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Periapical Microsurgery: The effect of root dentinal defects on short and long term outcome

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Abstract

Introduction—The purpose of this prospective clinical study is to evaluate the clinical outcome of endodontic microsurgery on roots exhibiting the presence or absence of dentinal defects at one year and three-year follow up period.

Methods—155 teeth were treated with periapical microsurgery using a modern microsurgical protocol in a private practice setting. The root apices were resected and inspected for dentinal defects with a Surgical Operating Microscope and a 0.8mm head diameter LED microscope diagnostic probe light. After inspection, retrograde preparations were performed using ultrasonic tips and retrograde fillings were placed. Follow up visits occurred at one year and three years post-operatively. The primary outcome measure employed was the change in the radiographic apical bone density and the secondary outcome measure used was the absence of clinical symptoms.

Results—Out of the 155 treated teeth, a total of 134 teeth were assessed at the one-year follow-up and 127 teeth at the three-year evaluation. The “Intact” group had 94.8% healed at one year and 97.3% healed at three years. The “Dentinal Defect” group had 29.8% healed at one year and 31.5% healed at three years. The baseline root condition of either “Dentinal Defect” or “Intact” showed a statistical difference in the healing outcome at both one year and at three years.

Conclusions—This prospective periapical microsurgery study showed a significant superior clinical outcome for intact roots when compared to roots with dentinal defects at both 1 year and at 3 years post-operatively.

Keywords

Apicoectomy; Endodontic microsurgery; Craze line; dentinal defect; Outcome

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Introduction

Periradicular surgery is an important treatment option in modern endodontic practices (1). Current surgical endodontic protocols (2) used in conjunction with contemporary retrofilling materials have shown excellent success rates (3–5). Despite this, some teeth still fail to heal and the exact cause for these failures has not been established.

Recent endodontic literature has suggested that dentinal defects (also referred to as micro-cracks or craze lines) on the root canal walls are more likely to appear after root canal shaping and obturation (6–9). Furthermore, contemporary rotary instruments have been shown to cause more dentinal defects compared to hand instruments (10). The clinical significance of dentinal defects identified on the resected root surface following root-end resection remains unclear (11). It has been speculated that radicular dentinal defects may propagate during normal function and in this way result in potential pathways for leakage or in root fractures (12–14). The clinical significance of dentinal defects has been so far speculative, but they may be of increased concern if there are residual bacteria present, or if coronal leakage occurs with subsequent bacterial colonization (15).

The effect of these dentinal defects has never been clinically investigated in periapical microsurgery and remains a problem for clinical diagnosis and management. Therefore, the purpose of the present clinical prospective study is to evaluate the post-surgical periapical healing response of roots with dentinal defects when compared to intact roots with no sign of dentinal defects at one year and three year follow up time points

Material and Methods

Case Selection

The study subjects were regular patients in need of periapical microsurgery in an endodontic private practice setting who were enrolled consecutively between 2009 and 2010. Patients were informed in detail about the surgical procedure and were instructed about postoperative care, follow-up examinations and alternative treatment options available to them. Informed written signed consent was acquired from all participants according to the Declaration of Helsinki and exempt status was approved by the Institutional Review Board Office of Human Research Ethics at the University of North Carolina at Chapel Hill.

Radiographs of all teeth were made (Gendex GX 770, Gendex Dental Systems, Lake Zurich, IL) using a digital sensor (Visualix eHD, Gendex Dental Systems, Lake Zurich, IL) and paralleling devices (Dentsply Rinn, Elgin, IL). A straight periapical radiograph was taken along with a second 20-degree distal-angled view. All root-filled cases diagnosed with symptomatic or asymptomatic apical periodontitis as defined by the AAE Consensus Conference Recommended Diagnostic Terminology (16) were included. Teeth with severe periodontal mobility (class II or greater), furcation involvement, localized probing defects greater than 5mm and any form of perforations were excluded from the study.

Surgical phase

With the exception of suturing, all microsurgical procedures were performed using a Surgical Operating Microscope (Global G6 Microscope, Global Surgical Corporation, St. Louis, MO) using modern microsurgical techniques (17,18).

After deep anesthesia, a full thickness periosteal flap was reflected and a bony window was prepared (2,18). Granulation tissue when present was carefully curetted from the periapical region of each root. Racellet epinephrine pellets (Pascal Co., Bellevue, WA) were applied with pressure in the bony crypt for five minutes to obtain hemostasis (19). 3mm of the root ends were resected as perpendicular as possible to the long axis of the root (20). Following resection, the root tips were smoothed and polished with a carbide Endo Z bur (Brassler USA, Savannah, GA). Finally, an application of methylene blue stain confirmed the completed root resection indicated by the 360-degree presence of PDL surrounding the root. The root inspection was done directly with a Surgical Operating Microscope (Global G6 Microscope, Global Surgical Corporation, St. Louis, MO) and a HD Micro Surgical Mirrors (JEDMED, St Louis, MO). Transillumination of the root tip was also done to help with the examination process using a 0.8mm head diameter LED microscope diagnostic probe light (Q-optics Quality Aspirators, Duncanville, TX) [Figure 1]. Retrograde preparations of 3mm depth were then prepared using ProUltra surgical ultrasonic tips (Dentsply Maillefer, Johnson City, TN) and powered by a Satelec P5 ultrasonic unit (Dentsply Maillefer, Johnson City, TN) at a medium power setting. The retro-cavities were rinsed, dried with the Stropko-irrigator (SybronEndo Corporation, Orange, CA) and prepared for a final visual inspection using the Surgical Operating Microscope (Global G6 Microscope, Global Surgical Corporation, St. Louis, MO) and a HD Micro Surgical Mirror (JEDMED, St Louis, MO). Transillumination of the root tip was also done to optimize this final visual examination using a 0.8mm head diameter LED microscope diagnostic probe light (Q-optics Quality Aspirators, Duncanville, TX) that was placed directly into and around the retrograde preparation [Figure 1]

To avoid confusing definitions such as micro-fractures, micro-cracks, incomplete cracks and craze lines, two distinct categories were defined by Shemesh et al (7). “Intact” was defined as root dentin on the resected root end devoid of any lines or cracks either on the external surface of the root or within the internal root canal wall. This “Intact” group served as the control group. “Dentinal Defects” were defined as all lines that appeared to disrupt the integrity of the dentin on the root end surface that extended either from the external root surface onto the resected dentin surface or from within the root canal lumen onto the resected root surface (7). None of the dentin defects so defined in this study exhibited either staining from methylene blue or resulted in a tactile catch when an explorer tine was passed across the defect in question.

After the inspection was completed and documented, the retro-preparations were filled with a modern retro-filling material. Gray ProRoot MTA (Dentsply Maillefer, Johnson City, TN) was used by the first endodontist and SuperEBA (Bosworth, Skokie, IL) was used by the second endodontist; several studies have shown similar outcomes when these two materials are used in periapical microsurgery (21,22)

After the wound area had been debrided and irrigated, the reflected soft tissues were repositioned and primary wound closure was accomplished with interrupted 5.0 Chromic Gut sutures (Hu-Friedy Manufacturing Company, Inc). The patients were followed up at 5–7 days post-operatively for a check-up and suture removal.

Radiographic and Clinical Evaluation

The patients were followed up at one year and at three years to assess both radiographic and clinical signs of healing (23). At every follow-up visit, a routine radiographic and clinical examination was performed.

The primary radiographic findings, established by viewing two angles (straight-on and a 20° distal-angled view), were assessed independently by two examiners using a similar but simplified set of criteria based on the work of Rud et al (24) and Molven et al (25–27). Incomplete Healing (also known as scar tissue healing), Uncertain Healing and Unsatisfactory Healing were all grouped into a single “Not Healed” group. Consequently, the simplified classification used in this study was as follows:

1. **Healed:** Complete healing of the periapical radiolucency with re-establishment of the lamina dura.
2. **Not Healed:** Increase, no apparent changes, reduction or incomplete resolution of the periapical radiolucency size without re-establishment of the lamina dura.

The two examiners standardized the evaluation criteria before healing was evaluated. Prior to evaluation of the images, each examiner graded a series of twenty radiographic images not related to the study sample. Cases where disagreement occurred were reassessed jointly and if agreement was still not obtained, further evaluation and classification was conducted by a third standardized and blinded evaluator.

The secondary clinically related outcome measures were the presence of clinical symptoms or abnormal findings at one year and again at three years. Any tooth that showed abnormal findings such as swelling, sinus tract, pain, tenderness to percussion, tenderness to palpation, mobility or periodontal pocket formation was classified in the “Not Healed” group. Furthermore, any cases that required treatment after the one-year follow-up visit were included in the study and were considered as “Not Healed” at the three-year follow-up visit. The two examiners standardized their evaluation criteria prior to evaluating outcomes so that their results were based on the same examination methodology. Disagreement regarding any possible clinical outcome was resolved by discussion until an agreement between the two examiners was reached. If any doubt persisted, the tooth was classified in the “Not Healed” group.

Final Assessment of Outcome

Each final outcome category consisted of a combination of both radiographic and clinical findings and they were classified as follows:

1. **Healed:** Included the absence of clinical signs and symptoms with radiographic evidence of complete radiographic healing (re-establishment of the lamina dura).

2. **Not Healed:** The criteria for unsuccessful outcome included any abnormal clinical signs and/or radiographic evidence (Increase, no apparent changes, reduction or incomplete resolution of the periapical radiolucency size without re-establishment of the lamina dura).

Statistical Methods

Descriptive statistics were generated to characterize follow-up time and proportions of subjects who did not return for follow-up evaluation for both follow-up periods. Contingency table methods were used to test associations between baseline root conditions and states of healing using fisher's exact tests. Risk differences and exact 95% confidence limits were estimated to evaluate differences in proportions between baseline root conditions and probability of being "not healed" at each period of follow-up. Unconditional multivariate logistic regression was used to evaluate possible confounding effects of tooth location, filler type, patient age, and patient sex on the association between baseline root condition and healing status. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC). The *a priori* type I error rate for all statistical tests was set at alpha = 0.05.

Results

The study included 155 treated teeth with endodontic microsurgery. The distribution of the included cases is shown in Table 1.

Table 2 provides the overall median follow-up time of the 155 treated teeth for the one-year and three year follow-up periods, which were 13.1 and 35.7 months, respectively. For both periods of follow-up, the median follow-up time did not differ by baseline root condition. The proportion of study participants who did not show-up for each follow-up period increased from 10.3% at the one-year follow-up period to 14.8% at three-year follow-up.

The Graph Columns (Figure 2) shows the healing at one year and three years of both groups. At one year the Dentinal Defect group had a success of 29.8% (17/57) and the Intact group had a success of 94.8% (73/77). At three years the Dentinal Defect group had a success of 31.5% (17/54) and the Intact group had a success of 97.3% (71/73)

Table 3 summarizes the states of healing for baseline root condition by follow-up period and provides proportions and statistical tests of significance not presented in figure 1. At the one-year follow-up period, the percentage of "not healed" for the dentinal defect baseline root condition was statistically significantly different from the same percentage among teeth with an intact baseline root condition ($p=3.8 \times 10^{-16}$). Further, the probability of being "not healed" at the one-year follow-up period for teeth with a dentinal defect was 0.65 [95% CI: 0.50–0.77] greater than teeth that were intact at baseline. For the three-year follow-up period, the differences in percentage of teeth classified as "not healed" between teeth with dentinal defects at baseline versus those that were intact was also highly statistically significant ($p=1.6 \times 10^{-16}$). In agreement with this statistically significant difference, teeth with dentinal defects had a 0.66 [0.50–0.78] greater probability of being classified as "not healed" compared to intact roots at the final follow-up period.

Table 4 shows that among the 40 teeth with dentinal defects classified as “not healed” at the one year follow-up period, 31 remained “not healed”, 6 teeth “healed”, and three did not present for re-evaluation. For the four intact teeth that were classified as “not healed” at the one-year follow-up visit, all four of these teeth were deemed as “healed” at the final follow-up period. These general trends were statistically significant by the extended fisher’s exact test ($p=2.8 \times 10^{-3}$). Among the 17 teeth classified as “healed” at the one-year follow-up visit, 11 teeth remained “healed” and 6 were determined to be “not healed”. For the intact teeth, two teeth were determined to be not healed, four teeth were lost to follow-up, and the remaining 67 teeth were still classified as “healed” at the final follow-up period. These general associations at the three-year follow-up period were also statistically significant by the extended fisher’s exact test ($p=8.1 \times 10^{-4}$).

Table 5 shows the logistic regression model assessing the clinical outcome predictors evaluated in this study, the presence of dentinal defect significantly influenced the clinical outcome of periapical microsurgery at three-year follow-up. The same results were observed at one year.

Discussion

The purpose of the present study was to evaluate the post-surgical periapical healing response of roots with dentinal defects when compared to intact roots with no sign of dentinal defects after a one year and a three year follow up period in a clinical prospective study. Our results showed a significantly superior healing outcome for intact roots when compared to roots with dentinal defects at both short and long term follow-up.

In the present study, all data was interpreted using strict healing criteria to minimize the risk of over-estimating healing outcomes. Cases classified under uncertain or incomplete healing categories in previous studies (23–25) were all classified as “not healed” in this study. Teeth with dentinal defects that were “not healed” one year postoperatively tended to result in definite failure at the three-year follow-up visit. Furthermore, in the dentinal defect group, teeth with lesions that appeared to be decreasing in size and responding normally to clinical testing after one year tended to present with larger radiographic lesions and/or exhibit clinical symptoms at the three-year follow-up evaluation. The delayed failure phenomenon described by multiple studies may be a result of dentinal defects, which adversely affected the post-surgical healing dynamics in the longer term (30–32). In agreement with these research findings, Gutmann and colleagues have previously recommended that cases showing incomplete healing one year post-surgery should be followed up at regular intervals because of the increased risk of late failure in these teeth (32*).* The intact group showed predictable healing patterns in both the short and long term. It is worth noting that the intact teeth classified as “not healed” consisted of two upper lateral incisors. It is possible that the lack of radiographic healing in these two isolated cases could be due to scar tissue formation rather than because of a persistent pathologic process (33). Both of these cases had lesions that decreased in size over time and responded within normal limits to routine clinical testing at follow-up appointments (33). Nevertheless, given the strict evaluation criteria used in this study, these two cases were assigned to the “not healed” group.

When we consider apical microsurgery, we see a fall in success rates with the passage of time. Von Arx and colleagues (30) demonstrated that at 5 years, the healing rate of apical microsurgery cases was almost 10% lower than at one year post-operatively. This study showed that the integrity of apical root dentin could play a role in longer-term clinical outcomes. From a biological standpoint, it has been speculated that radicular dentinal defects may enlarge during function (12–15). This can potentially result in a pathway for residual bacteria to survive, multiply and eventually result in the delayed failure phenomenon that has been described in several studies (30–32).

We believe that this is the first apical microsurgical study to incorporate the use of transillumination to determine the integrity of root apices. We used a 0.8mm head diameter LED diagnostic probe light (Q-optics Quality Aspirators, Duncanville, TX) to provide the transillumination. The authors strongly recommend that this tool be routinely incorporated into endodontic microsurgical protocols.

This paper uses the term “dentinal defects” as described by Shemesh (7) to describe any break in the continuity of the dentin surface. Although craze lines and cracks are terms frequently used in the literature, there is no consensus as to which term should be applied to any particular set of clinical circumstances. Hüseyin (28) showed that all the retreatment techniques he used created defects in the root dentin. More significantly, perhaps, is whether such physical damage to roots results in poorer healing outcomes for retreatment cases due to a possible breach in the apical seal (29).

The clinical significance of dentinal defects has been so far speculative, but the results of this study suggest that the presence of dentinal defects directly affected the outcome in microsurgery. The other questions that we will have to answer are: 1) when dentinal defects are seen, would a higher resection of the root past the location of the dentinal defect be possible; and 2) would that improve the outcome?

Predictable treatment is one of the key objectives in dentistry. If efforts to conserve teeth through apical microsurgery can be focused on teeth with structurally intact root apices and to develop a strategy to better address dentinal defects, these approaches may have far-reaching consequences regarding the predictability of endodontic microsurgery in the years ahead.

Conclusion

This prospective clinical study of endodontic periapical microsurgery showed a statistically significant clinical outcome for intact roots when compared to roots with dentinal defects on short and long-term follow-up. The fact that dentinal defects decrease significantly the outcome of the teeth in question is very valuable to clinicians and patients in overall treatment planning; therefore, we encourage clinicians in incorporating the use of transillumination with a microscopic LED light to systematically determine the integrity of root apices during periapical microsurgeries.

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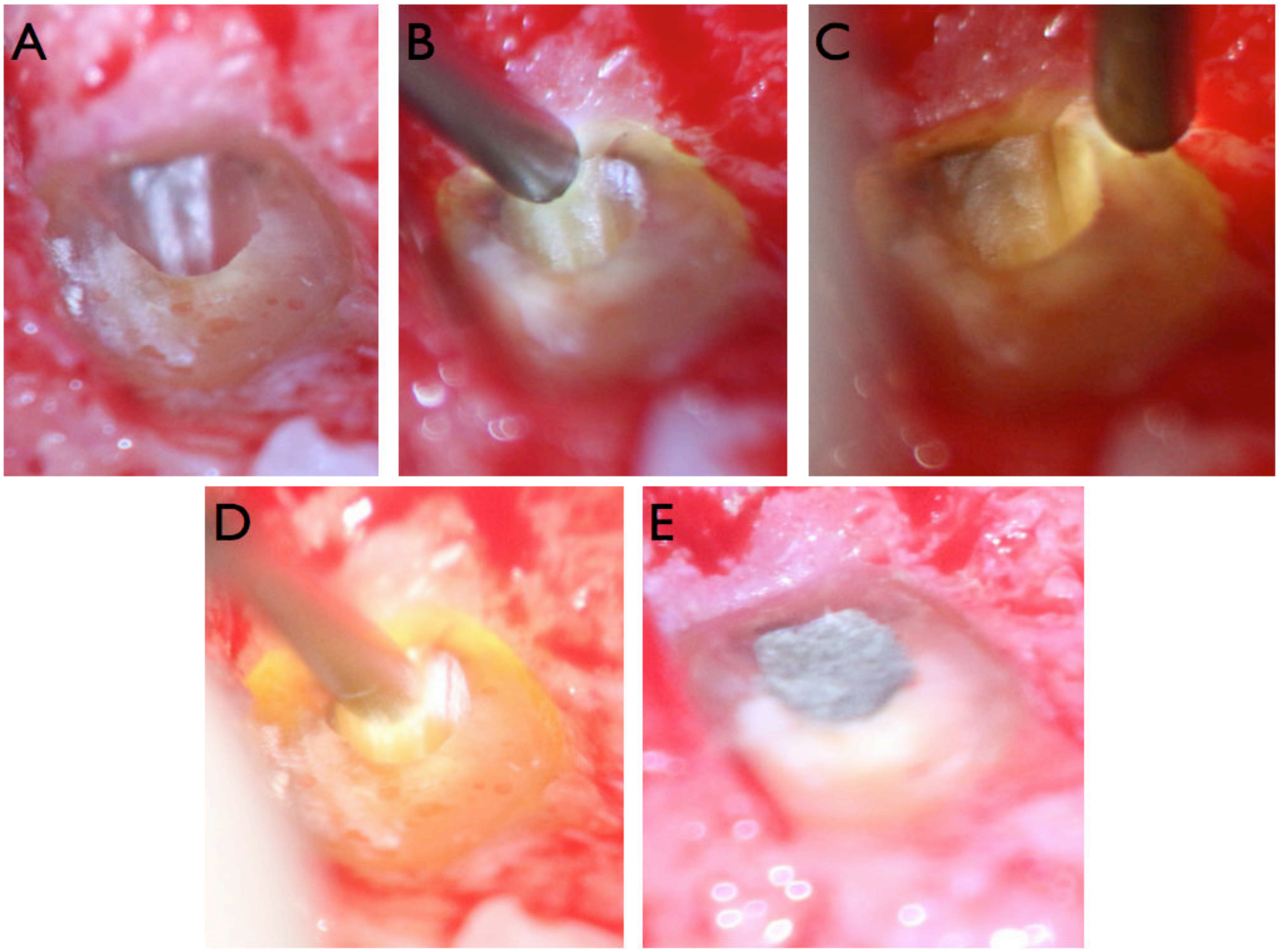

Figure 1.
(A) Root tip seen through the microscope. (B), (C) Transillumination with 0.8mm head diameter LED microscope diagnostic probe light around the external surface of the resected root tip revealing a dentinal defect. (D) Transillumination with 0.8mm head diameter LED microscope diagnostic probe light inside the retrograde cavity revealing a dentinal defect. (E) MTA retrofilling seen through the microscope.

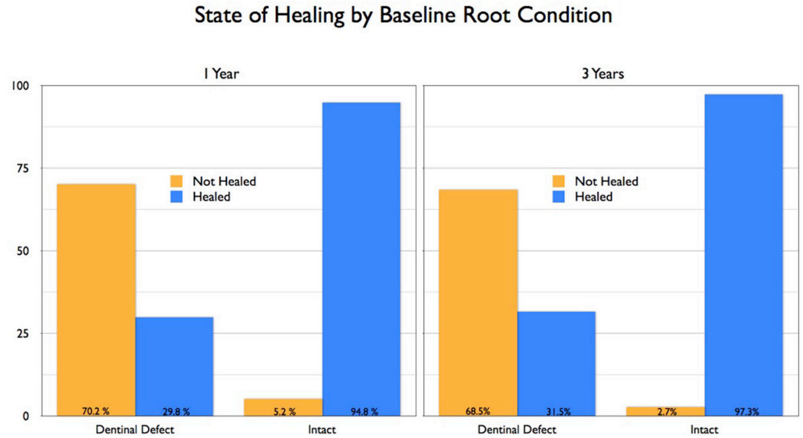

Figure 2.
Column graph showing the state of healing of both groups (Dentinal Defect and Intact) at the one year period and three years follow-up periods

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Table 1

Case Distribution

Variables	Number of Teeth	Intact	Dentinal Defect	Fracture
Tooth Type				
Anterior	64	41	22	1
Posterior	91	46	41	4
Sex				
Male	67	37	27	3
Female	88	50	36	2
Age				
<40	95	56	36	3
>40	60	31	27	2
Root-filling material				
MTA	84	51	30	3
Super-EBA	71	36	33	2

Table 2

Median follow-up time and no-show proportion by follow-up period

	1-yr Follow-up		3-yr Follow-up	
	Follow-up in months	**Discontinuers**	**Follow-up in months**	**Discontinuers**
Baseline root condition	**Median[range]**	**N[%]**	**Median[Range]**	**N[%]**
Dentinal defect	12.4[1.0–20.1]	6[9.5]	32.4[8.1–46.3]	9[14.3]
Intact	13.8[6.2–22.4]	10[11.5]	35.9[15.4–46.2]	14[16.1]
Overall	13.1[1.0–22.4]	16[10.3]	35.7[8.1–46.3]	23[14.8]

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Table 3

Summary of State of Healing for baseline root condition by follow-up period

Baseline root condition	**N[%]**		**N**		
1-yr Follow-up	Not healed	Healed	Totals	P-value	Risk difference [95% CI]
Dentinal defect	40[70.2]	17[29.8]	57	3.8×10^{-16}	0.65 [0.50–0.77]
Intact	4[5.2]	73[94.8]	77		
Totals	44	90	134		
3-yr Follow-up	Not healed	Healed	Totals	P-value	Risk difference [95% CI]
Dentinal defect	37[68.5]	17[31.5]	54	1.6×10^{-16}	0.66 [0.51–0.78]
Intact	2[2.7]	71[97.3]	73		
Totals	39	88	127		

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Table 4

State of healing at 2nd follow-up period conditional on state of healing at 1st follow-up period

Baseline root condition	State of healing at 3-yr Follow-up N[%]			N	
"Not healed" at 1-yr Follow-up	Not healed	Healed	No show	Totals	P-value
Dentinal Defect	31[77.5]	6[15.0]	3[7.5]	40	2.8×10^{-3}
Intact	0[0.0]	4[100.0]	0[0.0]	4	
Totals	31	10	3	44	
"Healed" at 1-yr Follow-up	Not healed	Healed	No show	Totals	P-value
Dentinal Defect	6[35.3]	11[64.7]	0[0.0]	17	8.1×10^{-4}
Intact	2[2.7]	67[91.8]	4[5.5]	73	
Totals	8	78	4	90	

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Table 5

Logistic regression model assessing the predictors of clinical outcomes in apical microsurgery among patients enrolled in this study at 3-year follow-up[§]

Risk factors	Odds ratio (95% CI)
Sex	
Male (ref)	1.00
Female	0.77 (0.26 – 2.34)
Age	
≥40 years (ref)	1.00
< 40 years	1.26 (0.41 – 3.93)
Location	
Anterior teeth (ref)	1.00
Posterior teeth	1.08 (0.35 – 3.34)
Dentinal defect	
No (Intact) (ref)	**1.00**
Yes*[*]	**0.01 (0.00 – 0.06)**
Retrofilling material	
Super EBA (ref)	1.00
MTA	1.30 (0.44 – 3.89)

[§]N=127

[*]Statistically significant (*P*<0.0001)