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Prognostic Predictors of Endodontic Microsurgery: Radiographic Assessment

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ABSTRACT

Objective: This study aimed to compare the healing outcomes of endodontic microsurgery (EMS) using 2-dimensional (2D) and 3-dimensional (3D) radiographic evaluation in a Chinese population. The prognostic factors of EMS were identified according to the 2D and 3D healing classifications.

Materials and methods: The teeth (n = 82) were studied using 2D and 3D radiographic examinations. The 2D and 3D healing criteria were used to evaluate the healing outcome. Prognostic factors were investigated based on healing outcomes. Data were analysed using SPSS, and \( P < .05 \) was considered significant.

Results: There were significant differences between 2D and 3D healing outcomes (\( P = .004 \)). For the 3D images, age older than 45 years was found to be a significant negative predictor (\( P = .005 \)).

Conclusions: Cone-beam computed tomographic images provided more precise evaluation of periapical lesions and healing outcomes of EMS than conventional periapical radiographs. Age (>45 years) of the patients exhibited a significant influence on the healing outcome of EMS as determined using 3D images.

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Key words: Endodontic microsurgery, Prognostic factors, Cone-beam computerised tomography

Introduction

Endodontic microsurgery (EMS) is a surgical endodontic retreatment technique characterised by modern microsurgical techniques that integrate the use of an operating microscope or endoscope, root-end cavity preparation with ultrasonic tips, and more biocompatible root-end filling materials such as immediate restorative material, super ethoxybenzoic acid, or mineral trioxide aggregate. The overall pooled success rate of EMS is more than 90%. CPR is the most common radiographic examination for routine clinical use. Rud's and Molven's criteria have been developed as efficacy diagnostic criteria for 2-dimensional (2D) images. CPR is used to detect lesions when there is perforation of the cortical plate or erosion of the inner or outer surface of the cortex. Diagnostic reliability is compromised by limitations of 2D imaging. Greater than 30% of mineral content loss of bone is a radiographic change that can only be captured during CPR screening. Moreover, geometric distortion and overlying anatomic structures may make it difficult to demonstrate true bone changes.

Cone-beam computed tomography (CBCT) visualisation of the true extent of periapical lesions and their proximity to important vital structures and anatomical landmarks is superior to that of CPR. CBCT has been more predictive for periapical lesions, root perforations, apicocoronal bone defects, and through-to-through bone defects. In another study, 125 cases of EMS were assessed using preoperative CBCT images. The buccal cortical bone status was accurately predicted. Recently, CBCT has been...
accepted as a reliable tool for the assessment of EMS outcomes. A retrospective study concluded that postoperative CBCT imaging was more sensitive and specific than CPR in assessing periapical radiolucency and was useful in outcome assessment. Schloss et al also reported that CBCT images presented a more precise healing evaluation for EMS. In this study, modified PENN 3-dimensional (3D) criteria were introduced, which proposed a detailed evaluation grading.

Although CBCT has shown superior detection of periapical bone lesions, few studies have used CBCT healing criteria to evaluate the healing outcomes and prognostic factors of EMS. The purpose of this study was to compare the healing outcomes of EMS using these 2 radiographic examinations in a Chinese population. Evaluating prognostic factors accurately based on reliable healing outcomes assessed using 3D images might be valuable. Therefore, we investigated the potential prognostic factors based on postoperative CPR healing criteria and CBCT healing criteria in a Chinese population.

Materials and methods

Sample selection

The study was approved by the Ethics Committee of the School and Hospital of Stomatology (2017B03), Wuhan University. Patients who underwent EMS performed by 2 experienced endodontic specialists (L.M., R.Z.) in the Hospital of Stomatology from 2012 to 2016 were selected from the medical database of Wuhan University. Patients whose follow-up period was more than 1 year were called or emailed to undergo examination for EMS. The participants were fully informed of all potential risks and provided signed informed consent. Data were collected according to the inclusion/exclusion criteria. During the follow-up period, clinical symptoms and radiographic assessments were collected.

1. Inclusion and exclusion criteria

1.1 The inclusion criteria were as follows:
(1) Radiologically and clinically intact restorations at follow-up
(2) History of primary EMS
(3) Available preoperative and postoperative CPR and CBCT
(4) Minimum 1-year follow-up period

1.2 The exclusion criteria were as follows:
(1) Patients with a history of systemic disease
(2) Teeth with root perforation or apical cracks
(3) History of other endodontic surgery
(4) Lack of preoperative and/or postoperative CPR and CBCT examination
(5) Less than 1-year follow-up
(6) Incomplete restoration, either radiologically or clinically, at follow-up

2. EMS Procedures

EMS procedures included incision, full mucoperiosteal flap elevation, and root resection using a surgical operating microscope. Root end resection was performed in all cases. All root ends were prepared using ultrasonic tips and filled with mineral trioxide aggregate (MTA, Dentsply Tulsa Dental) under an operating microscope. All included teeth were operated on under EMS guidelines. All clinical procedures were performed by 2 experienced endodontic specialists, as mentioned previously.

3. Clinical and Radiographic Evaluation

Clinical examination recorded the presence of symptoms (pain, sensitivity to percussion, and/or palpation) and signs (fistula, swelling). Radiographic assessment was performed using not only the CPR healing criteria but also the CBCT healing criteria. Radiographic assessment was performed using both Rud’s and Molven’s criteria and modified PENN 3D criteria.

3.1 Radiographic Evaluation and Criteria for CPR

CPR was performed using an X-ray unit operating at 60 kV and 7 mA (Planmeca). The outcomes of EMS were classified into 4 types: complete healing, incomplete healing, uncertain healing, and unsatisfactory healing according to Rud’s and Molven’s criteria. The assessment was performed independently by 2 departmental endodontists (C.Y., Z.W.). Any disagreement between the 2 examiners was resolved through discussion. Agreement between the faculty members regarding healing outcomes was compared using Cohen’s kappa statistics. Finally, the failed cases were those with radiographic evidence of uncertain or unsatisfactory healing. Complete healing and incomplete healing without clinical signs or symptoms were dichotomised as successful. Cases in which teeth were extracted because of persistent clinical symptoms were also regarded as failed cases.

3.2 Radiographic Evaluation and Criteria for CBCT

The CBCT images were obtained using a CBCT machine operating at 110 kV and 3.41 mA (Newtom VGi) with a voxel size of 0.2 mm. The maximum diameter and volume of the apical lesions were measured on preoperative CBCT images using Mimics software (Materialize). The periapical bone defect diameter was measured in 3 axial orientations (mesiodistal, apico-coronal, and buccolingual), and the maximum diameter was recorded. The volumes of the radiolucent lesions were counted as more than twice the width of the periodontal ligament. The data were measured by C.Y. and Z.W. The modified PENN 3D criteria were used to evaluate EMS healing on postoperative CBCT images. Complete healing and limited healing with no clinical signs or symptoms were considered successful. Meanwhile, uncertain healing and unsatisfactory healing were labeled as failures. Cases in which teeth were extracted because of persistent clinical symptoms were regarded as failures.

4. Investigated Factors

Factors possibly influencing the surgical outcome were recorded as patient-related factors (sex and age) and tooth-related factors (tooth type, arch type, maximum lesion size, preoperative bone palatal defect, preoperative lesion volume, probing depth, and restoration type). These factors were evaluated during clinical and radiographic examinations.
Statistical analysis

The kappa test was used to calculate observer reliability. To confirm significant prognostic factors, chi-square tests or Fisher’s exact tests were applied for univariate factors. Finally, all univariate factors with a significance level of 0.2 were assessed using the logistic regression model. The comparison of EMS healing outcomes between CPR and CBCT was performed using McNeMar’s test.

Results

A total of 76 patients receiving primary EMS at least 1 year previously returned to undergo postoperative examination. According to the inclusion and exclusion criteria, 55 patients (82 teeth) were assessed in this study. The mean follow-up duration was 28 months. The patients’ ages ranged from 12 to 52 years. Of the 55 patients, 34 were male and 21 were female. The weighted kappa value between the 2 examiners for healing outcomes was 0.803. The Cohen’s kappa value between the 2 examiners for lesion size and lesion volume ranged from 0.829 to 0.943. The analysis showed that the success rate of EMS was 95.1% (78/82) and 84.1% (69/82) as evaluated using CPR and CBCT images, respectively. The outcome assessment between CPR and CBCT images was significantly different (P = .004). There were no prognostic factors that had a statistically significant influence on the outcome of EMS identified using CPR evaluation. However, preoperative maximum lesion size >12 mm was a potential factor in the univariate analysis based on CBCT evaluation (P = .034) (Table 1). Patients aged ≤45 years were found to have better healing outcomes in the univariate analysis (P = .002) (Table 1) and logistic regression model (P = .005) (Table 2).

Discussion

Diagnostic sensitivity and specificity are clinically important in evaluating therapeutic methods and clinical conditions.20 CPR is still the most used method for the diagnosis and assessment of healing outcomes. However, its diagnostic reliability is limited owing to image distortion and compression of 3D structures.15 Persistent periapical lesions after EMS cannot be observed when anatomic noise or geometric distortion exist.21 Ernest et al suggested that the inability of CPR to reveal true bone changes could potentially be overcome with the use of 3D images.21

CBCT shows more anatomic details by using 3D scanning images and is regarded as a powerful tool in diagnosis and follow-up.14,15,22-25 Patal et al showed that CBCT examination was 100% successful in detecting the presence and absence of periapical lesions, whilst the sensitivity of CPR was 24.8%.21 Endodontists believe that CBCT enhances the diagnosis of odontogenic pathologies, anatomical structures, treatment ofiatrogenic errors, and diagnosis of nonodontogenic pathoses by 96.4%, 96.3%, 92.2%, and 88%, respectively.26 Meanwhile, CBCT provided similar outcomes compared to the histologic results of animal studies.27,28 In our study, there were significant differences between the CPR and CBCT outcomes. Of the 82 teeth in which there was a diagnostic disagreement, CBCT provided similar outcomes compared to the histologic results of animal studies.27,28 In our study, there were significant differences between the CPR and CBCT outcomes. Of the 82 teeth in which there was a diagnostic disagreement, CBCT identified success in 9 teeth (11%) in which CPR did not. CBCT should be considered for better postoperative evaluation of EMS, especially with the advent of novel low-dose CBCT protocols in the future.

We assessed potential prognostic predictors according to healing outcomes revealed using CPR and CBCT. One patient-related variable (age) was evaluated as a significant prognostic factor according to the CBCT criteria,14 whereas there were no significant factors found in the CPR evaluation.6,7 Age was not significantly associated with the CPR criteria,6,7 which is consistent with previous studies.29,30 Barone et al reported that patients aged 45 years or older had better EMS outcomes, which is contradictory to our present study. In their study, the outcome was assessed using a 2D imaging modality, and they did not provide much explanation for this result.7 The disparity may be due to the different evaluation methods and inclusion and exclusion criteria. Previous studies have also shown that patient-related factors (ie, sex and

### Table 1 – Distribution of investigated factors and analysis in the evaluated cases.

| Factors                        | Cases | Success rate (%) | P value |
|-------------------------------|-------|------------------|---------|
|                               | CPR   | CBCT             | CPR     | CBCT   |
| Sex                           |       |                  |         |        |
| Female                        | 47    | 97.9             | 85.1    | .308   |
| Male                          | 35    | 91.4             | 82.6    | .783   |
| Age                           |       |                  |         |        |
| ≤45 y                         | 77    | 96.1             | 88.3    | .226   |
| >45 y                         | 5     | 80.0             | 20.0    | .002   |
| Preoperative probing depth    |       |                  |         |        |
| ≤3 mm                         | 67    | 95.5             | 82.1    | .562   |
| >4 mm                         | 15    | 93.3             | 93.3    | .281   |
| Restoration type at follow-up |       |                  |         |        |
| Direct restoration            | 49    | 91.8             | 79.6    | .569   |
| Indirect restoration          | 33    | 100.0            | 90.9    | .048   |
| Tooth type                    |       |                  |         |        |
| Anterior                      | 77    | 94.8             | 83.1    |         |
| Posterior                     | 5     | 100.0            | 100.0   |         |
| Arch type                     |       |                  |         |        |
| Maxilla                       | 71    | 95.8             | 83.1    | .444   |
| Mandible                      | 11    | 90.9             | 90.9    | .829   |
| Preoperative bone palate defect |       |                  |         |        |
| Yes                           | 63    | 93.7             | 81.0    | .569   |
| No                            | 19    | 100.0            | 94.7    | .279   |
| Maximum lesion size           |       |                  |         |        |
| ≤12 mm                        | 41    | 95.1             | 92.7    | .034   |
| >12 mm                        | 41    | 95.1             | 75.6    |         |
| Preoperative volume (V (mm³)) |       |                  |         |        |
| ≤500 mm³                      | 48    | 95.8             | 89.6    | 1.000   |
| >500 mm³                      | 34    | 94.1             | 76.6    | .109   |
| Total                         | 82    | 95.1             | 84.1    | .004   |

Direct restoration: Teeth were restored by resin composite or glass ionomer cement.

Indirect restoration: Teeth were restored by full crown or onlay.

* P < .05 comparison of microsurgery healing outcome evaluated by 3-dimensional criteria between different factors.
# P < .05 comparison of microsurgery healing outcome between CPR and CBCT. CBCT, cone-beam computed tomography; CPR, conventional periapical radiograph,
age) did not seem to influence surgical outcomes. In the present study, age older than 45 years was found to be a negative predictor based on the CBCT criteria. It is possible that younger patients had better healing capacity. Some authors have shown that female patients experience a higher success rate than male patients. However, our study showed that there was no significant difference between sexes in both CPR and CBCT evaluation, which is consistent with previous studies.

Regarding tooth-related factors, some studies have shown that maxillary teeth had a higher success rate than mandibular teeth. This may be related to access to the surgical approach, complexity of the root canal anatomy, presence of isthmus, and axis of root canal preparation, amongst other factors. Our study demonstrated that arch type (maxilla 77, mandible 11) was not a significant prognostic factor, which is consistent with the results of previous studies. Differences between anterior and molars were significant, whereas differences between anterior and premolars were not. This may be due to the comparably difficult surgical access required for premolars and molars, together with the reduced visibility. Clinicians are advised to prudently select posteriors for EMS and consider treatment alternatives. In addition, several previous studies also showed greater success for anterior teeth, which may be explained by easier surgical access and less complex root canal anatomy. Von Arx et al showed a higher success rate for maxillary molars (95.2%) than for maxillary premolars (66.7%). Nevertheless, other studies have reported different results regarding this factor. Regarding tooth type, there was no significant difference between anterior and posterior teeth in our study, which might be related to the small sample size of posteriors.

Previous studies showed that lesion size was also a significant factor as evaluated using the CPR criteria, and the size for statistical analysis varied. It was reported that the failure rate for EMS for preoperative lesions >5 mm, >6 mm, or >10 mm increased based on CPR evaluation. Von Arx et al reported that healed cases had a smaller apical bone defect (7.04 mm) than that of non-healed cases (8.60 mm). Few studies have analysed the diameter of apical lesions using CBCT. In our study, the failure rate was significantly higher with a maximum lesion size of >12 mm. A lesion size of 12 mm was selected for statistical analysis because it was the median value of the total distribution (12.08 mm ± 5.31 mm) in our study. It is not easy to remove residual tissue of a larger lesion thoroughly during EMS, which may lead to persistent inflammation. A similar study suggested that a large lesion size (>10 mm) is one of the major factors influencing the prognosis, as these lesions demonstrate a significantly lower rate of complete healing, with an increased rate of incomplete healing rather than failure. In addition, a previous study evaluated based on CPR showed that preoperative lesion size <12 mm had a higher success rate, which is consistent with our results.

It has been shown that the success rate of the mean size of the bony crypt (395 ± 41.66 mm³) was significantly different from those in non-healed cases (554 ± 51.61 mm³). Kreisler et al reported that cases with smaller lesions had a higher probability of healing. Kim et al reported that cases with lesion volumes greater than 50 mm³ had significantly lower success rates. The difference in volumes greater than 500 mm³ was not identified in the present analysis. The inconsistency of lesion volume may be caused by different inclusion and exclusion criteria of cases or different stages of the measurement.

The limitations of the present study include the relatively small sample size, which influences statistical power. In addition, there was a maldistribution of the anterior and posterior teeth, possibly because of difficult access to the surgical approach. More participants older than 45 years of age and more posterior teeth should be included in subsequent research to verify the results. Although CBCT has shown superiority over CPR in evaluating the healing outcome of EMS, it is not routinely used for assessment during the follow-up period because of its higher costs and higher levels of radiation exposure over those of CPR. A possible solution may be the advent of a novel low-dose CBCT protocol in the future.

Conclusions

The healing outcomes were significantly different between CPR and CBCT images. Postoperative CBCT imaging is more sensitive and specific than CPR for assessing healing outcomes following endodontic microsurgery. Age older than 45 years was related to a lower probability of successful healing as evaluated using CBCT criteria.

Conflict of interest

None disclosed.

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Table 2 – Logistic regression model of investigated factors with significance in univariate analysis.

| Independent variables | P value | Odds ratio | 95% CI Lower | 95% CI Upper |
|-----------------------|---------|------------|--------------|--------------|
| Restoration type at follow-up | .162 | 3.313 | 0.610 | 17.982 |
| Maximum lesion size (≤12 mm) | .127 | 0.206 | 0.027 | 1.569 |
| Preoperative volume (≤500 mm³) | .620 | 1.598 | 0.250 | 10.203 |
| Age (>45 y) | .005* | 0.031 | 0.003 | 0.351 |

Odds ratio shows the failure rate.

Restoration type is as follows:
- Direct restoration: Teeth were restored by resin composite or glass ionomer cement.
- Indirect restoration: Teeth were restored by full crown or onlay.

* P < .05 comparison of microsurgery healing outcome evaluated by 3-dimensional criteria between different factors.
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**Author contributions**

Chaonan Su and Rui Zhang contributed equally to this article.

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