Original article

Differences in the corono-apical location of sinus tracts and buccal cortical bone defects between vertically root-fractured and non-root-fractured teeth based on periradicular microsurgery

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Abstract: This retrospective study aimed to investigate whether the corono-apical location of sinus tracts differs according to the presence/absence of vertical root fracture (VRF) in microsurgically treated root-filled teeth. The cases included were (1) anterior and premolar teeth with a probing depth of ≤3 mm, (2) those with a periodontal probing depth of ≤3 mm, (3) those for which preoperative cone-beam computed tomography (CBCT) scans and intraoperative video records were available, VRF was diagnosed intraoperatively. The locations of buccal cortical bone defects and fracture lines were categorized on video images, and the corono-apical sinus tract locations were determined by superimposing video images onto volume-rendered CBCT images. Eleven of the 78 teeth investigated had VRF, and there was no significant difference in the incidence of sinus tracts between vertically fractured and non-fractured teeth (Mann-Whitney U-test, P > 0.05). The location of the sinus tract was significantly more coronal in vertically fractured than in non-fractured teeth (Mann-Whitney U-test, P < 0.0001). In microsurgically treated anterior and premolar teeth with a probing depth of ≤3 mm, sinus tracts were more coronally located in vertically fractured than in non-fractured teeth, and were highly correlated with the location of cortical bone defects.

Keywords: cortical bone defect, endodontic microsurgery, sinus tract, vertical root fracture

Introduction

Vertical root fracture (VRF) is a significant cause of loss of endodontically treated teeth [1-4]. VRF has been reported in approximately 3-25% of all extracted root-filled teeth [1-3,5,6] and is a major cause of refractory apical periodontitis diagnosed by general dentists [7], suggesting that undetected VRF has treatment-resistant signs and symptoms leading to unnecessary and difficult endodontic treatment.

Clinical signs of VRF include the presence of fracture line(s), formation of deep narrow isolated periodontal pocket(s), sinus tract formation, and increased mobility [1,8,9]. Common radiographic features include a halo- or ‘J’-shaped radiolucency around the fractured root and visible separation of the root [6,10,11]. The simultaneous presence of these clinical and radiological features, in particular a deep narrow isolated periodontal pocket, with a sinus tract is often pathognomonic for VRF [6,9,12,21,22], suggesting that the location of a sinus tract is diagnostically valuable for teeth with a difficult-to-detect VRF. However, detailed analysis of these findings, especially in VRF, has been lacking. The present study was therefore conducted to investigate whether the corono-apical location of sinus tracts differs according to the presence/absence of VRF, and whether it is related to the cause of VRF. For this purpose, intraoperative findings in cases requiring endodontic microsurgical retreatment with normal probing depths and no preoperative diagnosis of VRF were investigated. The null hypothesis was that there is no difference in the corono-apical location of sinus tracts and cortical bone defects between teeth with and without VRF.

Materials and Methods

Case selection

This retrospective study was approved by the Tokyo Medical and Dental University Ethics Committee (no. D2016-102). All subjects and data were from all cases (154 teeth in 154 patients) that had been treated by endodontic microsurgery at the Department of Operative Dentistry & Endodontics, Tokyo Medical and Dental University Dental Hospital, Tokyo, Japan between March 2016 and February 2018.

The cases included in this study were (1) root canal-treated teeth with persistent signs and symptoms treated by endodontic periradicular microsurgery, (2) teeth without a preoperative diagnosis of VRF by visual and/or radiographic detection of fracture line(s), (3) anterior and premolar teeth having a radiolucent lesion associated with a single tooth, (4) teeth with a periodontal probing depth of ≤3 mm, (5) available preoperative CBCT scans, and (6) available intraoperative video records. Teeth with perforations, cemental tears, lateral canals, or multiple sinus tracts were excluded.

Clinical procedure

Preoperative CBCT was performed for each subject using a 3DX multi-image Micro CT instrument (Morita, Kyoto, Japan). The radiation field was 30 mm in height and 40 mm in width at the center of rotation. The imaging time was 17 s at 60-80 kV and 1-10 mA. Slices were reconstructed with different directions and thicknesses (0.125-2 mm).

All surgical procedures were performed under an operating microscope (OPMI pico; Carl Zeiss, Jena, Germany). Videos were recorded before and during surgery using an HD digital video camera (THD-311, Ikegami, Tokyo, Japan) attached to the microscope. The presence of VRF was confirmed during each step of surgery, i.e., flap reflection, osteotomy, apical curettage, and root-end resection, under the operating microscope with the aid of methylene blue dye (Waldeck, Münster, Germany).

Evaluation

The cases were classified as “VRF” or “non-VRF” according to the presence or absence, respectively, of VRF. The classification was determined...
sequent analyses were based on the values obtained by Y. K. carried out by the same examiners to assess intraobserver reliability. Suband scored the images. More than 3 weeks later, the same evaluation was independently viewed and 7 years, respectively, of clinical experience) independently viewed and volume-rendered CBCT images. This was necessary because the video records did not show the full length of the root due to higher magnification, which made it impossible to determine the relative location. The volume-rendered CBCT images were created and adjusted using Amira v.5.4.4 software (Visage Imaging GmbH, Berlin, Germany) so that the angle and direction were most similar to those of the corresponding video images. The superimposition and evaluation were performed using PowerPoint software (Microsoft, Redmond, WA, USA). The location of the sinus tract was scored according to the corono-apical level as follows: 1) apical area (apical one-third of the root), 2) mid-root area (middle one-third of the root), and 3) gingival marginal area (coronal one-third of the root from the gingival margin) (Fig. 1A).

The location/shape of buccal cortical bone defects and the location/extension of the root fracture line were categorized based on the findings in the video records. Static images were captured from the video records, imported into PowerPoint, and viewed randomly on a personal computer with a screen resolution of 1,920 × 1,080 (DTU-2231; Wacom, Saitama, Japan).

Buccal cortical bone defects were scored according to the corono-apical level as follows: (1) localized apical bone defect, (2) elliptical bone defect extending from the apex to the mid-root area, (3) bone defect within the mid-root area, and (4) dehiscence (Fig. 1B). In teeth with VRF, the location/extension of vertical root fracture lines was scored as follows: (1) localized apical root fracture line, (2) root fracture line extending from the apex to the mid-root area, and (3) root fracture localized within the mid-root area (Fig. 1C).

Two examiners (Y. K. and Y. I., specializing in endodontics with 4 and 7 years, respectively, of clinical experience) independently viewed and scored the images. More than 3 weeks later, the same evaluation was carried out by the same examiners to assess intraobserver reliability. Subsequent analyses were based on the values obtained by Y. K.

on the basis of intraoperative microscopic examination as mentioned above.

The location of the sinus tract in relation to the corono-apical level of the root was assessed by superimposition of preoperative video images and volume-rendered CBCT images. This was necessary because the video records did not show the full length of the root due to higher magnification, which made it impossible to determine the relative location. The volume-rendered CBCT images were created and adjusted using Amira v.5.4.4 software (Visage Imaging GmbH, Berlin, Germany) so that the angle and direction were most similar to those of the corresponding video images. The superimposition and evaluation were performed using PowerPoint software (Microsoft, Redmond, WA, USA). The location of the sinus tract was scored according to the corono-apical level as follows: 1) apical area (apical one-third of the root), 2) mid-root area (middle one-third of the root), and 3) gingival marginal area (coronal one-third of the root from the gingival margin) (Fig. 1A).

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### Table 1 Incidence of sinus tracts and cortical bone defects in VRF and non-VRF teeth

|                         | Total (n = 78) | VRF (n = 11) | Non-VRF (n = 67) | P-value |
|-------------------------|---------------|-------------|-----------------|---------|
| Sinus tract             |               |             |                 |         |
| Yes                     | 43 (55.1)     | 9 (81.8)    | 34 (50.7)       | 0.099   |
| No                      | 35 (44.9)     | 2 (18.2)    | 33 (49.3)       |         |
| Location of sinus tract |               |             |                 |         |
| Apical                  | 28 (65.1)     | 0 (0)       | 28 (82.4)       | <0.0001*|
| Mid-root                | 13 (30.2)     | 7 (77.8)    | 6 (17.7)        |         |
| Gingival marginal       | 2 (4.7)       | 2 (22.2)    | 0 (0)           |         |
| Buccal cortical bone defect |           |             |                 |         |
| Yes                     | 59 (75.6)     | 11 (100.0)  | 48 (71.6)       | <0.05*  |
| No                      | 19 (24.4)     | 0 (0)       | 19 (28.4)       |         |
| Location of cortical bone defect |       |             |                 |         |
| Apical                  | 50 (84.7)     | 3 (27.3)    | 47 (97.9)       | <0.0001*|
| Apical to mid-root      | 3 (5.1)       | 2 (18.2)    | 1 (2.1)         |         |
| Mid-root                | 3 (5.1)       | 3 (27.3)    | 0 (0)           |         |
| Dehiscence              | 3 (5.1)       | 3 (27.3)    | 0 (0)           |         |

*Significantly different between VRF and non-VRF teeth (Mann-Whitney U-test). VRF, vertical root fracture.

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### Statistical analysis

Statistical analysis was performed using SPSS v23.0 software (IBM Corp, Armonk, NY, USA). The Mann-Whitney U-test was used to analyze differences between VRF and non-VRF cases (α = 0.05). Spearman’s correlation coefficient was used to calculate the correlation among the scores for the sinus tract, cortical bone defect, and fracture line. Kappa values were used to assess the intraobserver and interobserver reliability.

### Results

A total of 78 teeth from 74 patients (13 males and 61 females; mean age = 53.00) met the inclusion criteria; 76 teeth in 76 patients were excluded. Among the included teeth, 11 (14.1%) and 67 (85.9%) had been diagnosed during surgery as VRF and non-VRF, respectively. The incidence and location of sinus tracts and cortical bone defects in the VRF and non-VRF teeth are shown in Table 1.

The overall prevalence of sinus tracts was 55.1% (Table 1). There was no significant difference in the incidence of sinus tract formation between VRF and non-VRF (P = 0.099). In teeth with VRF, however, the score for sinus tracts was significantly higher in VRF than in non-VRF (P < 0.0001).

The overall prevalence of buccal cortical bone defects was 75.6% (Table 1). The score for buccal cortical bone defects was significantly higher in VRF teeth than in non-VRF teeth (P = 0.044).

The incidence of sinus tracts and fracture lines in each category according to the location/shape of the cortical bone defect is shown in Table 2. Spearman correlation analysis demonstrated that both sinus tracts and fracture lines were highly correlated with cortical bone defects (Spearman’s correlation coefficient = 0.933 and 0.648, respectively; P < 0.0001). However, sinus tracts and fracture lines were weakly correlated (Spearman’s correlation coefficient = 0.439; P = 0.237).

Kappa values were high for intraobserver reliability (0.85, 0.67 and 0.85 for the assessment of sinus tract, fracture line and bone defect, respectively) and interobserver reliability (0.75, 0.66 and 0.83).
Discussion

The varying clinical signs and symptoms of VRF [6,9,12,13], especially in their early stage of development [10,11], often pose great diagnostic challenges [14], although their presence has a markedly negative influence on the outcome of root canal treatment [3,12]. This study focused on sinus tracts, which are considered a diagnostic factor representing the possibility of VRF [6,9,12,21,22] and reported to occur in 14-64.9% of VRF cases [5,6,9,13,22,23], and examined whether the corono-apical location of sinus tracts and buccal cortical bone defects differs between VRF and non-VRF cases. The results suggested that VRF teeth presented a more coronally located sinus tract and cortical bone defect than non-VRF teeth (Table 1), thus rejecting the null hypothesis.

In this study, the presence of VRF and its relationship with buccal cortical bone defects was assessed by direct microscopic visualization, which is regarded as the most definitive method for detecting these conditions [13]. CBCT is another method for detection of VRF [15-18]. However, its diagnostic ability for VRF is not sufficient, particularly in root-filled teeth where imaging artifacts from radio-dense obturating materials impair diagnostic accuracy [18-20]. CBCT may also be useful for detection of osseous changes associated with a VRF [24], although its accuracy for detection of buccal cortical bone defects requires attention because it may underestimate their presence [25,26].

This appears to be the first study to have confirmed the empirical notion that sinus tracts are formed closer to the gingival margin in teeth with a VRF, in contrast to failed root canal treatment where sinus tracts are often located more apically [9,12,21,22]. Moreover, as this analysis was restricted to teeth with normal probing pocket depths, the present findings may have some diagnostic value for difficult-to-detect VRF cases, particularly those lacking probing defects.

The location of cortical bone defects was highly correlated with the location of fracture lines (Table 2). Cortical bone resorption associated with a VRF may initially spread along the fracture and widen laterally to form an oval or oblong defect [13,27]. The variable shape and location of the buccal bone defect in VRF teeth (Table 2) may reflect the difference in the location of the fracture and the stage of resorption in each case. Previous studies have demonstrated that dehiscence is the typical pattern of VRF-related bone defects, accounting for 79% [13] and 91% [27] of VRF teeth. In this study, however, the incidence of dehiscence was 27% (Table 2). This lower incidence may have been due to the exclusion of “typical” cases having a deep narrow probing defect, which is highly associated with dehiscence [13].

The locations of buccal cortical bone defects and sinus tracts were highly correlated (Table 2), indicating that the location of bone resorption resulting from the spread of inflammation is a decisive factor determining where a sinus tract will emerge. Thus, the finding that the sinus tract location was significantly more coronal in VRF teeth than in non-VRF teeth may be ascribed to the bone defect location being more coronal in VRF teeth. However, the correlation between the locations of sinus tracts and fracture lines was weak, suggesting that the original site of infection has a limited role in determining the sinus tract location. This may be because a sinus tract can emerge away from the site of causative infection [28]. The diversity in the location of sinus tracts can be explained by the flow of pus through less resistant areas depending on the local structural/pathological conditions, which differ in each case.

This study suggested that the location of sinus tracts is useful for diagnosis in cases of suspected VRF lacking probing defects. However, molars and teeth with deep periodontal pockets, cemental tears, and perforations were excluded. As these cases present more complex clinical features, further investigation is required.

Within the limitations of the present study, it can be concluded that, in microsurgically treated anterior and premolar teeth with a normal probing depth, the location of sinus tracts is more coronal in vertically fractured teeth than in non-fractured teeth, and is highly correlated with the location of cortical bone defects.

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Conflict of interest

The authors have no conflict of interest related to this study.

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