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# Newly Perio-Endo Combined Lesion Classification and Clinical Prognostic Analysis in 637 Cases of Endodontic Microsurgery

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**KEYWORDS**

Periodontal Endodontic Combined Lesions; Endodontic Microsurgery; Classification of Endodontic Microsurgery; Classification of combined lesions; Vertical Root Fracture; Symmetrical Lesion

**ABSTRACT:**

**Aim:** The aim of this study was to investigate the clinical implications of the newly proposed classification system for periodontal-endodontic (perio-endo) combined lesions in a cohort of 637 cases undergoing endodontic microsurgery.

**Methodology:** Clinical and radiographic data from patients undergoing endodontic microsurgery at the Department of Endodontics, West China School of Stomatology, Sichuan University from January 2013 to October 2022 were collected and analyzed. The clinical and radiographic data of all the combined periodontal and pulpal lesions of Class II3 cases that underwent endodontic microsurgery were collected and analysed. Patients with vertical root fracture (VRF) (determined by IOPA radiographs or CBCT or discovered after surgical extraction) in follow-up cases were included in the collection even if less than a year had gone by. Inclusion criteria required accurate, detailed records and at least one year of follow-up. CBCT imaging was used preoperatively, and apical X-rays postoperatively. Patients with vertical root fracture (VRF) were included, even with less than one year of follow-up. Exclusion criteria included root fracture, external root absorption, or incomplete data.

**Result:** In this study, data from 637 cases of combined lesions were analysed using SPSS25.0. Among them, 436 cases (68.42%) showed successful treatment outcomes, while 201 cases failed after one year of observation. Significant differences were observed in the success rate of endodontic microsurgery among different classes of combined lesions ($P<0.05$), except between subclasses I1 and I2, II1, and II2. Subclasses II1 and II2 showed better healing outcomes compared to subclasses I1, I2, and I3 ($P<0.05$). Additionally, the incidence of VRF in subclass II3 cases was the highest, contributing to the lowest success rate in this subclass. Notably, preoperative CBCT manifestations of symmetric bone lesions in the buccolingual direction correlated significantly with the detection of VRF ($P<0.05$), particularly in subclass II3 cases.

**Conclusion:** Endodontic microsurgery is effective for combined lesions but less so than for chronic periapical inflammation. The new classification helps predict outcomes, with class II lesions performing better than class I. Success rates decrease with severe periodontal damage and are higher for anterior teeth. Preoperative CBCT exams are crucial for detecting vertical root fractures (VRF), especially in subclass II3 lesions, which have the highest VRF incidence and lowest success rates, necessitating cautious surgical selection.

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## Introduction

Periodontal-Endodontic Combined Lesions are characterised by simultaneous pulp/periapical inflammation and periodontal destruction in affected teeth with communication between the lesions. These combined lesions can arise from pathological developmental abnormalities and iatrogenic perforations, creating a complex clinical scenario with multiple infection sources, varied radiographic manifestations, and delayed treatment challenges [1]. Endodontic microsurgery is often the final treatment option for these lesions. Root canal therapy is generally effective for periapical diseases, boasting first-time success rates of 53%-98% and retreatment success rates of 47%-81%. However, it tends to be less successful in cases involving combined periodontal-endodontic disorders due to the complex anatomy of the pulp and root canals, such as MB2 and mandibular incisor double canals [2]. Challenges include unsealed delta pulp areas and lateral root canals that are difficult to clean mechanically and chemically.

Chronic apical cysts, which do not respond well to root canal treatment, present another challenge. Nair found that 17% of chronic periapical lesions are apical cysts, of which 12% are pocket cysts and 5% are true cysts, while 83% are abscesses and granulomas [2]. Pocket cysts can heal with root canal treatment, but true cysts typically require endodontic microsurgery. Factors such as full crown repair, root canal posts, bacterial biofilms outside the apex, lateral root canal penetration, and external root resorption complicate root canal therapy for combined lesions [2], necessitating endodontic microsurgery. The advent of the operating microscope has significantly improved root canal treatment over the past 40 years. Cone Beam Computed Tomography (CBCT) is a reliable visual aid for diagnosing, designing, and assessing apical periodontitis [3]. Advances in bioceramic retrograde filling materials, like MTA, have enhanced sealing, hydrophilicity, and biocompatibility, becoming the standard for microsurgery retrograde fillings [4]. MTA promotes alveolar bone, dentin, and cementum growth in vitro and offers superior sealing and biocompatibility compared to amalgam and Super EBA apical fillings [5]. Traditional apical surgery has a success rate of 40%-75 [6,7]. However, with the operating microscope, improved illumination, CBCT, ultrasonic root end preparation equipment, and advanced retrograde filling materials, modern endodontic microsurgery achieves success rates of 61%-90% [8]. Various factors, including gender, age, tooth position, retrograde filling material, apical lesion size, and the state of the pulp during root canal therapy, influence the prognosis of endodontic microsurgery [9,10].

Dr. Kim of Penn dental school introduced endodontic microsurgery in the 1990s, and his classification system from a 2006 JOE review (A, B, C, D, E, and F) is widely used [11]. Retrospective analysis indicates that patients without periodontal involvement (classes A, B, and C) have higher success rates than those with pulpal and periodontal diseases (classes D and E) [12]. This underscores the importance of periodontal health for the success of endodontic microsurgery. However, Dr. Kim's classification has limitations, particularly in describing the extent and nature of periodontal pockets and in distinguishing between cases with different clinical prognoses [11].

Recent literature, including studies by Shen Jing and Villa, indicates that worse periodontal conditions correlate with poorer endodontic microsurgery outcomes [13-15]. Effective treatment of periodontal-endodontic disorders requires comprehensive periodontal treatment in conjunction with microsurgery [16,17]. However, many studies still rely on the 1999 AAP classification of periodontal and endodontic lesions, which differentiates between periapical lesions with secondary periodontal involvement, periodontal lesions with secondary periapical involvement, and true combined lesions of unknown origin [18]. This classification system remains prevalent in China [18]. Since CBCT does not diagnose or prognose, surgery is like unlocking the blind box. According to the 2018 classification of combined lesions [19], this paper uses periodontal damage and CBCT manifestations to assess the prognosis of endodontic microsurgery for different types of combined lesions, compare their differences, determine success rates, improve predictability, and boost surgeon confidence.

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**Table 1** Classification of combined periodontal and endodontic lesions at the 2018 European EFP annual meeting

| | | |
|---|---|---|
| Endo-periodontal lesion with root damage | Root fracture or cracking | |
| | Root canal or pulp chamber perforation | |
| | External root resorption | |
| Endo-periodontal Lesion without root damage | I Endo-periodontal lesion in periodontitis patient | subclass I1 ： narrow deep periodontal pocket in 1 tooth surface |
| | | subclass I2 ： wide deep periodontal pocket in 1 tooth surface |
| | | subclass I3 ： deep periodontal pockets in >1 tooth surface |
| | II Endo-periodontal lesion in non-periodontitis patient | subclass II1 ： narrow deep periodontal pocket in 1 tooth surface |
| | | subclass II2 ： wide deep periodontal pocket in 1 tooth surface |
| | | subclass II3 ： deep periodontal pockets in >1 tooth surface |

## Methodology

### Case Source and Screening

Clinical and radiographic data of patients undergoing endodontic microsurgery from January 2013 to October 2022 at West China School of Stomatology, Sichuan University were collected. Inclusion criteria required complete records of patient information, medical history, clinical and radiographic data, treatment process, and follow-up visits (minimum 1 year). CBCT imaging was mandatory preoperatively, and apical X-rays were required postoperatively. Exclusion criteria included obvious root fractures, external root resorption, or missing data. Patients with vertical root fractures were included even if follow-up was less than one year. The number of teeth available for follow-up was recorded.

The clinical and imaging data of subclassI3 and subclass II3 combined lesions were also collected and sorted. Patients with vertical root fracture (determined by periapical radiographs or CBCT or found after surgical extraction) in follow-up cases were included in the collection even if less than one year had gone by.

### Patient Data Collection and Classification

The evaluation team was composed of 2 postgraduates from the department of endodontics, who have passed the standard training of radiographic evaluation. The general, clinical and imaging data of the patients were recorded, and the consistency test and self-replication verification of the recorded results were conducted until the Kappa value was 90%, indicating that the display results were completely reliable.

According to the latest classification of combined periodontal pulp lesions at the 2018 European Annual Meeting in Amsterdam, the included combined lesions were divided into I1, I2, I3, II1, II2, II3 subcategories.

**Experimental Equipment**

Root canal Surgical Microscope (Zeiss Co., Germany); Surgical Kit (FIG. 2, B & L Biotech., Korea), Mimics 17.o; Padi Ant DICOM Viewer, CBCT is a large-field Morita CBCT integrated radiological machine completed by West China Stomatology Hospital of Sichuan University (Morita Co., Japan)

**Surgical Procedure**

All cases were completed in the Department of Endodontics, West China Stomatology Hospital, Sichuan University, by a number of specialists who have obtained the qualifications to perform endodontic microsurgery. The main points of the routine surgery are as follows, and the procedure is shown in Figure 3.

1. Through clinical examination and preoperative CBCT examination, the location of the periapical lesion and the relationship with the fistula can be accurately displayed, so that appropriate treatment plan can be formulated, and the surgical approach can be determined.

2. Local anesthesia with anesthesia containing 1:100,000 epinephrine and 4% articaine (2% lidocaine can be added in the case of mandibular teeth), incision with a 15C microsurgical blade, and the periosteal elevator is used to elevate and reflect the full-thickness mucoperiosteal flap, use preoperative CBCT or the working length of the root canal to locate the apex, use a contra-angle handpiece (Impact Air 45°) and a Lindermann high-speed bone removal drill (Mani, Japan) to create bone window, and enter the apical lesion , remove the granulation tissue around the root tip, cut 3mm of the root tip, stain the root end with methylene blue, prepare and clean 3mm of the root end with ultrasonic tips, switch to the high power microscope to check whether there is missing root canal, whether the shape of the root canal has communicating branch, lateral branch root canal, root fracture, etc., the MTA/BP is mixed and retrograde filling of the prepared root end, and the gingival flap repositioned and sutured.

3. Postoperative instructions, such as ice compress, oral hygiene maintenance, suture removal time.

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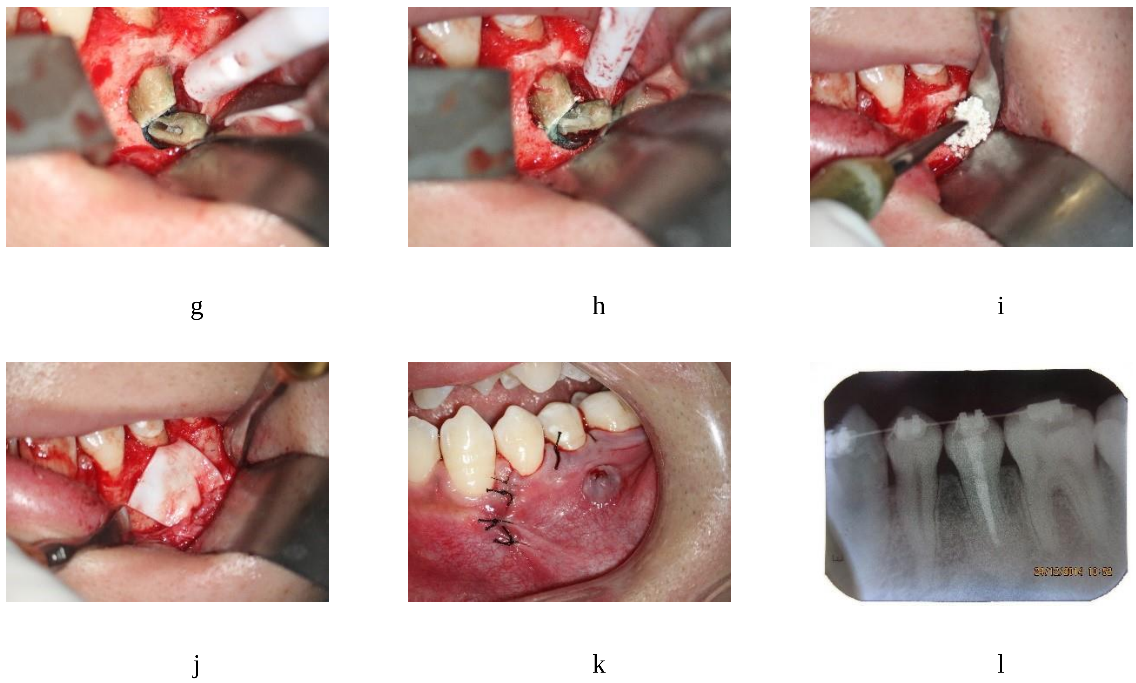


4.

**Figure 3** General procedure of endodontic microsurgery

a. Preoperative X-ray film; b. Preoperative photo; c. Flap; d. Root resection; e. Examination of cut section; f. Ultrasonic preparation; g. Preparation of cavity shape; h. MTA retrofill; i. Bone graft; j. placement of collagen membrane; k. Suture; l. Review of X-ray film.

**Efficacy Evaluation**

The quality of preoperative root canal filling was evaluated according to the following criteria [21]: ① Proper filling: X-ray film shows that the root canal is tightly filled, with no root canal space, and the root canal filling is 0.5-2.0 mm away from the apex in the X-ray ; ②Underfilling: the filling in the root canal is sparse or there is a radiolucent shadow in the root canal cavity, or the filling is shorter than the root tip in the X-ray film by more than 2 mm; ③Overfilling: The root filling exceeds beyond the root tip in the X-ray film. . The evaluation of root canal filling quality was based on the tooth. If underfilling or overfilling occurred in any root canal of multiple teeth, it was not included in the proper filling, that is, the affected tooth was classified as underfilling or overfilling. If both underfilling and overfilling occur in multiple canal teeth, the one farther away from the judgment will be standard (whichever is more obvious) [22].

According to the clinical examination and radiographic results, the curative effect of microsurgery after 1 year was evaluated. According to postoperative requirements, periapical X-ray film follow-up is required for half a year and one year after surgery. If the patient only has postoperative X-ray periapical film for half a year or one year, it is still included as a valid patient. Healed: radiographic examination showed that the shadow completely disappeared or basically disappeared, and there were no clinical symptoms and signs, such as fistula and apical pain and swelling. Uncertain: The shadow in the radiographic examination is slightly smaller than that before surgery, and there are no clinical signs or symptoms; Unhealed: The shadow in the radiographic examination shows no change (no increase or decrease), or there are clinical signs or symptoms, such as reappearance of apical fistula, pain and swelling. Both healed and uncertain were considered as successful clinical treatment, and unhealed was considered as treatment failure. The definition of healing for tooth cases undergoing GBR (Guided Bone Regeneration) at the same time is as follows: successful treatment: the

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bone graft interface is well formed, normal bone trabecular images appear, and there is no obvious distinction from the surrounding bone, and no clinical signs or symptoms. Treatment failure: No normal bone trabecular structure in the bone graft area, and obvious enlarged separation or transmission shadows at the interface, or appearance of clinical signs and symptoms [23].

According to classification of microsurgery by Dr. Kim, the quality of root canal filling, the size of the apical shadow and the tooth position were also factors affecting the prognosis of the surgery. Therefore, the influence of the above three factors on the prognosis of the apical surgery for periodontal pulp combined lesions was retained in this study.

### 1.6 Statistical Analysis

Data were processed using SPSS25.0, with chi-square or Fisher's exact tests to analyze success rates and factors affecting prognosis. A p-value $<0.05$ was considered statistically significant.

## Results

### General information

According to the inclusion and exclusion criteria of this study, a total of 637 teeth with periodontal and pulpal combined lesions were diagnosed, of which 284 were male and 353 were female. Of the 637 teeth included, 436 were successfully treated, with a success rate of 68.42%, and 201 failed, with a failure rate of 31.58%. The age distribution of affected teeth ranged from 11-82 years old. The specific tooth position distribution is shown in Table 2.

**Table 2** Distribution of tooth positions of affected teeth

| **Site** | **Anterior teeth** | **Premolars** | **Molars** | **Total** |
|---|---|---|---|---|
| Upper jaw | 372 | 31 | 71 | 474 |
| Lower jaw | 93 | 37 | 33 | 163 |
| Total | 465 | 68 | 104 | 637 |

### Efficacy and influence of endodontic microsurgery for various combined lesions

Among the 637 cases of combined lesions, 436 cases (68.42%) were successfully treated, and 201 cases failed, after one year of observation. The reasons for the failure were attributed to repeated fistulas that did not disappear, deepened periodontal pockets, root fractures, external root resorption, progressive increase in tooth mobility of the affected teeth, no repair after surgery, resulting in broken teeth and residual roots that cannot be repaired. Fisher's precision probability analysis showed that, except between I1 and I2, II1 and II2 subcategories, there were statistically significant differences in the success rate of microsurgery among other types ($P<0.05$). Further comparisons showed that except for subclass II3, the curative effect of microsurgery in class II II1 and II2 was better than that of I1, I2, and I3 subclasses ($P<0.05$). The effects of different combined lesion types, tooth positions, quality of root filling, and lesion size on the success rate of microsurgery are shown in Table 3 and Table 4. Analysis of Fisher's precision probability method showed that within each group there were differences in the maximum diameter (L) of the apical lesion, for example, in Class I1, but there was no statistical significance within the group ($P>0.05$), and different root canal filling quality (filling length and filling tightness) had no significant effect on apical surgery in all groups with combined lesions. There was a statistically significant difference in the curative effect of microsurgery in patients with combined lesions in different tooth positions ($P<0.05$). Furthermore, Pearson chi-square test analysis showed that the curative effect of anterior teeth was better than that of posterior teeth.

Journal of Chemical Health Risks

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JCHR (2024) 14(3), 1171-1189 | ISSN:2251-6727

**Table 3** The success rate of apical surgery for different combined lesions (%)

| Combined lesion classification | I | I1 | I2 | I3 | II1 | II2 | II3 | II |
|---|---|---|---|---|---|---|---|---|
| **Success rate** | 67.40 | 68.72 | 64.51 | 57.81 | 79.08 | 77.04 | 53.22 | 76.31 |

Note: Except between I1 and I2, II1 and II2, the success rate of each group has statistical difference P<0.05.

**Table 4** The success rate of different tooth positions, root filling quality and lesion size in each group with different combined lesions (%)

| | I1 | I2 | I3 | II1 | II2 | II3 |
|---|---|---|---|---|---|---|
| **Front teeth** | 75.31 | 74.70 | 65.22 | 85.17 | 84.79 | 56.21 |
| **Posterior teeth** | 64.11 | 57.51 | 52.88 | 72.80 | 71.08 | 40.71 |
| **Correct fill** | 66.00 | 67.78 | 59.29 | 81.81 | 76.08 | 56.23 |
| **Overfill, underfill, sparse** | 69.20 | 60.34 | 51.10 | 74.48 | 81.04 | 51.04 |
| **Lesion <5mm** | 69.93 | 70.09 | 64.53 | 83.03 | 80.34 | 57.77 |
| **<5mm lesion<10mm** | 66.71 | 64.31 | 63.51 | 78.84 | 80.71 | 55.60 |
| **Lesion >10mm** | 65.07 | 59.94 | 58.01 | 70.09 | 74.65 | 49.58 |

Note: Except between the anterior teeth and the posterior teeth, there is no statistical difference in the success rate within each group P>0.05.

**Correlation analysis of vertical root fractures in combined perio-endodontic cases**

The percentage of cases failed due to root fracture found in postoperative follow-up and intraoperative staining accounted for the total number of cases of all kinds of combined diseases, i.e., the percentage of root fracture in all kinds of combined cases, as shown in Table 5.

**Table 5** Incidence of intraoperative and postoperative root fractures of all kinds of combined lesions (%)

| Combined lesion classification | I1 | I2 | I3 | II1 | II2 | II3 |
|---|---|---|---|---|---|---|
| **Root fracture rate (%)** | 10.04 | 8.71 | 14.53 | 2.17 | 3.44 | 43.01 |

Fisher's precision probability analysis showed that there was no statistical difference between subgroups I 1 and I 2, II 1 and II 2 (P>0.05), that is, the probability of finding root fractures during the follow-up between subgroups II 1 and II 2 were similar, and there were statistical differences between the other groups (P<0.05), among which, subgroup II 3 had the highest probability of finding root fractures during and after the surgery.

Journal of Chemical Health Risks
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**Correlation analysis between vertical root fracture and preoperative CBCT image**

All cases of root fractures cannot be determined by combined preoperative clinical examination and CBCT examination, including two categories: one is vertical root fracture found intraoperatively (Figure 4) and the other is root fracture found during case tracking (found through clinical examination, periapical X-ray, CBCT or surgical extraction), and found through multi-factor correlation screening. The correlation of intraoperative and postoperative root fractures is shown in Table 6.

a b

**Figure 4** cases of root fracture found during surgery

a. Preoperative X-ray film; b. Root fracture found after root resection and dyeing during surgery

**Table 6** Correlation analysis between preoperative CBCT manifestations and cases of root fracture (%)

| **Lesion size** | **Pathway of lesion** | **Symmetry of lesion** | **VRF** | **Combined lesion classification** |
|---|---|---|---|---|
| Originating from the root apex and gradually becoming smaller in furcation area | Mostly unilateral gradually spreading to furcation area | Not symmetrical | 6.33 | More common in II1/II2 |
| Lesion size almost the same from root apex to furcation | Bilateral buccolingual symmetric lesion | Symmetrical | 67.41 | More common in II3 |

Note: The correlation between the two groups was statistically significant ($P<0.05$)

Fisher's precision probability method analysis showed that the preoperative CBCT findings of patients with combined lesions had buccal and lingual symmetry

Journal of Chemical Health Risks
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JCHR (2024) 14(3), 1171-1189 | ISSN:2251-6727

damage, and there was no rotation from the root tip to the root neck, and the correlation of root fractures found during and after surgery was 67.41% (Figure 5), which is much higher than the 6.33% correlation (Figure 6) of root fractures that do not meet the above CBCT manifestations, and there is a statistical difference (P<0.05).

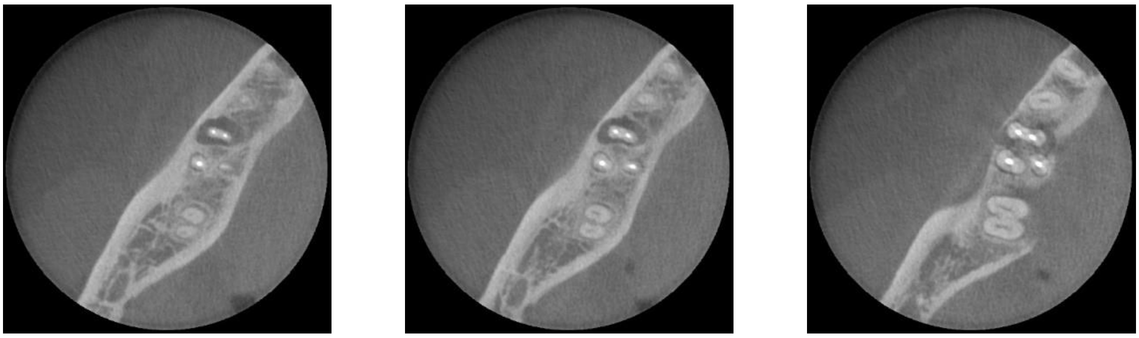

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**Fig. 5** Characteristics of CBCT axial image with strong correlation of root fracture

a. lesion around the root tips; b. The lesion in the middle root is not turned and buccal-lingually symmetrical; c. The lesion of the upper root segment remains unturned and has buccal-lingual symmetry

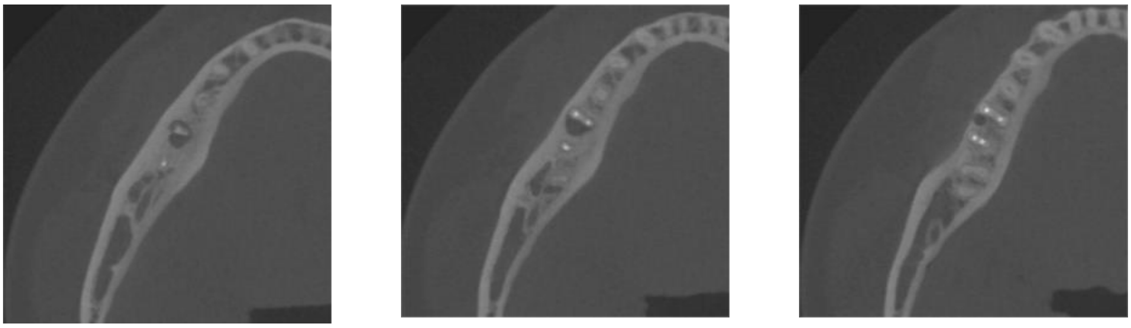

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**Figure 6.** Characteristics of CBCT axial image with weak correlation of root fracture

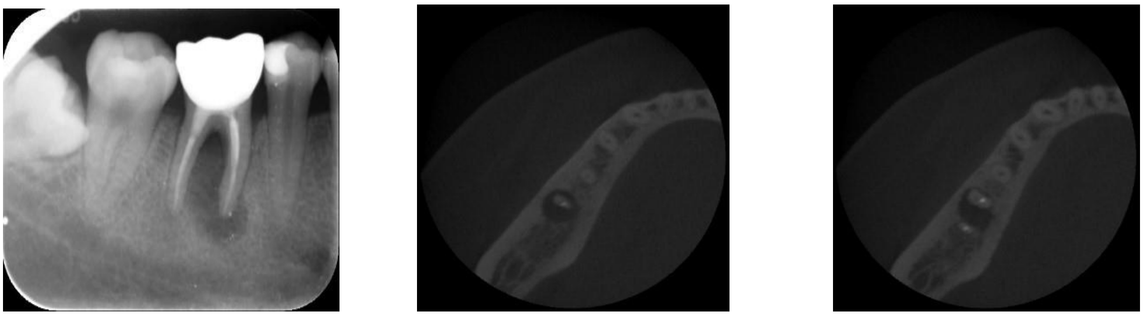
a. lesion around the root tips; b. The lesion in the middle of the root turns to the root bifurcation; c. The lesion of the upper root segment perforated the buccal bony plate from the bifurcation of the buccal root

In the follow-up of various types of combined lesions after microsurgery, the experiment found that the probability of finding vertical root fractures in subclassII3 was the highest. Therefore, this study separately analyzed the incidence of root fractures found in various combined lesions during the follow-up process and concluded that the root fractures found in subclass II3 during surgery or follow-up were the reason for the lower success rate of subclass II3 than that of subclass I3 and had the lowest success rate.

At the same time, in the latest 2018 classification of combined lesions, the deep periodontal pockets on different tooth surfaces have been included in the classification index, which is consistent with the clinical CBCT examination [34]. Therefore, the preoperative clinical examination and CBCT examination of combined lesion cases can be used to analyze the correlation between subclass II3 and CBCT manifestations of root fractures at the same level, and provide auxiliary clinical reference for the prognosis of microsurgery for such combined lesions.

**Description of typical cases**

Case 1 A 21-year-old female patient presented with recurrent fistula and swelling 1 year after root canal treatment of the lower posterior right tooth. Clinical examination: 46 teeth porcelain crown restoration, cold diagnosis (-), percussion (-), no mobility, visible sinus on buccal mucosa. A deep periodontal pocket could be detected at the buccal root bifurcation, reaching the root tip. Except for 46 teeth, the patient had no periodontitis background in other teeth. CBTC showed: 46 teeth have completed root canal treatment, mesial apex deviation, mesial apex shadow, root apex lesion expands along the mesial root to the coronal direction, gradually turned to bifurcation between the mesial root and the distal root, and finally broke through the buccal bone plate below the bifurcation. Diagnosis: 46 perioendodontic combined lesions, subclass II1. Routine microsurgery steps for 46 teeth: right inferior alveolar block anesthesia with 2% lidocaine, infiltration anesthesia with 4% articaine in the surgical area, triangular flap with distal vertical incision at 43 teeth, scrape off periapical granulation tissue, root end resection 3mm from the apex of the mesial root, staining with methylene blue, 3mm root-end preparation with ultrasonic instruments, MTA placement, and suture with 5-0 suture. Follow up 1 year after surgery with periapical X-ray films. Clinical examination: tooth 46 had no pain on percussion, no obvious mobility, buccal periodontal pockets were not obvious, no fistula was found in the buccal mucosa, and the apical shadow disappeared on the apical X-ray film (Fig. 7).



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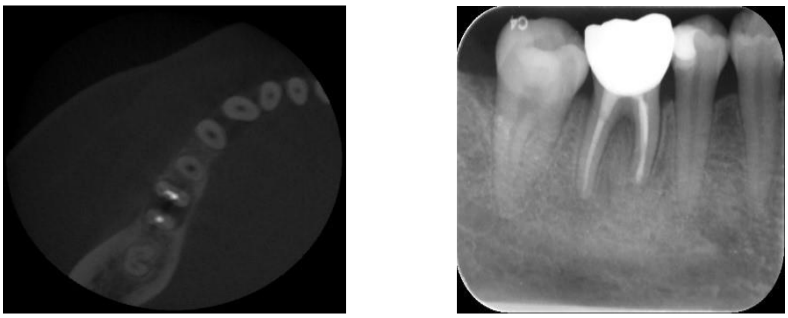

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**Figure 7** Combined lesion II1 subclass cases

a. Preoperative X-ray film; b c d. CBCT axial apical root, middle root and upper root appearance, without symmetrical damage; e. Radiographs were reviewed one year after surgery

Journal of Chemical Health Risks
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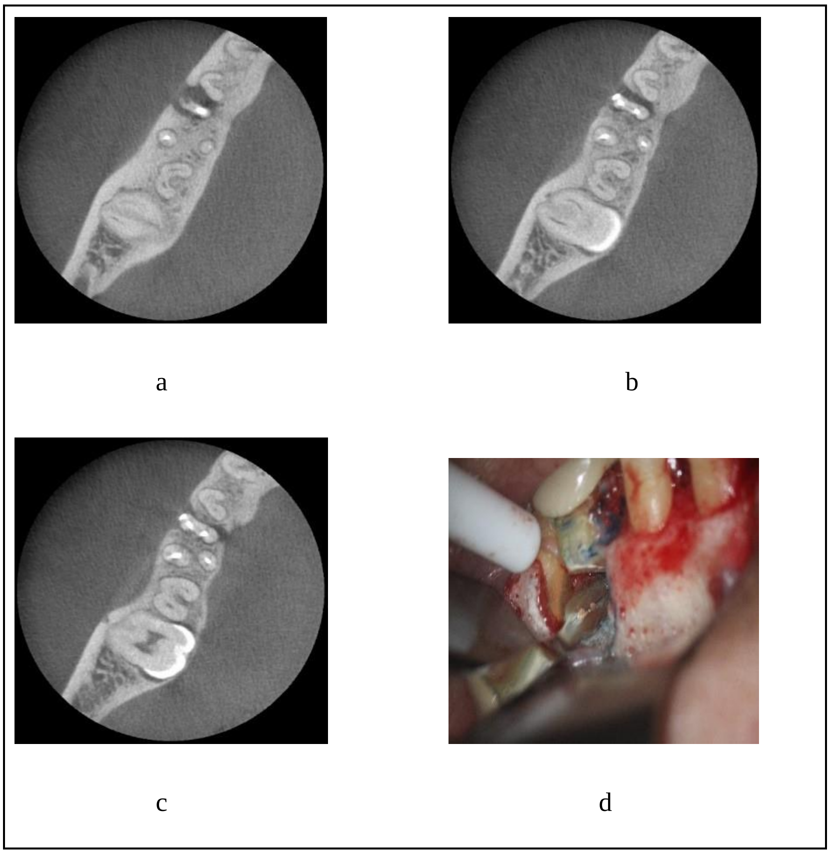


**Figure 8** Combined lesion II3 subclass cases

a b c. All segments of the axial root of CBCT showed symmetrical damage; d. Intraoperative staining revealed buccal-lingual root fracture

Case 2 A 49-year-old male patient presented with a buccal sinus 3 years after root canal treatment and full crown restoration of the lower right posterior tooth. Clinical examination: 46 teeth were restored with porcelain fused metal crown, redness and swelling in the apical area, percussion (+-), deep periodontal pockets can be detected on the lingual and buccal side, reaching the root apex, and the other teeth of the patient had no periodontitis background except for 46 teeth. CBCT showed the root canal treatment had been completed, fiber post in the mesial root, the shadow in the mesial root apex, no obvious root fracture, the root apex shadow spreads along the root towards the crown, the shadow does not disappear in the middle 1/3 of the root, and 1/3 of the root neck, and there was damage in the buccal and lingual sides, which is symmetrical. Diagnosis: perioendodontic combined lesions of 46 teeth, subclass II3. Routine microscopic root apical surgery steps for 46 teeth: right inferior alveolar block anesthesia with 2% lidocaine and infiltration anesthesia with 4% articaine for the surgical area, triangular flap with distal vertical incision at 43 teeth, and periapical scraping off of granulation tissue, mesial root-end resection 3 mm from the root tip, stained with methylene blue, preparation of 3mm of root-end with ultrasonic instruments, restoration with MTA, and sutured with 5-0 suture. Follow-up: Three months after the surgery, the buccal fistula was still present, and deep periodontal pocket bucccolingually in the mesial root, reaching the apex of the root. Flap exploration revealed vertical root fracture of the mesial root which was then extracted (Fig. 8).

## Discussion

### Anatomic and pathological basis of combined periodontal and pulp lesions

In addition to hard tissue and pulp, dental tissue includes periodontal supporting tissues. Simring et al. (1964) [24]

first noted the close relationship between periodontal and dental pulp tissue, both of which originate from mesoderm or ectoderm during embryogenesis. This connection is evident through lateral and accessory root canals, dentinal tubules, Sharpey's fibers, small blood vessels, and lymphatic capillaries. Anatomical abnormalities and certain conditions can also create pathways between periodontal and pulpal tissues [25].

Through an in-vitro study of 1140 isolated teeth, DeDeus et al. found that 313 teeth (27.4%) had lateral accessory root canals, and the statistical proportions according to the location were: 1/3 of the root tip accounted for 17%, and 1/3 of the middle root accounted for 8.8%, the upper 1/3 accounted for 1.6%. Primary pulp lesions can spread to periodontal tissue through these anatomical factors, and periodontal tissue lesions may also affect the pulp. In 1999, the American Academy of Periodontology (AAP) Classification Symposium defined periodontal and endodontic lesions as the coexistence of periodontal lesions and pulp lesions in the same tooth, and they are fused and communicate with each other. Infection may originate from the pulp or the periodontium, or both may occur independently, but are interlinked. Both periodontitis and pulpitis are mixed infections dominated by anaerobic bacteria, and their inflammatory and immune responses are similar. The most common periodontal destruction caused by pulpitis is localized apical granuloma, mainly caused by diffusion of bacterial metabolites spread through the apical foramen, and discharge of pus to the periodontal tissue along the path of least resistance [26], resulting in the alveolar bone resorption and occasionally root resorption. The most typical type of pulpitis caused by periodontitis is retrograde pulpitis. The extent to which periodontitis affects the dental pulp is still controversial. Langeland et al. observed 60 teeth with periodontitis and found that the pulp shows no changes until the periodontitis involves the apical foramen and calcification, fibrosis, collagen absorption or direct inflammatory response, etc. will appear. Mazur et al. observed 106 teeth of 26 patients with severe periodontitis, and found that the changes of dental pulp were similar regardless of the degree of periodontitis progression, and such changes was more likely related to the patients' systemic diseases. Based on this, it is considered that periodontal disease has no great impact on dental pulp, and complete pulp necrosis caused by periodontal disease is rare, unless there is extensive lateral communication between the tooth and the periodontium; as long as the lateral root canals are intact, and cementum is protected, pulp necrosis usually does not occur. As long as the microvascular communication of the apical foramen is not violated, the pulp will remain vital.

**The influence of lesion size, root filling quality, tooth position and other factors on the prognosis of endodontic microsurgery for combined lesions**

In the past ten years, there is no lack of data on the factors affecting the prognosis of microscopic apical surgery [27], such as gender and age factors, systemic diseases, smoking status, presence of fistula, periodontal condition before microsurgery, and pulp status before root canal treatment etc. However, after comprehensive analysis, the factors that affect the prognosis of microsurgery are still controversial.

There is conflicting opinion on whether lesion size affects the efficacy of microsurgery [28]. Some researchers believe lesion size impacts prognosis, categorizing lesions as <5mm, 5-10mm, and >10mm. They found that larger lesions, especially those with apical cysts, had poorer prognoses. However, Dr. Kim's study on microscopic apical surgery found no significant difference in success rates based on lesion size ($P>0.05$). In evaluating this experiment, cases where apical lesions shrank but did not disappear, without clinical symptoms, were considered successful. This experiment also concluded that lesion size did not significantly affect prognosis ($P>0.05$). Additionally, some cases involved guided bone regeneration (GBR). Success was determined by the absence of symptoms and signs, and the lack of a widening boundary between the bone graft and alveolar bone on X-rays. Over time, the interface between grafted and natural bone faded, with new bone growth becoming indistinguishable from natural bone after about six months. Current research suggests that bone grafting in microsurgery influences healing time but not the overall success. Bone grafts accelerate lesion disappearance, but even without grafts, lesions will eventually heal, albeit more slowly. This experiment supports this view.

The impact of root canal filling quality on the prognosis of apical surgery is debated. Some researchers argue that poor-quality root fillings, such as underfilling or sparse filling, compromise the success of microsurgery by

Journal of Chemical Health Risks
www.jchr.org
JCHR (2024) 14(3), 1171-1189 | ISSN:2251-6727

allowing infected substances to leak through the apical retrograde filling. In contrast, Dr. Kratchman and others suggest that apical resection of 3mm effectively eliminates most apical divergences and side branch canals, thereby reducing apical infections. This study found no significant difference in prognosis based on root filling quality in apical surgery with various lesions (P>0.05). The relationship between tooth position and the prognosis of endodontic microsurgery is also controversial. Most scholars agree that apical surgery on anterior teeth has a higher success rate than on posterior teeth, and single-rooted teeth fare better than multiple-rooted teeth. This is attributed to better surgical access, simpler root canal systems, and easier apical sealing in anterior teeth. However, some, like Kreisler et al., believe premolars have the highest success rate, with anterior teeth having lower success rates.

This study found that posterior teeth with combined lesions had a lower success rate than anterior teeth. This is due to factors such as reduced surgical field visibility, illumination, patient positioning, and operator convenience in posterior teeth. Additionally, the more complex periodontal damage and root structures in posterior teeth, like bifurcated and multiple roots, make controlling periodontal infection more challenging, thereby decreasing the success rate of microsurgery in posterior teeth.

**Microsurgery improves the success rate of traditional cases of combined periodontal and endodontic lesions**

Teeth affected by combined lesions exhibit both pulp/periapical inflammation and periodontal destruction simultaneously, with communication between these tissues. Normal anatomical structures, such as the apical foramen, dentinal tubules, lateral and accessory root canals, and apical divergences, facilitate this communication. Pathological defects, such as the maxillary lateral incisor palatogingival groove and iatrogenic perforations (e.g., lateral perforation of root canal posts or pulp chambers), also allow infections to spread between pulp and periodontal tissues, complicating treatment and reducing success rates [29-31]. The 2018 classification of combined lesions provides a more detailed and accurate prognosis for such cases in microsurgery. Literature reports indicate that the one-year success rate of microsurgery for teeth without periodontal lesions can reach approximately 95%. However, for cases with combined periodontal lesions, the success rate drops by about 20%, to 77%. This decrease confirms that periodontal infections and lesions can affect periapical tissue, leading to a lower success rate for microsurgery in combined lesion cases.

In Class I cases, where other teeth also have periodontal damage, the severity of periodontal pockets impacts the success rate of microsurgery. The classification progresses from Class I 1 (narrow and deep periodontal pockets on a single tooth surface) to Class I 2 (wide and deep pockets on a single surface) to Class I 3 (deep pockets on multiple surfaces). As periodontal lesions worsen, success rates decrease: Class I 1 (68.72%) > Class I 2 (64.51%) > Class I 3 (57.81%). Similarly, in Class II cases, where only the affected teeth have periodontal lesions, the success rate also declines with worsening conditions: Class II 1 (narrow and deep pockets on a single surface) to Class II 2 (wide and deep pockets on a single surface) to Class II 3 (deep pockets on multiple surfaces). The success rates are Class II 1 (79.08%) > Class II 2 (77.04%) > Class II 3 (53.22%). This pattern indicates that more severe periodontal lesions reduce the success rate of microsurgery.

Overall, the success rate in Class I cases (67.40%) is lower than in Class II cases (76.31%). In Class II, where other teeth lack a periodontitis background, the affected teeth have deep pockets that often facilitate the spread of infection from the apical to the coronal region. For instance, in the mandibular first molar, the thick buccal cortical bone prevents rapid destruction, causing the lesion to progress towards the crown, leading to deep pockets on a single surface.

This study suggests that such combined lesions, previously prone to misdiagnosis and extraction, can still be managed surgically, improving success rates. The success rate of microsurgery for combined periodontal and pulpal lesions is about 68.42%, lower than for chronic apical periodontitis. Understanding the latest classification of combined lesions and accurately assessing the periodontal status of affected teeth can help doctors predict the prognosis of microsurgery, choose appropriate treatments, and communicate effectively with patients. The poorer the periodontal condition, the lower the success rate of microsurgery.

Journal of Chemical Health Risks
www.jchr.org
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**The new classification of periodontal and endodontic combined lesions is more helpful to the prognosis of microsurgery for combined lesions**

Combined periodontal and endodontic lesions are common oral diseases where a tooth suffers from both pulpal and periodontal disease simultaneously [32]. Due to anatomical connections between the pulp and periodontal tissue, an infection in one can led to infection in the other, potentially resulting in simultaneous infections of both tissues [33]. This dual involvement complicates diagnosis and treatment, requiring expertise from both endodontics and periodontology. These cases demand high patient compliance and significant medical resources, making treatment more complex than managing pulpal or periapical disease alone [34]. Historically, these lesions were classified according to Simon's 1972 classification [35], which categorized lesions into five types: Category 1; Only pulp and periapical lesions, Category 2; Pulp and periapical lesions with secondary periodontal lesions. Category 3; Only periodontal lesions. Category 4; Periodontal lesions with secondary pulp and periapical lesions. Category 5; True combined lesions. The 1999 AAP classification, commonly used in China, follows Simon's classification but excludes the first and third types.

Dr. Kim’s classification of lesions without microsurgery includes combined lesions in categories D, E, and F, describing two-dimensional periodontal lesions. For instance, category E involves teeth with deep periodontal pockets connected to apical lesions. However, this classification does not address three-dimensional periodontal lesions, such as the presence of periodontal pockets on multiple tooth surfaces, buccolingual or mesiodistal symmetrical pockets, or the extent and direction of alveolar bone destruction visible in preoperative CBCT scans. Consequently, it provides a generalized view of cases with periodontal lesions, and the success rate of microsurgery on such teeth ranges from 50% to 72% [36].

The 1999 American Academy of Periodontology (AAP) classification did not consider the degree of periodontal damage, limiting its ability to evaluate the efficacy of microsurgery for combined lesions based on periodontal severity. It primarily distinguished between postoperative outcomes for microsurgery on combined lesions versus endodontic lesions alone, without analyzing how the extent of periodontal damage impacts the success of microsurgery for combined lesions [37,38]. Current clinical studies often focus on the efficacy of root canal treatment for combined lesions of pulpal origin. Root canal therapy is considered effective for these lesions, with microsurgery being evaluated for prognosis only in rare cases of root canal therapy failure. Studies by Song M. (2018) and Kim E. (2008) compared microsurgery outcomes for patients with combined lesions versus those with only apical lesions, finding significantly lower success rates for combined lesions.

The 2018 European Federation of Periodontology (EFP) introduced a refined classification for combined periodontal and pulpal lesions, considering the background of periodontitis and the degree of periodontal damage: Class I: Patients with a background of periodontitis, including both true combined lesions (per Simon's classification) and lesions of periodontal origin. Class II: Patients without a periodontitis background except for the affected teeth, where lesions are mostly of pulpal origin. This classification is concise and clear, allowing for better prognosis evaluation. The study found that microsurgery success rates for Class II (76.31%) are higher than for Class I (67.40%). Combining this classification with CBCT analysis of periodontal damage degree enables a more accurate surgical prognosis. At the same time, according to the degree of periodontal damage in class I and class II, combined with CBCT analysis, a more accurate prognosis of surgery can be determined [39].

**The spread path of apical infection in class** II **periodontal and endodontic combined lesions**

Class II periodontal and endodontic combined lesions refer to cases where periodontal damage in the affected tooth is secondary to pulpal infection, without a broader periodontitis background. In these cases, the periodontal damage results from the spread of infection from the pulp to the surrounding periodontium. It is essential to rule out other causes such as poor or overhanging restorations, food impaction, and defective prostheses. These combined lesions of pulpal origin are most common in the mandibular first molar. When chronic periapical inflammation occurs, the initial lesion appears at the tooth's apex. Periapical X-ray films or CBCT scans reveal radiolucency due to bone destruction in the apical region [40,41]. Given the thick buccal and lingual

cortical bone plate in the mandibular molar area (3-5mm), the lesion cannot break through this barrier. Instead, it spreads along the root towards the crown, entering between the mesial and distal roots, and finally passing through the buccal bifurcation area of least resistance. This results in a narrow, deep periodontal pocket and fistula in the buccal bifurcation area. CBCT imaging shows the lesion spreading from the apical region along the root towards the coronal surface, entering the weak bone area between the mesial and distal roots in the middle third of the root, and breaking through the cortical bone at the buccal root bifurcation area, causing bone destruction.

In contrast, for maxillary teeth and mandibular anterior teeth, the labial and buccal cortical bone in the apical area is thinner (0.5-2.0mm). Inflammation here quickly penetrates the cortical bone, forming a fistula in the labial or buccal region. CBCT reveals periapical radiolucency due to bone fenestration in the labial and buccal apical regions, where fistula formation occurs. The lesion rarely spreads along the root to the coronal side, hence alveolar bone destruction at the cervical region and fistula formation at the gingival margin are uncommon. Periapical bone destruction is often due to poor apical sealing after root canal treatment, allowing pathogenic microorganisms, like Enterococcus faecalis, to form biofilms at the apical foramen. These biofilms, along with inflammatory mediators and the body's immune response, activate osteoclasts, leading to periapical alveolar bone destruction. This destruction follows two primary paths: centering around the leakage area at the apical foramen and spreading through areas of low resistance, such as cancellous bone along the root bifurcation area.

Therefore, since most of the type II combined lesions are from the periapical pulp, and the deep periodontal pockets formed by them are the pathway of pus for the spread of lesion. Even if the effect of root canal treatment is not good for such combined lesions, microsurgery can still be used to treat the apical lesions, and through retrograde preparation and filling, the apical seal can be formed again. Therefore, the prognosis of microsurgery is better, even close to the success rate of microsurgery with only periapical lesions. However, it still cannot explain that the success rate of microsurgery in subclass II3 was the lowest in all categories.

**Correlation between subclassII3 periodontal and endodontic lesions and vertical root fractures**

VRF (Vertical Root Fracture) [42] refers to the longitudinal root fracture along the vertical axis of the tooth root, which starts at the apex of the root and extends in the coronal direction towards the crown, and even reaches the root neck. It usually occurs in posterior teeth, and is more common in buccolingual direction [43]. It has been reported that VRF occurs in both non-endodontically and endodontically treated teeth, with an incidence rate between 3.7% and 30.8% [44], but the incidence of VRF endodontically treated teeth is higher than for non-endodontically treated teeth [45,46]. These differences in incidence can be attributed to a number of risk factors, such as whether or not root canal treatment was performed, the instrumentation during root canal preparation, the size of the root canal preparation, the root canal post, the depth of the post, restoration with crown, the patient's occlusion, and periodontal condition, etc., have brought great challenges to clinical diagnosis and treatment. For the diagnosis of VRF [47-49], because the affected teeth are asymptomatic or have symptoms similar to periodontal and endodontic lesions in the early stages, it often goes undetected for a long time, eventually resulting in tooth loss. Clinical features commonly reported to be associated with VRF include [50]: localized deep periodontal pockets; fistula; “J” shaped periapical shadow, which is clinically and radiologically similar to periodontal and endodontic lesions. VRF is an important cause of tooth extraction, especially after endodontic treatment, because once diagnosed, it can only be recommended for extraction or root resection in case of multi-rooted teeth, but root resection is rarely recommended these days due to poor long-term prognosis.

The emergence of CBCT has improved the early diagnosis of vertical root fractures [51]. Tyndll et al. [52] found that CBCT can accurately provide data similar to periodontal probing when measuring the status of alveolar bone, and can clearly display enamel, dentin, pulp cavity, root canal, cortical bone plate structure, cancellous bone, bone wall destruction etc., and the resolution is greatly improved, so it is easier to detect vertical root fractures early on than in periapical X-ray films. However, CBCT does have limitations in the early diagnosis of VRF. Teeth with VRF mostly include teeth

that have undergone endodontic treatment. Saati et al. [53] found that the presence of metal posts and root canal filling materials significantly reduced the sensitivity and accuracy of CBCT. Metal crowns, metal posts, root canal filling materials, etc. will produce artifacts. These artifacts may cover, superimpose, or imitate root fracture lines, which can lead to misdiagnosis [54]. Similarly, all-ceramic restorations, such as zirconium-ceramic crowns, zirconium-ceramic posts, and fiber posts, can also cause artifacts in CBCT images. The diagnostic ability of CBCT for vertical root fractures is also affected by the image conversion ability of the computer processor of the CT machine [55], and the image conversion ability is affected by factors such as spatial resolution, contrast, plane spacing, photosensitive elements, calculation methods, and noise. Meanwhile, in the early stage of VRF stage, only hidden cracks are generated on the root without displacement, which also makes it difficult for CBCT in early diagnosis of VRF [56,57].

The loss of vertical buccolingual alveolar bone can serve as important indirect evidence of VRF. Studies have shown that the direct evidence of CBCT image diagnosis of VRF in teeth after endodontic treatment is poor (it is difficult to find early root VRF images that are similar to cracked tooth, Subtle VRF, Incomplete VRF) [58,59], but the loss of alveolar bone in the buccal and lingual direction can be found. In the finite element analysis model of the root the shape of the root, the root canal morphology, and the shape and distribution of the root canal are important reasons for affecting the stress distribution. For the oval-shaped and flat tooth root, the buccolingual diameter is significantly larger than the mesiodistal diameter [60], which is a buccal-lingual stress concentration area with long-term repeated chewing force [61]. There are also multiple root canals in the buccal-lingual direction and these multiple root canals in flat or oval shaped root when enlarged and prepared, reinforced with posts, results in the decline of the mechanical properties of the pulpless tooth root, forming a buccal and lingual stress weak zone in the apical area [62], similar to postage stamp punch. Under the action of long-term repeated stress, tears along the perforation line of the stamp occur, resulting in a symmetrical VRF in the buccal-lingual direction of the tooth root. Once buccal-lingual symmetric VRF occurs [63,64], a symmetrical leakage area is formed. According to discussion 2, pathogenic microorganisms and inflammatory mediators will destroy the alveolar bone along the crack and the buccal lingual alveolar bone along the crack line, ultimately forming a buccal lingual symmetrical deep periodontal pocket. Based on this, this experiment proposes for the first time that symmetric bone destruction in the buccal lingual direction is important indirect evidence for the early diagnosis of VRF.

Subclass II3 of the new combined lesion classification refers to deep periodontal pockets on multiple tooth surfaces of affected teeth without periodontitis, especially deep periodontal pockets with buccal-lingual symmetry. Combined with CBCT analysis, in addition to apical lesions, there are also symmetric lesions on the buccal lingual side, and they extend from the root tip to the root neck. Therefore, compared with other subclass, the II3 subclass has the highest correlation with vertical root fractures.

## Conclusion

In conclusion, while microsurgery remains effective for treating periodontal and endodontic lesions, its success rate is lower compared to chronic periodontitis cases. The new classification of combined lesions serves as a crucial indicator for predicting surgical outcomes. Type II combined lesions show better response to microsurgery compared to Type I, with success rates decreasing with worsening periodontal damage. Tooth position also affects success rates, with anterior teeth showing better outcomes than posterior ones. Furthermore, subclass II3 lesions exhibit the highest incidence of VRF, leading to the lowest microsurgery success rates. Preoperative CBCT examinations, along with assessing lesion size, orientation, and symmetry, significantly correlate with detecting VRF during and after surgery in subclass II3 lesions. The buccal-lingual apical region's susceptibility to stress and weakness post-root canal treatment predisposes it to VRFs. Symmetrical bone destruction following root fractures further underscores the importance of classifying combined lesions and considering lesion symmetry to enhance microsurgery predictability.

Journal of Chemical Health Risks
www.jchr.org
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