ All of these lesions were not detected with PA

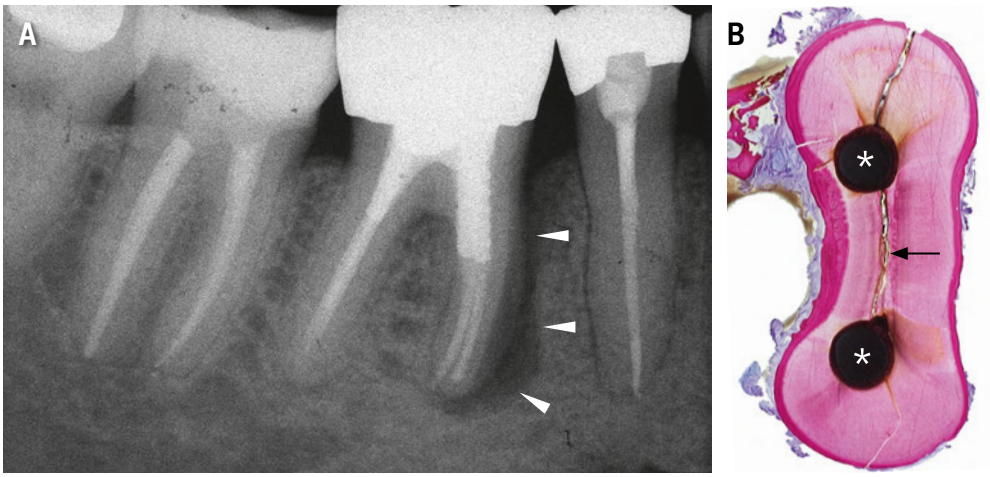

Fig. 10 Typical J-shape lesion (arrowheads) along the mesial root surface of the mesial root in a first mandibular molar. Note that two metallic posts are present in the mesial root (A). The histologic mid-root section (B) exhibits a complete VRF engaging the thin isthmus (arrow) – again note the two metallic posts (*).

tulae were present in one out of two patients having VRFs in both mesial and distal roots of a lower first mandibular molar (Fig. 9). The isolated deep periodontal pockets were located in nine cases on the buccal and in two cases on the oral aspect. One tooth presented isolated periodontal pockets both on buccal and oral aspects.

With regard to radiographic findings, periapical radiographs had been taken in each case, but CBCTs were only available in 10 out of 30 patients. A periapical location of the radiolucency (in 53.3%) was the most frequent finding in PA (Tab. V). J-shape lesions were seen in five cases with PA, but in an additional three cases with CBCT (Fig. 10). Dehiscence defects of the marginal buccal bone (two cases) as well as fenestration defects of the buccal bone plate (two cases) were only observed with CBCT (Fig. 11/12).

In 43.8% of the VRF-affected roots, a post- or screw-retention was present (14 roots had 16 retentions including 11 metallic posts, 2 metallic screws and 3 glass fibre posts). The majority (83.3%) of the evaluated teeth were reconstructed with a ceramic-fused-to-metal crown; four of these teeth served as a pillar for a conventional bridge (fixed prosthesis).

Discussion

The present study assessed 32 VRFs from a histological perspective but also included clinical and radiographic correlates. To our knowledge, VRFs have been histologically evaluated only in a study >30 years ago (Walton et al. 1984). Thus, the present data provide further insight with regard to the extent, course and location of VRFs. While all teeth were carefully extracted and handled with great care during histologic processing, it cannot be excluded that these measures affected the VRF. Besides, the retrospective design and the limited sample size did not allow determining the cause of the VRFs and their actual clinical and radiographic progress. Due to methodological rea-

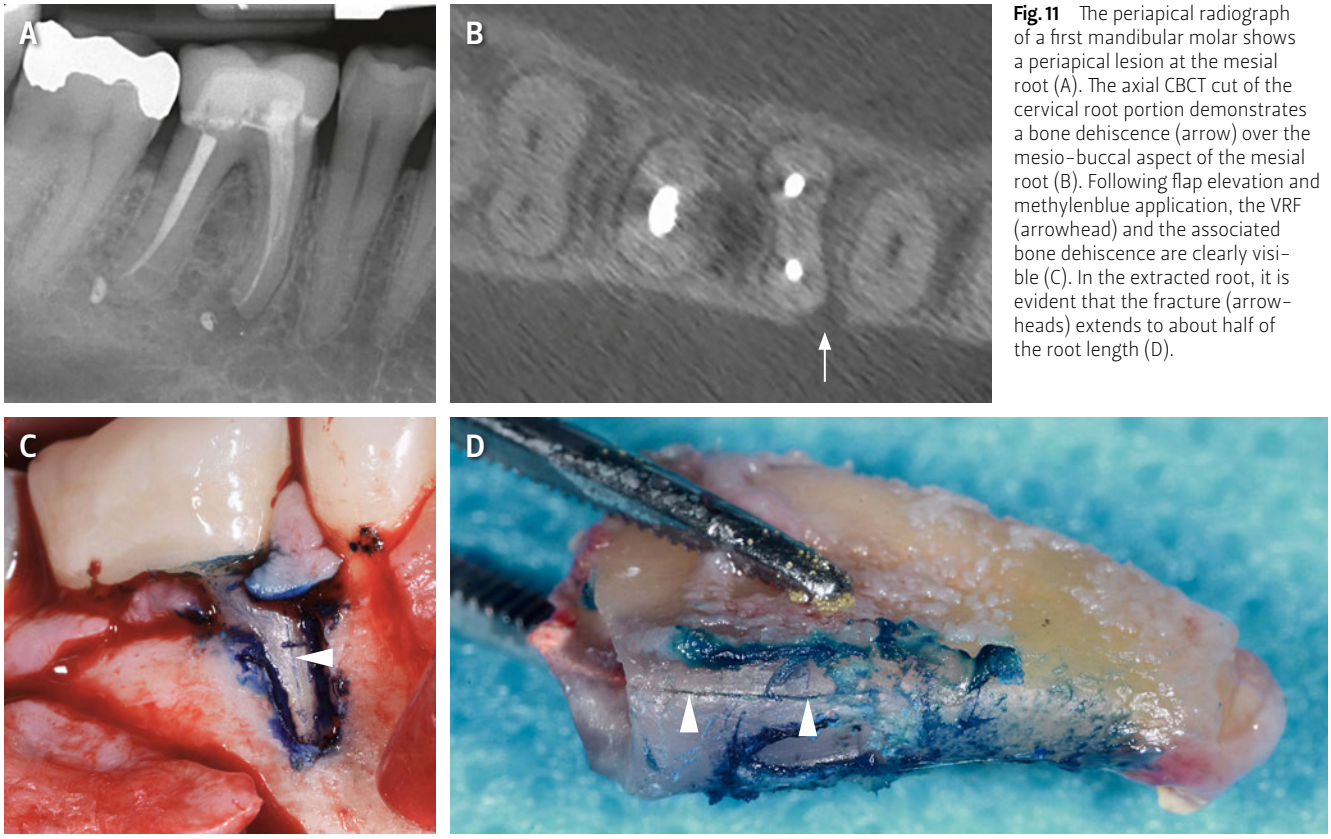

Fig. 11 The periapical radiograph of a first mandibular molar shows a periapical lesion at the mesial root (A). The axial CBCT cut of the cervical root portion demonstrates a bone dehiscence (arrow) over the mesio-buccal aspect of the mesial root (B). Following flap elevation and methylenblue application, the VRF (arrowhead) and the associated bone dehiscence are clearly visible (C). In the extracted root, it is evident that the fracture (arrowheads) extends to about half of the root length (D).

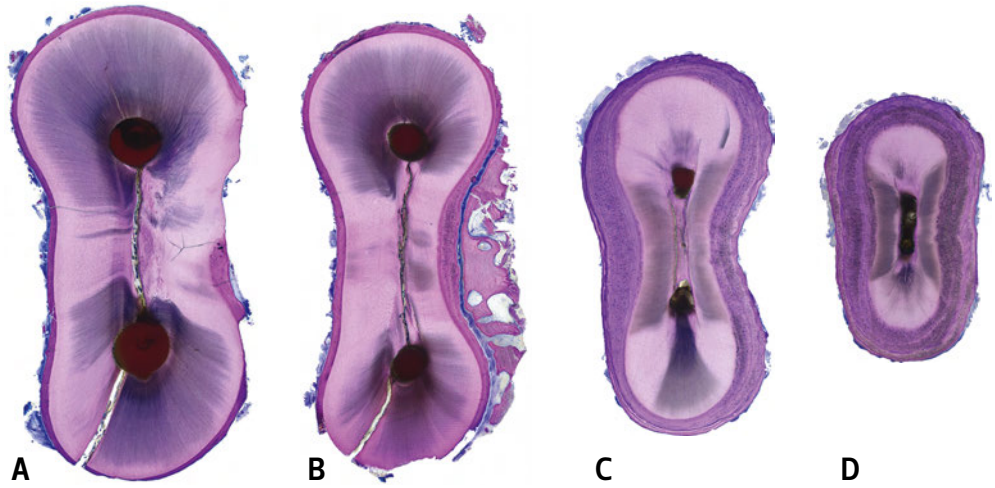

Fig. 12 The histologic sections through different root levels (A/B = cervical areas, C/D = apical areas) demonstrate that the VRF is incomplete in the longitudinal and horizontal dimensions, thus only involving the cervical and buccal root portions.

sons, only extracted teeth with proved VRFs, i.e. late-stage situations, were evaluated.

Generally, VRF originating from the root must be distinguished from cracks starting from the crown (cracked tooth) and spreading to the root. However, the retrospective study design and the fact that 83.3% of the studied teeth were reconstructed with a ceramic-fused-to-metal crown did not allow a distinction between the two entities.

Sugaya et al. (2015) propagated that VRFs may originate from the apical root area; also Schwarz et al. (2012), using scanning electron microscopy of fractured roots, described that VRFs started at the root canal wall in the apical part of the root and then extended toward the outer root surface and coronally. However, such a finding could not be observed in the present material – none of the cases with an incomplete vertical extent was located in the apical portion; in contrast, five out of six VRFs with incomplete vertical extent were found in the cervical root portion, indicating a possible origin from the cervical area.

VRFs are dynamic in nature, and an incomplete VRF may propagate into a complete VRF after having been exposed to mastication for a longer time. Thus, the time point of extraction relative to the disease process may influence the extent of the VRF. Nine teeth of the study sample had previous apical surgery, and thus the apical root portion was not available for assessment. However, in all nine teeth, the VRFs extended from the cervical root portion to the apical resection plane.

With regard to the horizontal extent of VRFs, complete fractures extending from the buccal to the oral root aspects (50%) and incomplete fractures involving only the buccal aspect of the root (40.6%) were the predominant axial features. It was strik-

ing to see that incomplete fractures related to the horizontal extent predominantly involved the buccal root portion (93.8%). One may speculate that fractures propagate from the root canal to buccal root portions due to laterally directed forces of mastication. The preponderance of the bucco-oral direction of the VRFs may also be related to the wedging forces of root-canal preparation and obturation.

In the histologic study by Walton et al. (1984), VRFs passed completely through the root to include opposite surfaces in 90%. This difference of 40% compared to the present study might be explained by the type of evaluated roots that were unfortunately not specified by Walton et al. (1984). Similar to the present study, the majority of the cases of Walton et al. (1984) extended from the cervix to the apex.

Some authors also pointed to the isthmus as a predilection site for fracture occurrence (Chai & Tamse 2015). In fact, the latter authors demonstrated in an *in-vitro* mechanistic model that the isthmus connecting two canals could be regarded as a natural weak plane. They concluded from their experimental data, that 2-canal mesial roots of mandibular molars were more prone to a VRF than 1-canal distal roots. In fact, all roots with two canals in the present study also had an isthmus; yet in one third of these cases, the VRF did not involve the isthmus. One may speculate, that not only the isthmus but also the ratio of the bucco-oral and mesio-distal root dimensions influences the occurrence of VRFs. Furthermore, finite element models demonstrated that canal curvature seems more important than external root morphology for VRF development following endodontic treatment (Lertchirakarn et al. 2003).

According to Kishen (2015), the resistance of the root to flex will also depend upon the distribution of dentin material around the canal wall. Hence, residual dentin, root canal geometry and canal volume are factors to be considered with regard to resistance to fracture. Furthermore, a post-core restoration will alter the stress concentration zones within the root and will increase tensile stresses in the residual dentin (Kishen 2015). Using finite element analysis, Santos et al. (2009) demonstrated that a lack of effective bonding between post and root increases the risk of a VRF; hence not the presence of the post but rather the inadequate bonding of the post may induce a VRF.

In the present study, only premolars and molars with VRF were analyzed. According to Fuss et al. (2001), premolars and mesial roots of mandibular molars of endodontically treated teeth are particularly susceptible for VRF. In fact, very low occurrence rates for VRFs have been reported for anterior teeth (Tamse et al. 1999, Chan et al. 1999). From these data, one may speculate that the higher mastication forces in posterior compared to anterior jaw segments may influence the occurrence rate of VRF with regard to different tooth types.

According to Vire (1991) who evaluated over a 1-year period the causes of failure of 116 endodontically treated teeth, VRF due to instrumentation failures amounted to 4.3%, mostly in mandibular molars. An additional 8.6% presented root fractures in conjunction with post-restorations. The majority of those teeth were premolars or other teeth with narrow roots. Also Fuss et al. (2001) concluded that post placement and root canal treatment were the major etiological factors for VRF in a sample of 154 extracted endodontically treated teeth presenting VRFs. A post was observed in 61.7% compared to 43.3% in the present study.

In summary, the present study demonstrates the unique histologic features of VRFs in 32 premolar or molar roots. VRFs were predominantly complete in terms of vertical extent, and involved the isthmus when present (in 66.7%). Buccal root portions (in 93.8%) were by far the most frequently affected sites. The chief clinical symptoms/signs included pain (60%) and fistulae (46.7%) that were typically located close to the gingival margin. The most frequent radiographic finding was periapical radiolucency (53.3%). Due to the retrospective nature of the analysis and the limited sample size, no firm conclusions should be drawn from this case series.

Acknowledgements

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Résumé

Une fracture radiculaire verticale (FRV) est définie par la séparation partielle ou totale de la substance radiculaire dans l'axe longitudinal de la dent. Les causes possibles d'une FRV sont: traitement de racine surdimensionné, surcharge sur les parois canalaires lors de la préparation ou de l'obturation radiculaire, tenons ou vis canalaires, isthme, surcharge occlusale. Une FRV passe souvent inaperçue. Ce n'est que lors de l'apparition de pathologies associées telles que des poches parodontales isolées, des fistules ou des douleurs que le patient consulte le médecin-dentiste. Il est bien documenté dans la littérature que souvent, la cause de l'extraction d'une dent avec traitement de racine est une FRV.

Dans la présente étude, les différents paramètres de FRV ont été examinés histologiquement sur 30 dents extraites: l'extension verticale et horizontale de la fracture, forme de la fracture dans le plan axial, partie de la racine concernée, association fracture/isthme. En outre, les constatations cliniques et radiologiques ont été analysées rétrospectivement.

Après l'extraction, les dents, plus particulièrement les racines, ont été teintées au bleu de méthylène et inspectées cliniquement. Les échantillons ont été rincés et déshydratés dans l'alcool. Des coupes en séries de 500 µm ont été réalisées après fixation dans le méthacrylate de méthyle. Ces dernières ont été collées sur du plexiglas avant d'être recoupées pour atteindre des coupes d'épaisseur de 100 µm qui étaient colorées en surface avec de la toluidine bleue et de la fuchsine.

Au total, il y avait 32 FRV sur les 30 dents examinées. L'âge moyen des patients était de 58,7 ans (39–86 ans). Les dents le plus souvent concernées étaient les premières molaires mandibulaires. La plupart des fractures étaient découvertes lors de la première consultation (60%), particulièrement lorsque les cas étaient référés pour une résection apicale.

Au niveau histologique, 81,3% des FRV s'étendaient intégralement du collet à l'apex et 50% à travers toute la dimension horizontale de la racine (vestibulo-oral). Dans 40,6% des cas, la FRV se limitait à la partie vestibulaire de la racine. Les formes des traits de fracture dans le plan axial (droite, coudée, en biais ou en zigzag) étaient uniformément réparties (21,9–28,1%). Les parties vestibulaires (93,8%) et orales (65,6%) des racines étaient le plus souvent concernées, les parties mésiales et distales, au contraire, n'étaient que très rarement atteintes. Dans 56,3% des cas, la fracture était associée avec l'isthme.

Les manifestations cliniques les plus fréquentes étaient des douleurs (60%), la présence d'une fistule (46,7%) tout comme

une poche parodontale isolée ≥6 mm (40%). Les fistules, à une exception près, étaient toutes situées du côté vestibulaire et dans la partie la plus coronaire de la racine. Les poches parodontales isolées étaient, dans 9 cas sur 11, aussi vestibulaire. La manifestation radiologique la plus fréquente sur les radiographies apicales était une radiotransparence apicale (53,3%). Au total, huit cas avaient des lésions en forme de «J». De ces lésions, trois étaient seulement visibles sur une radiographie tridimensionnelle. Des déhiscences ou fenestrations de la corticale vestibulaire (deux cas) n'étaient visibles aussi uniquement que sur une radiographie tridimensionnelle. Des ancrages au moyen de vis ou de tenons étaient présents dans 43,3% des cas. 83,3% des dents examinées étaient restaurées au moyen d'une couronne céramo-métallique.

En conclusion, dans le matériel examiné, les FRV concernaient principalement les parties vestibulaires de la racine et leur origine se situait dans la partie cervicale de la racine. Une location vestibulo-orale des FRV pourrait être favorisée par la présence d'un isthme ou éventuellement aussi par les forces masticatoires latérales ou les forces vestibulo-orales de la préparation canalaire. Dans la littérature, l'analyse d'éléments finis montre que la courbure des canaux radiculaires peut avoir une influence principale sur la survenue de FRV.

Zusammenfassung

Eine vertikale Wurzelfraktur (VWF) wird definiert als partielle oder vollständige Trennung der Wurzelsubstanz in der Längsachse der Wurzel. Mögliche Ursachen von VWF sind: überdimensionale Wurzelkanalbehandlung, Kraftübertragung auf die Kanalwände während der Aufbereitung und Obturation, Wurzelkanalstift oder -schraube, Isthmus, okklusale Überlastung. VWF entstehen oft unbemerkt, und erst nach Auftreten von Begleitpathologien wie isolierte parodontale Taschenbildung, Fistel oder Schmerzen sucht der Patient den Zahnarzt auf. In der Literatur ist gut dokumentiert, dass bei einer Extraktion eines endodontisch behandelten Zahnes oft eine VWF der Grund ist.

In der vorliegenden Studie wurden 30 extrahierte Zähne histologisch auf verschiedene Parameter der VWF untersucht: vertikale und horizontale Ausdehnung der Fraktur, Form der Fraktur in der axialen Ebene, betroffene Wurzelabschnitte, Assoziation Fraktur mit Isthmus. Zudem wurden retrospektiv klinische und radiologische Befunde analysiert.

Die Zähne bzw. Wurzeln wurden nach der Extraktion mit 1% Methylenblau angefärbt und klinisch inspiziert. Danach wurden die Proben gewaschen und in Alkohol dehydriert. Nach Einbettung in Methylmethacrylat erfolgten Serienschnitte (Dicke 500 µm). Diese Schnitte wurden dann auf Plexiglas aufgeklebt, abschliessend auf eine Dicke von 100 µm zurückgeschliffen und oberflächlich mit Toluidinblau und Fuchsin gefärbt.

Insgesamt fanden sich 32 VWF bei den untersuchten 30 Zähnen. Das Durchschnittsalter der Patienten betrug 58,7 Jahre (39–86 Jahre). Am häufigsten waren erste Molaren im Unterkiefer betroffen. Meistens wurden die VWF bei der Erstuntersuchung von Fällen entdeckt (60%), die zur Abkläung bzw. Durchführung einer Wurzelspitzeresektion zugewiesen worden waren.

Histologisch zeigten die VWF in 81,3% eine vollständige Ausdehnung von zervikal bis apikal. In der horizontalen Dimension durchquerten die VWF in 50% die Wurzel vollständig von bukkal nach oral. In weiteren 40,6% beschränkte sich die VWF auf den bukkalen Wurzelanteil. Die Formen des Frakturverlaufs in der axialen Ebene (gerade, gebogen, schräg, zickzack) waren gleichmässig verteilt (21,9–28,1%). Bukkale (93,8%) und orale (65,6%) Wurzelabschnitte waren häufig von einer VWF betroffen, mesiale und distale hingegen sehr selten. In 56,3% war die VWF mit einem Isthmus assoziiert.

Klinisch häufige Befunde waren Schmerzen (60%), Vorhandensein einer Fistel (46,7%) sowie eine isolierte Parodontaltasche ≥6 mm (40%). Die Fisteln waren mit einer Ausnahme immer auf der bukkalen Seite der Zähne lokalisiert und lagen deutlich näher beim Gingivarand als in der Apikalregion. Auch die isolierten Parodontaltaschen fanden sich in neun von elf Fällen bukkal. Der häufigste radiologische Befund im Einzelzahnröntgenbild war eine apikale Radioluzenz (53,3%). In insgesamt acht Fällen waren «J-shape»-Läsionen vorhanden, wobei drei dieser Läsionen nur im DVT gesehen wurden. Dehiszenz- oder Fenestrationsdefekte (je in zwei Fällen) der bukkalen Kortikalis waren ebenso nur im DVT sichtbar. Stift- oder Schraubenverankerungen fanden sich in 43,3% der Fälle. In 83,3% waren die untersuchten Zähne mit einer Verbundmetallkrone rekonstruiert.

Abschliessend kann festgehalten werden, dass VWF im untersuchten Material bevorzugt die bukkalen Wurzelanteile betrafen und ihren Ursprung wahrscheinlich im zervikalen Wurzelabschnitt hatten. Der meist bukko-orale Verlauf der VWF wird durch das Vorhandensein eines Isthmus begünstigt, evtl. auch durch Kaukräfte nach lateral oder Überwiegen von Kräften in bukko-oraler Richtung bei der Wurzelkanalaufbereitung. Finite-Element-Analysen in der Literatur zeigten, dass vor allem die Kurvatur der Wurzelkanäle einen Einfluss auf die Entstehung von VWF haben kann.

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