CLINICAL RESEARCH

Clinical Outcome and Predictors of Endodontic Microsurgery Using Cone-beam Computed Tomography: A Retrospective Cohort Study

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SIGNIFICANCE

The clinical outcome and prognostic factors of endodontic microsurgery were assessed based on CBCT scans in order to optimize surgical endodontic management.

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ABSTRACT

Introduction: The aim of this retrospective cohort study was to evaluate the clinical outcomes and identify the prognostic factors of endodontic microsurgery based on cone-beam computed tomographic (CBCT) scans. **Methods:** Patients who underwent endodontic microsurgery in teeth with asymptomatic apical periodontitis were included. The clinical outcomes were determined based on clinical and radiographic examinations after surgery 12–48 months. Radiographic healing was assessed on CBCT images by using the modified PENN 3-dimensional criteria and classified into 4 categories: complete, limited, uncertain, and unsatisfactory healing. Multivariate logistic regression was performed to detect outcome risk factors. **Results:** Of the 204 teeth in 173 invited patients, 148 teeth of 126 patients were examined at review. On CBCT images, 88 teeth (59.5%) showed complete healing, and 42 (28.4%) teeth showed limited healing. All these 130 teeth were asymptomatic and achieved a clinical success rate of 87.8%. Uncertain healing was observed in 9 teeth, one of which was symptomatic. The remaining 9 teeth were unsatisfactory healing on CBCT scans, including 6 teeth with clinical symptoms and 3 free. Lesion type and root-end filling quality were significant outcome predictors ($P < .05$). The risk of treatment failure for teeth with combined endodontic-periodontal lesions was 8.6 times higher than that for teeth with isolated endodontic lesions. Adequate root-end filling quality improved the probability of success by 5.3 times. **Conclusions:** Based on CBCT data, an adequate performed endodontic microsurgery could have predictable success in teeth without periodontal involvement. *(J Endod 2023;49:1464–1471.)*

KEY WORDS

Cone-beam computed tomography; endodontic microsurgery; outcome; prognostic factors

Endodontic surgery is considered as an important therapeutic option vs endodontic retreatment or tooth extraction for teeth presenting with postendodontic infection[1]. The integration of operating microscopes, ultrasonic microtips, and highly biocompatible materials in modern microsurgical principles since the 1990s has revolutionized endodontic surgical approaches[2]. In 5 published meta-analyses of original studies evaluating outcomes based on radiographic parameters and clinical assessment that were published up to December 2016, the weighted pooled success rates of endodontic microsurgery were 89%–94%[3-7].

Cone-beam computed tomography (CBCT) has been proven to be helpful in assessing the characteristics of apical periodontitis, the adjacent teeth, and anatomic structures[8]. According to statements of American Association of Endodontists and American Academy of Oral Maxillofacial Radiology, CBCT is the recommended imaging modality for presurgical treatment planning[9]. In 2009, Christiansen et al first used CBCT to assess the outcome of endodontic microsurgery and identified 28% more apical lesions on CBCT than on periapical (PA) radiograph[10]. By rating the radiographic healing after periapical surgery, von Arx et al observed that the CBCT-rating and the PA-rating were different in 40% of cases[11]. Although the success rate of endodontic microsurgery ranging from 50% to 92% has been reported in clinical studies using CBCT evaluation, limited information is available with regard to clinical outcome and prognostic factors with variations in the characteristics of study design[10-15].

The aim of this retrospective cohort study was to assess the clinical outcome of endodontic microsurgery at least 1 year postsurgery based on CBCT scans using modified PENN 3-dimensional (3D) criteria proposed by Schloss et al in 2017[15]. In addition, potential prognostic factors on the outcome were analyzed to optimize surgical endodontic management.

MATERIALS AND METHODS

Patient Inclusion

This retrospective cohort study protocol was approved by the ethics board of Peking University Hospital of Stomatology, Beijing, China (no. PKUSSIRB-202059182). Patients with teeth diagnosed as apical periodontitis based on CBCT imaging together with clinical testing who underwent endodontic microsurgery from January 2018 to December 2019 at the Department of Cardiology and Endodontics of the Peking University School of Stomatology were included.

The exclusion criteria were as follows:

1. Patients with poorly controlled systemic diseases, resulting in American Society of Anesthesiologists class III–V
2. Patients who were pregnant
3. Teeth with root fractures or with a history of resurgery

In total, the cohort consisted of 204 teeth from 173 patients.

Endodontic Microsurgery Procedures

All surgical procedures were performed by endodontic specialists under operating microscopes (OPMI PICO; Carl Zeiss, Oberkochen, Germany). After anesthesia induction with 4% articaine with 1:100,000 epinephrine (Primacaine; Acteon Pharma, Bordeaux, France), incisions were made to reflect a full-thickness flap. The root apex was exposed following osteotomy using fissure burs (Lindemann H161 burs; Brasseler USA, Savannah, GA), and granulation tissue was removed. Then, the root end was resected 3 mm perpendicular to the long axis of the root. Methylene blue was used to stain the resected root surfaces for detailed anatomical inspection under high magnification. The root-end cavity was prepared using ultrasonic microtips (Kis Tips; Obtura Spartan, Fenton, MO) that extended into the canal space 3 mm or more and then obturated with ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK) or iRoot BP (Innovative BioCeramix Inc, Vancouver, BC, Canada). Guide tissue regeneration (GTR) was performed on indicated teeth by using bovine-derived hydroxyapatite Bio-Oss and/or collagen membranes Bio-Gide (Geistlich Pharma AG, Wolhusen, Switzerland). The wound was closed with 5-0 monofilament sutures (NC165; UNIK Surgical Sutures MFG. Co, Taipei Hsien, Taiwan), and the sutures were removed 5–7 days after surgery.

TABLE 1 - Analysis of Preoperative Clinical Factors in the Included and Reviewed Cases

Clinical factors	No. (teeth)	Reviewed cases	Dropout cases	*P* value
Age				.921
≤45 y	163	118	45	
>45 y	41	30	11	
Sex				.364
Male	72	55	17	
Female	132	93	39	
Tooth type				.583
Anterior	133	94	39	
Premolar	41	30	11	
Molar	30	24	6	
Arch type				.469
Maxillary	153	113	40	
Mandibular	51	35	16	
Lesion type*				.451
I	120	91	29	
II	66	45	21	
III	18	12	6	
Total	204	148	56	

I: Uncomplicated endodontic lesion.
II: Complicated endodontic lesion.
III: Endodontic-periodontal combined lesion.
*Classification scheme from Guess and Kratchman[16].

Follow-up Examination

The included patients after treatment more than 1 year were contacted by telephone, e-mails, or letters to encourage them to attend the follow-up appointment.

After informed consent was obtained, the follow-up clinical examination was carried out by one examiner who did not participate in the surgical treatment. The clinical information, including subjective discomfort, swelling, sinus tract formation, tenderness to palpation or percussion, mobility, periodontal pocket depth, and the quality of coronal restoration, was recorded.

Then, a limited field of view CBCT scan was taken with Morita 3D Accuitomo 170 (J Morita, Kyoto, Japan) or NewTom VGi (NewTom, Verona, Italy), which was matched preoperatively and at the follow-up. The operating parameters for Morita 3D Accuitomo 170 were set as 90 kVp, 5 mA, and an exposure time of 17.5 seconds, and those for NewTom VGi were set as 110 kVp, automatic mA, and an exposure time of 5.5 seconds. The CBCT images were reconstructed with matching software i-Dixel 2.8 (J Morita, Kyoto, Japan) or NNT software, version 4.00.1 (NNT, Verona, Italy).

Clinical Outcome Assessment

Two endodontists were trained and evaluated the CBCT images independently twice. In case of disagreement, the case was discussed until consensus was achieved. To evaluate the healing of an individual root, the axes of multiplanar reconstruction CBCT images were aligned to obtain ideal mesiodistal and buccolingual sections. Then, the radiographic outcomes were determined based on the modified PENN 3D criteria and classified into complete, limited, uncertain, and unsatisfactory healing[15].

The clinical outcome was assessed based on clinical and radiographic measures. Teeth showing complete or limited healing on CBCT imaging and no clinical symptoms were indicative of successful treatment, whereas treatment failure was indicated by teeth showing uncertain or unsatisfactory healing on CBCT imaging and/or clinical symptoms.

Investigation of Clinical Factors

The factors that could possibly influence the surgical outcome were recorded as follows:

Tooth-related Factors

Tooth type. Anterior, premolar, or molar.

Arch type. Maxillary or mandibular.

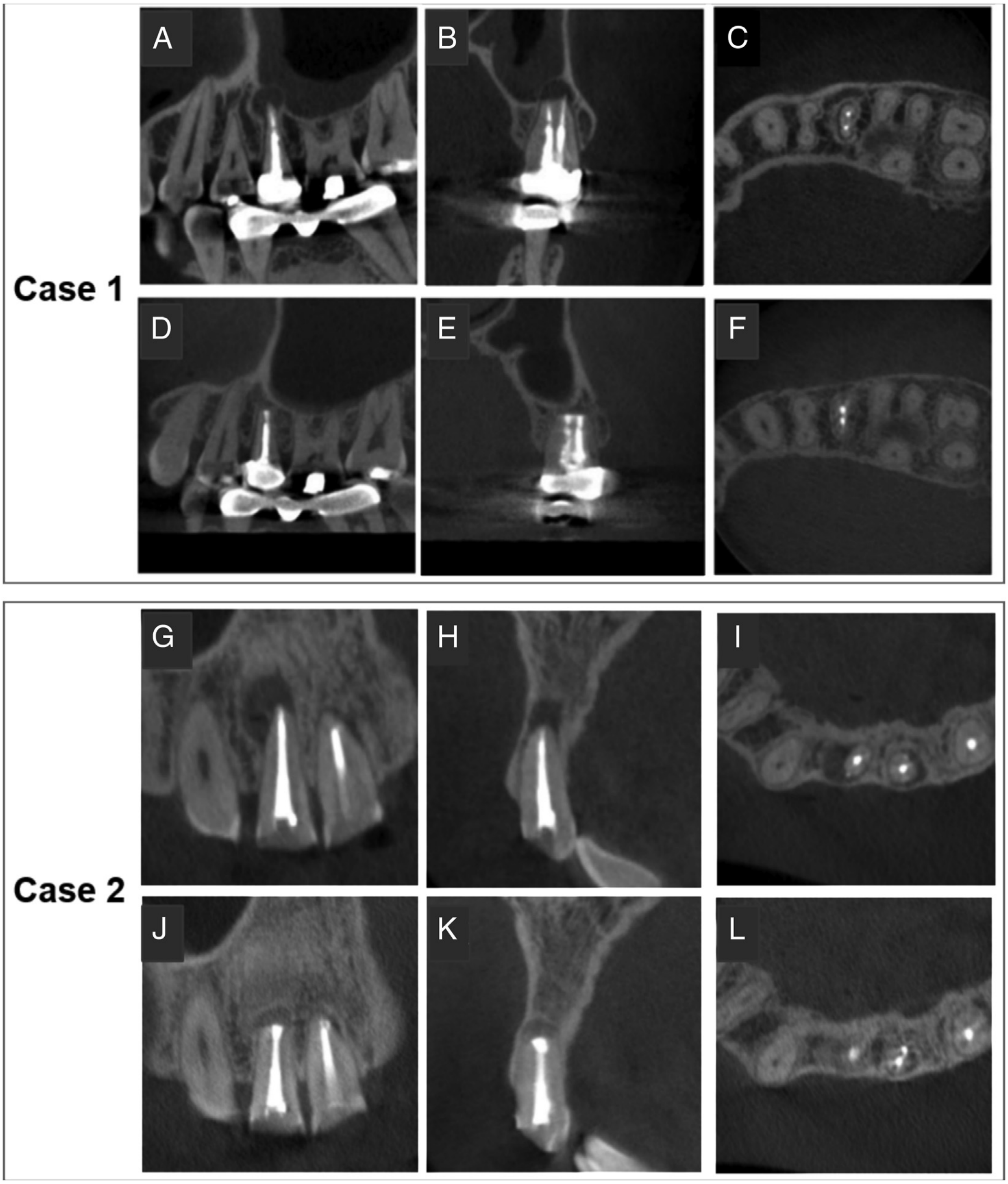

FIGURE 1 – Radiographic healing on cone-beam computed tomography (CBCT) images of teeth with successful clinical outcomes. The preoperative (*A–C* and *G–I*) and the follow-up (*D–F* and *J–L*) CBCT scans. Case 1: Tooth 25 showed complete healing 39 months after a properly performed surgery. Case 2: Tooth 12 was treated with guide tissue regeneration during microsurgery. CBCT imaging at 16 months postoperatively showed that radiolucency had decreased with low density bone structure formed inside, indicating limited healing. The teeth in both cases were absence of clinical symptoms.

Lesion type. The preoperative periradicular lesions were classified into 3 categories[16]:

Type I: Uncomplicated isolated endodontic lesions represent cases that bone loss confined to the apical area with normal probing.
Type II: Complicated isolated endodontic lesions represent lesions with normal probing, but the lesion size is larger than 10 mm and/or buccal-lingual plates of bone resorbed (through-and-through).
Type III: endodontic-periodontal lesions, such as loss of buccal plate, dehiscence, denuded root and furcal involvement.

Quality of Orthograde Root-filling. The quality of orthograde root filling was determined on presurgery CBCT scans in coronal and sagittal sections by considering both length and density of root filling according to the classifications mentioned in our previous studies[17,18]. Satisfactory root-filling quality was defined as a flush length and satisfactory density; otherwise, the root filling was considered unsatisfactory.

Treatment-related Factors

Guide Tissue Regeneration. The application of GTR therapy was recorded by checking medical charts.

Angle of Root Resection. The resection angle was measure between the resection plane and the reference line perpendicular to the long axis of the root. Adequate resection

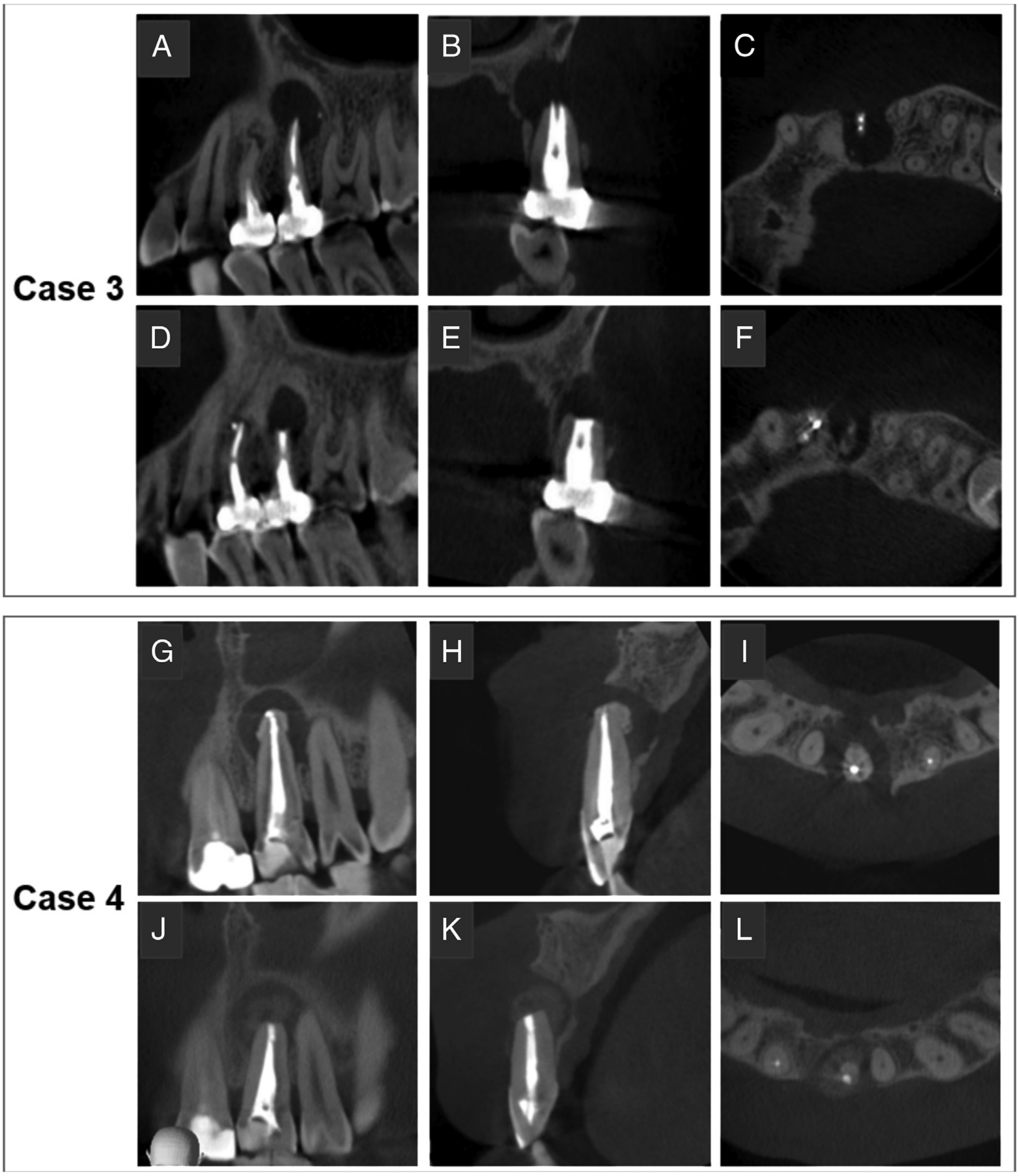

FIGURE 2 – Radiographic healing on cone-beam computed tomography (CBCT) images of teeth with poor clinical outcomes. The preoperative (*A–C* and *G–I*) and the follow-up (*D–F* and *J–L*) CBCT scans. Case 3: Tooth 25 showed uncertain healing with decreased radiolucency symmetrically located around the apex on CBCT image at the 28-month follow-up despite being normal, both clinically and functionally. Case 4: Tooth 11 with an endo-perio lesion was treated with guide tissue regeneration during surgery. However, 25 months after surgery, a sinus tract was detected, and the radiolucency surrounding the bone filler remained unchanged, which indicated treatment failure.

angle was defined when the angle was less than or equal to 20°[19].

Root-end Filling Quality. Adequate root-end filling should fulfill root-end cavity without voids and extend to length of 3 mm or more.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows Version 26.0 (IBM Corp, Armonk, NY). Cohen kappa was used to calculate interexaminer and intraexaminer agreement. The chi-square test or Fisher's exact test was used to assess response bias between the dropout and reviewed groups in the preoperative characteristics. For the analysis of the predictors, the dependent variable was the dichotomous clinical outcome (success vs failure). All the investigated variables were used as covariates for multivariate logistic regression analysis to identify prognostic factors. In this model, $P < .05$ was used as the entry criterion whilst $P > .10$ was the removal criterion. The level of significance was set at $\alpha = 0.05$.

RESULTS

Information of Recalled Cases

Of the 173 patients (204 teeth) included, 126 patients (148 teeth) who aged 18–63 years (mean 36.3 years and median 34 years) participated in the follow-up. The mean follow-

TABLE 2 - Multivariate Logistic Regression Analysis of the Association between Prognostic Factors and Endodontic Microsurgery Outcome

Factors	Number of teeth (%)*	Adjusted odds ratio	95% confidence interval		*P* value
			Lower	Upper	
Tooth-related factors					
Tooth type‡					.198
Anterior	94 (88.3)				
Premolar	30 (93.3)	0.51	0.09	3.04	.461
Molar	24 (79.2)	3.59	0.67	19.29	.136
Arch type‡					.207
Maxillary	113 (88.5)	0.33	0.06	1.84	
Mandibular	35 (85.7)				
Quality of orthograde root filling‡					.347
Unsatisfactory	43 (89.6)	0.53	0.14	2.00	
Satisfactory	87 (87.0)				
Lesion type‡					**.014**†
I	91 (91.2)				
II	45 (88.9)	1.30	0.39	4.37	.667
III	12 (58.3)	8.60	1.98	37.34	.004
Treatment-related factors					
Regeneration treatment‡					.075
Without	64 (82.8)	0.29	0.07	1.13	
With	84 (91.7)				
Angle of root resection‡					.267
Inadequate	104 (91.3)	0.35	0.05	2.25	
Adequate	44 (79.5)				
Root-end filling quality§					**.008**†
Inadequate	79 (94.9)	5.25	1.55	17.84	
Adequate	69 (79.7)				

CI, confidence interval.
*The values are given as number of subjects and percentage of successful outcome.
†Bold font highlights statistical significance measured by backward Wald test.
‡The association between factors and failure.
§The association between root-end filling quality and success.

up period was 26 months, ranging from 12 to 46 months. The recall rate was 72.5% for teeth and 72.8% for patients. A response bias analysis revealed that the preoperative characteristics were not significantly different between the dropout and reviewed groups ($P > .05$) (Table 1). Forty-seven patients dropped out because they relocated or refused to comply with the follow-up procedure.

Clinical Outcome Based on CBCT

The interexaminer kappa value of outcome evaluation on CBCT scans was 0.826. The intraexaminer values were 0.747 and 0.817, respectively. Radiographic healing was categorized according to the modified PENN 3D criteria, as follows: 88 (59.5%) of the 148 teeth showed complete healing, 42 (28.4%) showed limited healing, 9 showed uncertain healing, and 9 showed unsatisfactory healing. These 130 teeth with radiographically complete or limited healing were absence of clinical symptom and determined as successful cases (Fig. 1). Together, the clinical success rate was 87.8%. For the remaining 18 teeth (Fig. 2), 7 symptomatic teeth presented with sinus tracts and/or spontaneous pain at the follow-up, of which 1 tooth had uncertain healing and 6 had unsatisfactory healing on CBCT imaging.

Prognostic Factors

Multivariate logistic regression analysis revealed that lesion type ($P < .05$; odds ratio = 8.60; CI: 1.98–37.34) and root-end filling quality ($P < .05$; odds ratio = 5.25; CI: 1.55–17.84) were significant predictors for surgery outcome (Table 2). The value of Nagelkerke R^2 for this multivariable model was 0.20. The failure risk was 8.6 times higher for teeth with preoperative endodontic-periodontal combined lesions than for those with isolated uncomplicated or complicated (larger than 10 mm or through-and-through) endodontic lesions. At the same time, satisfactory root-end filling quality had a positive effect on the outcome in that the probability of success was 5.3 times higher than that of teeth showing unsatisfactory root-end filling quality.

DISCUSSION

In the present study, CBCT scans were used to evaluate periapical healing after endodontic microsurgery. Although histology remains the gold standard for healing assessment, the association between the radiographic features on CBCT imaging and the histologic characteristics after surgical or nonsurgical endodontic treatment has been confirmed in animal studies[20,21]. In addition, the validity of CBCT imaging in detecting the absence or presence of periapical lesions, measuring their size, and monitoring the related changes has also been proven in previous studies[10,18,22]. In this study, a limited field of view CBCT scan was prescribed as radiographic modality at the follow-up, considering the risk of radiation exposure and its benefits after the approval of the ethical board[9]. In terms of exposure setting, the as low as reasonably achievable principle was applied, and all the patients wore a thyroid collar[23].

In the present study, the modified PENN 3D criteria were used to determine the CBCT-based radiographic outcomes, rather than the Rud and Molven criteria which were proposed on the studies about correlation between histology and radiography in 1972 and had been widely used as evaluation criteria on PA radiographs[24,25]. According to the modified PENN 3D criteria, 3-dimensional healing parameters consisting of resected root-end surface, periapical area, and cortical plate suggested by Chen et al provided a comprehensive assessment on CBCT images[21]. On this basis, the radiographic outcome was classified into complete, limited, uncertain, and unsatisfactory healing. In recently published clinical studies, it has showed that the modified PENN 3D criteria had a high inter- and intra-observer agreement for 3D outcome assessment, which was similar in our study[26,27].

A success rate of 87.8% was provided using CBCT data after endodontic microsurgery from 12 to 46 months in the current study. This result was comparable to that of Su et al's retrospective study, which reported a success rate on CBCT data of 84% in 82 teeth with a mean follow-up of 28 months in the Chinese population[26]. In another retrospective cohort study, a relatively high success rate of 93% was observed at the 2-year follow-up, and teeth treated with bone grafting or barrier materials were excluded[28]. Even though the success rate of endodontic microsurgery varied because of differences in the study design, it has achieved to the point of being equivalent to that of conventional retreatment[29]. It indicated that with the aid of an operating microscope, ultrasonic tips, and biocompatible root-end filling materials, endodontic microsurgery has become a reliable option rather than the last resort in patients with persistent endodontic diseases.

The adequacy of sample size for multivariate logistic regression analysis is to have at least 10–20 events per predictor. Given the retrospective nature of the present study, 7 factors which were clinically relevant and had been addressed in previous studies were selected as covariates[30]. Efforts were made to encourage patients to attend the follow-up, and the sample for analysis included 148 teeth from 126 patients, allowing for 21 cases for each predictor in the model. Meanwhile, the value of Nagelkerke R^2 was 0.20 for the present model, which indicated that the results of this study should be carefully explained to avoid over-interpreting of the predictive value.

Multivariate analysis revealed that, based on CBCT scans, lesion type had a significant influence on the clinical outcome in our study. In the current study, a 3-type bone lesion classification that was introduced by Guess and Kratchman[16] was used to assist in the analysis of the effect of clinical factors. We found that the rate of successful treatment of endodontic-periodontal lesions was 58%, which was 32% percent lower than that of isolated endodontic lesions. However, there was no significant difference in the clinical outcomes of teeth with various extents of isolated endodontic lesions. In a prospective clinical study, a significant higher success rate of 95.2% was shown for teeth without periodontal involvement, compared with 77.5% in teeth with different level of supporting bone loss[31]. These results indicated that endodontic-periodontal combined lesions created a compromised situation during endodontic microsurgery with a less favorable prognosis. Appropriate case selection is essential to obtain a successful outcome after endodontic surgery.

In this study, the quality of root-end filling was also identified as a predictor of clinical outcome. Root-end filling material that is appropriately placed provides a tight apical seal to prevent leakage[32], which also represents a proper root-end preparation or disinfection. By using the relatively strict definition of adequate root-end filling quality consisting of the length and angle measured on CBCT, 79 teeth (53%) were identified as adequate root-end filling with a success rate of 94.9%. Meanwhile, teeth with inadequate root-end filling achieved a success rate of 79.7%. A similar result was reported in that the quality of the root-end filling was a factor influencing the outcome of apical surgery in Friedman's review based on PA evaluation[30]. Further studies on the potential correlation between treatment-related factors and microsurgery outcomes based on CBCT are still needed.

GTR was performed in 84 teeth, including 40 teeth with uncomplicated isolated endodontic lesions, 35 teeth with complicated isolated endodontic lesions, and 9 teeth with endo-perio lesions in this study. Considering the compounding of radiographic interpretation resulting from a radio-opaque bone filler, cases showing radiolucency surrounding the remining bone filler on follow-up CBCT were considered to have unsatisfactory radiographic healing in our study (Fig. 2*J–L*). In total, the rate of a successful clinical outcome was 91.7% and 82.8% for cases with and without GTR, respectively. Although a trend of better outcome was found when GTR was applied, the results were not statistically significant. It is well accepted that GTR treatment could provide more chance of better outcomes in cases of large lesions (>10 mm), through-and-through lesions or endo-perio lesions[33,34]. However, the definitive indications for GTR in endodontic surgery have yet to be established[35]. Large-scale randomized controlled clinical studies assessing the benefit of GTR treatment for endodontic surgery are required to confirm the necessity and rationalize the application of GTR.

CONCLUSION

In this retrospective study, the clinical outcome and factors were determined and measured on CBCT scans. A success rate of 87.8% was achieved for teeth treated by endodontic microsurgery at a follow-up period from 12 to 46 months. Endodontic-periodontal combination lesion compromised clinical outcome, while adequate root-end filling quality had a positive effect on the success result.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Ming-Ming Zhang: Methodology, Investigation, Writing – original draft. **Gao-Feng Fang:** Investigation, Data curation, Formal analysis. **Yu-Hong Liang:** Conceptualization, Writing – review & editing, Supervision.

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Ming-Ming Zhang and Gao-Feng Fang contributed equally to this study.

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

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