Outcomes of Endodontic Microsurgery Using a Microscope and Mineral Trioxide Aggregate: A Prospective Cohort Study

Zu-Hua Wang, DDS,[*] Ming-Ming Zhang, DDS,[*] Ji Wang, DDS,[†] Lan Jiang, DDS,[‡] and Yu-Hong Liang, DDS, PhD[§]*

Abstract

Introduction: The aim of this study was to investigate the outcome of endodontic microsurgery and analyze the prognostic factors. **Methods:** Our prospective cohort study included 98 teeth in 81 patients. An endodontist performed all surgical procedures using endodontic microsurgical approaches. The treated teeth were recalled and examined clinically and radiographically at least 1 year after surgical treatment. The outcome was determined based on clinical and radiographic results. Radiographic healing was classified into 4 categories: complete, incomplete, uncertain, and unsatisfactory healing. An analysis of predictors was performed using multivariate logistic regression. **Results:** At recall, 74 of the 98 teeth (75.5%) were examined 12 to 30 months after surgery; 71 of the 74 teeth were analyzed clinically and radiographically, and 3 teeth had been extracted. On periapical radiographs, 55 (74.3%) of the 74 teeth showed complete healing, whereas 12 (16.2%) demonstrated incomplete healing. Together the percentage of complete and incomplete healing was 90.5% (67/74), and all 67 teeth were clinically normal. Uncertain healing was observed in 3 teeth (4.1%), one of which was symptomatic with swelling and sinus tract involvement and the other 2 were asymptomatic. The remaining 1 tooth (1.4%) showed unsatisfactory healing and was asymptomatic. The use as an abutment was found to be a negative factor associated with patient outcome ($P < .05$; odds ratio = 22; confidence interval, 20.47–23.53). **Conclusions:** The combined rate of complete and incomplete healing of teeth 12 to 30 months after endodontic microsurgery was 90.5%. The use as an abutment may have a negative effect on treatment outcome. *(J Endod 2017;43:694–698)*

From the *Department of Cariology and Endodontology and ‡First Clinical Division, Peking University School and Hospital of Stomatology, Beijing, China; †Center of Stomatology, China-Japan Friendship Hospital, Beijing, China; and §Department of Stomatology, Peking University International Hospital, Beijing, China.

Address requests for reprints to Dr Yu-Hong Liang, Department of Cariology and Endodontology, Peking University School and Hospital of Stomatology, Beijing, China 100081. E-mail address: leungyuhong@sina.com

0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2016.12.015

Significance

We assessed the outcome and predictors of endodontic microsurgery performed using a microscope and MTA in an adult Chinese population.

Endodontic surgery is performed to manage post-treatment periapical pathology when orthograde retreatment is impractical or unlikely to eliminate the cause of previous failures, such as infection in apically inaccessible areas, extraradicular infection, foreign body reactions, or radicular true cysts (1, 2).

The development of endodontic microsurgical devices and materials has led to the introduction of magnification and illumination devices, microinstruments, ultrasonic tips, and biocompatible materials (3). Compared with the traditional approach of using surgical burs and amalgam as root-end filling material (4, 5), the advantages of this modern approach include smaller osteotomies; shallower root resection angles; and easier identification of the isthmus, canal fins, lateral canals, and cracks, all of which make this approach more precise and less invasive (2, 3).

It has been speculated that the clinical outcomes of endodontic microsurgery are more successful and predictable than traditional approaches (6). The success rates of traditional endodontic surgery range from 44%–75% (7–9), whereas the success rates of endodontic microsurgery vary considerably from 57%–97% (10–15). Apart from patient selection, follow-up periods, and healing evaluation criteria, the treatment protocols, including magnification devices, root-end filling materials, and the experience of the surgeon, may also contribute to the variation in the success rate (16, 17).

Endodontic microsurgery has been used clinically in China for only about 10 years. Although in different countries many studies have been published evaluating the outcomes of endodontic microsurgery, there are few reports in the literature on the outcomes in the Chinese population.

The aim of this prospective cohort study was to assess the outcome and predictors of endodontic microsurgery performed using a microscope and mineral trioxide aggregate (MTA) by a single experienced endodontist in an adult Chinese population.

Materials and Methods

Patient Selection

The study protocol was approved by the ethics board of Peking University Health Science Center, Beijing, China (no. PKUSSIRB-2013057).

Patients requiring endodontic surgery were selected according to the following criteria between June 2011 and January 2013 at the Department of Cariology and Endodontics of Peking University School of Stomatology. All selected teeth showed radiographic evidence of periapical bone loss and had not received previous endodontic surgery. Teeth with fractures or perforations were excluded. Informed consent was obtained from all patients before treatment. In total, 98 teeth in 81 patients were included in the study. Then, the surgery was performed by a single endodontist according to the designed procedure.

Surgical Procedure

All surgical procedures were performed using an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany). Briefly, patients were anesthetized using 4%

TABLE 1. Radiographic Outcome Determined by Rud et al's and Molven et al's Criteria

Radiographic outcome	Number (%)
Complete healing	55 (74.3)
Incomplete healing	12 (16.2)
Uncertain healing	3 (4.1)
Unsatisfactory healing	1 (1.4)
Unknown (extracted teeth)	3 (4)

articaine with 1:100,000 epinephrine (Primacaine; Acteon Pharma, Bordeaux, France). Sulcular or mucogingival incisions were chosen depending on the tooth type and esthetic requirements of the case. Sulcular incisions were performed in 94 cases. Mucogingival incisions were chosen in the other 4 anterior teeth. Osteotomy was established with fissure burs (Lindemann H161 Burs; Brasseler USA, Savannah, GA) under copious water spray. Then, the granulation tissue was removed and sent for biopsy. A 3-mm root tip with a 0°–10° bevel angle was sectioned and irrigated with sterile distilled water. Epinephrine pellets (Racellet; Pascal Co, Bellevue, WA) were applied with light pressure to control local bleeding in the bone crypt. The resected root surfaces were stained with methylene blue and inspected using a micromirror (KMIR3; Obtura Spartan, Algonquin, IL) under 20 to 26× magnification to identify anatomic details. The root-end preparation extending 3 mm into the canal space along the long axis of the root was created using ultrasonically energized tips (Kis Tips, Obtura Spartan). Significant anatomic irregularities, such as isthmuses, cracks, or fins, were also repaired using the ultrasonic instrument. ProRoot MTA (Dentsply Tulsa Dental Specialties, Tulsa, OK) was used for the root-end filling material. The wound site was sutured with 5-0 monofilament sutures (NC165; UNIK Surgical Sutures MFG Co, Taipei Hsien, Taiwan), and a postoperative radiograph was taken. The sutures were removed 4 to 7 days after the procedure, and the healing progress was checked and recorded. All clinical procedures were performed by 1 experienced endodontist.

Clinical and Radiographic Evaluation

Patients were recalled for a follow-up examination at least 1 year after surgery. To reach a high recall rate, the endodontist who treated the patients encouraged them to return for follow-up through multiple telephone calls. At the recall examination, the clinical data, including subjective discomfort, swelling, sinus tract formation, tenderness to palpation or percussion, mobility, periodontal pocket formation, and the quality of coronal restoration, were recorded.

Periapical radiographs (PA) were obtained with the digital imaging system Digora Optime (Soredex, Helsinki, Finland) using a

Figure 1. Examples of complete and incomplete healing. (*A* and *D*) The preoperative condition, (*B* and *E*) the immediate postoperative condition, and (*C* and *F*) the follow-up. (*A–C*) Reformation of the normal width and lamina dura around the apex (*C*) 20 months after the operation showed complete healing of the periapical lesion. (*D* and *E*) The 12-month postoperative radiograph showed that the radiolucency had decreased and the outline of the radiolucency was irregular in a case showing incomplete healing.

parallel technique. Exposures of 0.12 seconds were obtained with a MinRay dental x-ray unit (Soredex) operating at 60–70 kV and 7 mA. The phosphor plates were immediately scanned after exposure using proprietary software (Dfw v.2.5, Soredex) with a 400-dpi scanning resolution.

Outcome was assessed based on clinical and radiographic measures. Two examiners, an endodontist and a radiologist, independently assessed the PA images twice. In cases with disagreement, the case was discussed until a consensus was reached.

The following radiographic healing classification was used according to the criteria proposed by Rud et al (5) and Molven et al(18):

1. Complete healing: reformation of the periodontal space shows a normal width or a slight increase, which is less than twice the width of the noninvolved root parts, and lamina dura around the apex; complete bone repair, bone bordering the apical area does not have the same density as the surrounding noninvolved bone; and complete bone repair, no apical periodontal space can be seen
2. Incomplete healing (scar tissue): rarefaction has decreased in size but is larger than twice the width of the periodontal space and is characterized by 1 or more of the following findings: the periphery of the rarefaction is irregular, the rarefaction is located asymmetrically around the apex, the connection of the rarefaction with the periodontal space is angular, and isolated scar tissue in the bone is observed along with the previously described findings
3. Uncertain healing: rarefaction has decreased in size but is larger than twice the width of the periodontal space and shows the following characteristics: a circular or semicircular periphery; location symmetrical around the apex, as a funnel-shaped extension of the periodontal space; and bony structures discernible within the bony cavity
4. Unsatisfactory healing: rarefaction has enlarged or is unchanged

Clinical Factors Assessed

Factors evaluated included the patient's age (≤45 years or >45 years), sex, tooth type (anterior, premolar, or molar), arch type (maxillary or mandibular), quality of orthograde root filling (satisfactory: 0–2 mm within the radiographic apex without voids on PA and unsatisfactory: short or long or with voids on PAs), coronal restoration (satisfactory both clinically and radiographically or unsatisfactory), post (absent or present), and the use as an abutment.

Statistics

The Cohen kappa statistic was used to test interobserver and intraobserver agreement. For statistical analysis of the prognostic factors, the dependent variable was the dichotomous radiographic outcome (ie, complete and incomplete healing vs uncertain and unsatisfactory healing). Significant associations between the outcome and all the variables were examined using a chi-square test or the Fisher exact test to identify the potential outcome predictors. Multivariate logistic regression analysis was performed to identify factors and evaluate risk on the association between factors and outcomes as estimated by the odds ratio and 95% confidence intervals. The level of significance was set at $\alpha = 0.05$.

Results

Of the 81 patients (98 teeth) enrolled, 59 (74 teeth) returned for the recall appointment 12 to 30 months (mean = 17.2 months) after

Figure 2. Examples of uncertain and unsatisfactory healing. (*A* and *B*) In a case showing uncertain healing, the radiolucency decreased, but the periphery of the radiolucency was semicircular and symmetrically located around the apex in (*B*) the 12-month follow-up radiograph image. The only unsatisfactory healing case is shown in (*C* and *D*) with an enlarged rarefaction (*D*) when recalled 28 months after surgery.

treatment. The recall rate was 72.8% (59/81) for patients and 75.5% (74/98) for teeth. The reasons for 22 dropout patients included the following: 3 patients were pregnant, 8 had relocated and could not be reached, and 11 did not respond for unknown reasons.

Of the 74 teeth that were recalled, 3 teeth had been extracted, 2 for root fracture and 1 for periodontal reasons. In the end, 71 teeth in 56 patients were examined clinically and radiographically at recall. The median age of the patients was 32 years (ranged from 14–57 years), with 34% being male and 66% female.

The interexaminer kappa value was 0.84, and the intraexaminer kappa values were 0.60 and 0.64. Table 1 lists the distribution of the radiographic healing classifications. Of the 74 teeth recalled, 55 (74.3%) were considered to have complete healing (Fig. 1*A–C*) and 12 (16.2%) to have incomplete healing (Fig. 1*D–F*). The percentage of complete and incomplete healing together was 90.5% (67/74). Three teeth were classified as uncertain healing (Fig. 2*A* and *B*), and 1 tooth was classified as unsatisfactory healing (Fig. 2*C* and *D*).

At the recall appointment, 1 tooth was symptomatic with swelling and sinus tract involvement and showed uncertain healing on PA. All of the other teeth were symptom free.

The bivariate analysis for the effects of clinical factors on the radiographic outcome is summarized in Table 2. All factors listed in Table 2 were not associated with significant differences. The multivariate analysis revealed that the use as an abutment had a negative effect on the outcome ($P < .05$; odds ratio = 22; 95% confidence interval, 20.47–23.53).

Discussion

Numerous studies focused on treatment outcome have been published since endodontic surgery was first used clinically more than 100 years ago (19). By reviewing the studies reported from 1968 to 2005, the expected rate of healing (complete or incomplete) ranges from 37%–91% (2). However, in recent decades, with a better understanding of the etiologic factors of periradicular disease and the evolution of techniques and materials used in endodontic surgery, the results of previous studies have become less relevant (20). In 2010 and 2013, meta-analyses on the outcomes of endodontic microsurgery were conducted, and the pooled healing rates were 94% and 89%, respectively (6, 17). In the present study, we observed a combined complete and incomplete healing rate of 90.5% in teeth that received endodontic microsurgery using MTA and a microscopy-guided approach, which is comparable with the reported rate (16, 17, 21).

In the present study, 3 teeth were extracted, 2 for root fracture and 1 for periodontal disease; the 3 teeth were included in the outcome data. Considering the extracted teeth, when analyzing the outcomes of orthograde or retrograde endodontic treatment, the teeth, which were extracted not for strictly endodontic factors, were excluded in some previous studies (22–26). However, other studies suggested that these teeth should be included (27)because it was difficult to figure out the original causes of the failure in the condition that apical surgery was performed in a wide variety of cases (28) and the exclusion of the extracted teeth might lead to overestimation of the outcome.

In most previous clinical studies, both clinical and radiographic findings have been used to determine the treatment outcome (11, 13, 14). Radiographic assessment is essential for determining the outcome of treatment (29) because many teeth, including those with periapical lesions, are asymptomatic at recall (30). In our study, at the recall appointment, only 1 tooth was symptomatic with swelling and sinus tract involvement. In the subsequent analysis of potential prognostic factors, the radiographic outcome was used as the dependent variable.

TABLE 2. Summary of Bivariate Analysis for the Effects of Clinical Factors on Radiographic Outcome of Endodontic Microsurgery

	Radiographic outcome				
Factors	Complete healing (%)	Incomplete healing (%)	Uncertain healing (%)	Unsatisfactory healing (%)	*P* values
Age (years)					.170
≤45	47 (66.2)	10 (14.1)	1 (1.4)	1 (1.4)	
>45	8 (11.3)	2 (2.8)	2 (2.8)	0 (0.0)	
Sex					.588
Male	19 (26.8)	3 (4.2)	1 (1.4)	1 (1.4)	
Female	36 (50.7)	9 (12.7)	2 (2.8)	0 (0.0)	
Tooth type					.268
Anterior	37 (52.1)	11 (15.5)	2 (2.8)	0 (0.0)	
Premolar	11 (15.5)	1 (1.4)	1 (1.4)	1 (1.4)	
Molar	7 (9.9)	0 (0.0)	0 (0.0)	0 (0.0)	
Arch type					.609
Maxilla	39 (54.9)	10 (14.1)	3 (4.2)	1 (1.4)	
Mandible	16 (22.5)	2 (2.8)	0 (0.0)	0 (0.0)	
Quality of orthograde root filling					.375
Satisfactory	21 (29.6)	7 (9.9)	2 (2.8)	0 (0.0)	
Unsatisfactory	34 (47.9)	5 (7.0)	1 (1.4)	1 (1.4)	
Post					.297
With	17 (23.9)	4 (5.6)	2 (2.8)	1 (1.4)	
Without	38 (53.3)	8 (11.3)	1 (1.4)	0 (0.0)	
Use as an abutment					.137
Yes	1 (1.4)	0 (0.0)	1 (1.4)	0 (0.0)	
no	54 (76.1)	12 (16.9)	2 (2.8)	1 (1.4)	
Coronal restoration					.686
Satisfactory	50 (70.4)	12 (16.9)	3 (4.2)	1 (1.4)	
Unsatisfactory	5 (7.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Recall period (months)					.204
≥12, <24	42 (59.2)	12 (16.9)	2 (2.8)	1 (1.4)	
≥24	13 (18.3)	0 (0.0)	1 (1.4)	0 (0.0)	

It is widely accepted that radiographic outcomes can be classified into 4 categories (ie, complete healing, incomplete healing, uncertain healing, and unsatisfactory healing) as defined by Rud et al (5)and Molven et al (18). This classification is based on the correlation between radiographic and histologic findings from 120 teeth (5). These radiographic criteria were used and evaluated in a study by Molven et al (18), and in separate examinations, the intraobserver (endodontist and radiologist) agreement was shown to reach 94% after joint evaluation (18). This high agreement shows that these criteria are reliable for clinical use.

In the present study, at the follow-up visit, there were 2 asymptomatic teeth with uncertain healing that required further monitoring. In some studies, the category of uncertain healing was classified as failure after a 1-year follow-up examination (21, 31). However, other studies suggest that teeth that show uncertain healing on a radiograph with clinical normalcy in a follow-up shorter than 4 years should be further reviewed (2). Rud et al (32)reported the outcome of 1000 teeth for 1 to 15 years. Of the 133 teeth in the uncertain healing group, 65% changed to either complete or incomplete healing, and 12% regressed to unsatisfactory healing. The rationale for including teeth exhibiting uncertain radiographic healing in the failure category after a short follow-up period may contribute to the underestimation of outcomes and lead to overintervention by dentists.

This study examined predictors that may have a significant effect on outcome (14, 20, 31). In the present study, only the use as an abutment was found to have a negative influence on healing after endodontic microsurgery. As postulated by Ante's law, the total periodontal membrane area of the abutment teeth should be equal or exceed that of the missing teeth when the fixed bridge restoration is designed (33). After endodontic surgery, which removes parts of the root, the periodontal membrane area of the root is decreased, which may lead to the abutment being unable to bear the same occlusal forces it was previously able to handle. Therefore, the prognosis of restoration and abutment may be influenced (34).

In conclusion, a predictably high healing rate (complete and incomplete healing) 12 to 30 months after treatment can be achieved using endodontic microsurgery with a microscope and MTA.

Acknowledgments

Zu-Hua Wang and Ming-Ming Zhang contributed equally to this study.

Supported by Beijing Municipal Science and Technology Commission (grant no. Z131107002213045).

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

References

1. Wu MK, Wesselink PR. Timeliness and effectiveness in the surgical management of persistent post-treatment periapical pathosis. Endod Topics 2005;11:25–31.
2. Friedman S. The prognosis and expected outcome of apical surgery. Endod Topics 2005;11:219–62.
3. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. J Endod 2006;32:601–23.
4. Dorn SO, Gartner AH. Surgical endodontic and retrograde procedures. Curr Opin Dent 1991;1:750–3.
5. Rud J, Andreasen JO, Jensen JE. Radiographic criteria for the assessment of healing after endodontic surgery. Int J Oral Surg 1972;1:195–214.
6. Setzer FC, Shah SB, Kohli MR, et al. Outcome of endodontic surgery: a meta-analysis of the literature—part 1: comparison of traditional root-end surgery and endodontic microsurgery. J Endod 2010;36:1757–65.
7. Mikkonen M, Kullaa-Mikkonen A, Kotilainen R. Clinical and radiologic reexamination of apicoectomized teeth. Oral Surg Oral Med Oral Pathol 1983;55:302–6.
8. Jesslén P, Zetterqvist L, Heimdahl A. Long-term results of amalgam versus glass ionomer cement as apical sealant after apicectomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:101–3.
9. Schwartz-Arad D, Yarom N, Lustig JP, Kaffe I. A retrospective radiographic study of root-end surgery with amalgam and intermediate restorative material. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:472–7.
10. Rubinstein RA, Kim S. Short-term observation of the results of endodontic surgery with the use of surgical operation microscope and Super-EBA as root end filling material. J Endod 1999;25:43–8.
11. von Arx T, Frei C, Bornstein MM. Periradicular surgery with and without endoscopy: a prospective clinical comparative study. Schweiz Monatsschr Zahnmed 2003;113:860–5.
12. Taschieri S, Del Fabbro M, Testori T, Weinstein R. Microscope versus endoscope in root-end management: a randomized controlled study. Int J Oral Maxillofac Surg 2008;37:1022–6.
13. Christiansen R, Kirkevang LL, Hørsted-Bindslev P, Wenzel A. Randomized clinical trial of root-end resection followed by root-end filling with mineral trioxide aggregate or smoothing of the orthograde gutta-percha root filling—1-year follow-up. Int Endod J 2009;42:105–14.
14. Song M, Kim SG, Lee SJ, et al. Prognostic factors for clinical outcomes in endodontic microsurgery: a prospective study. J Endod 2013;39:1491–7.
15. Shinbori N, Grama AM, Patel Y, et al. Clinical outcome of endodontic microsurgery that uses EndoSequence BC Root Repair Material as the root-end filling material. J Endod 2015;41:607–12.
16. von Arx T, Hänni S, Jensen SS. Clinical results with two different methods of root end preparation and filling in apical surgery: mineral trioxide aggregate and adhesive resin composite. J Endod 2010;36:1122–9.
17. Tsesis I, Rosen E, Taschieri S, et al. Outcomes of surgical endodontic treatment performed by a modern technique: an updated meta-analysis of the literature. J Endod 2013;39:332–9.
18. Molven O, Halse A, Grung B. Observer strategy and the radiographic classification of healing after endodontic surgery. Int J Oral Maxillofac Surg 1987;16:432–9.
19. Stock C, Walker R, Gulabivala K. *Endodontics*, 3rd ed. St Louis, MO: Mosby Elsevier; 2004.
20. Villa-Machado PA, Botero-Ramírez X, Tobón-Arroyave SI. Retrospective follow-up assessment of prognostic variables associated with the outcome of periradicular surgery. Int Endod J 2013;46:1063–76.
21. Song M, Kim E. A prospective randomized controlled study of mineral trioxide aggregate and super ethoxy-benzoic acid as root-end filling materials in endodontic microsurgery. J Endod 2012;38:875–9.
22. Friedman S, Abitbol S, Lawrence HP. Treatment outcome in endodontics: the Toronto Study. Phase 1: initial treatment. J Endod 2003;29:787–93.
23. Sjögren U, Hägglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990;16:498–504.
24. Liang YH, Jiang LM, Jiang L, et al. Radiographic healing after a root canal treatment performed in single-rooted teeth with and without ultrasonic activation of the irrigant: a randomized controlled trial. J Endod 2013;39:1218–25.
25. Wang N, Knight K, Dao T, Friedman S. Treatment outcome in endodontics: the Toronto Study—phases I and II: apical surgery. J Endod 2004;30:751–61.
26. Barone C, Dao TT, Basrani BB, et al. Treatment outcome in endodontics: the Toronto study—phases 3, 4, and 5: apical surgery. J Endod 2010;36:28–35.
27. Kim S, Jung H, Kim S, et al. The influence of an isthmus on the outcomes of surgically treated molars: a retrospective study. J Endod 2016;42:1029–34.
28. Rubinstein RA, Kim S. Long-term follow-up of cases considered healed one year after apical microsurgery. J Endod 2002;28:378–83.
29. Ng YL, Mann V, Rahbaran S, et al. Outcome of primary root canal treatment: systematic review of the literature – part 1. Effects of study characteristics on probability of success. Int Endod J 2007;40:921–39.
30. Wu MK, Shemesh H, Wesselink PR. Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. Int Endod J 2009;42:656–66.
31. Song M, Jung IY, Lee SJ, et al. Prognostic factors for clinical outcomes in endodontic microsurgery: a retrospective study. J Endod 2011;37:927–33.
32. Rud J, Andreasen JO, Jensen JE. A follow-up study of 1,000 cases treated by endodontic surgery. Int J Oral Surg 1972;1:215–28.
33. Ante IH. The fundamental principles of abutments. Mich State Dent Soc Bull 1926;8:14–23.
34. Fayyad MA, Al-Rafee MA. Failure of dental bridges. IV. Effect of supporting periodontal ligament. J Oral Rehabil 1997;24:401–3.