Jap. J. of Cons. Dent. 25(3):658–666,1982

Effects of Root Filling Extent and Periapical Status on Endodontic Treatment Outcomes

Kazutoshi Kojima
Second Department of Conservative Dentistry, Faculty of Dentistry, Kyushu University
(Director: Prof. Hisashi Nagasawa)
(Received for Publication: July 19, 1982)

In this follow-up study of 161 endodontically treated teeth (202 roots), the effects of root filling extent and preoperative periapical status on outcomes after 2–4 years were evaluated. Radiographic assessment was performed using a bisecting angle technique with orthoradial and eccentric projection for each tooth. The overall success rate was 95% (192/202 roots). Log-linear model fitting revealed that a conditional independence model best described the data; there were interactions between both root filling extent and periapical status with the outcomes after 2–4 years. An increased probability of success was associated with adequate root filling, as well as a radiographically normal appearance and widening of the apical periodontal ligament space at baseline. Overfilling and the presence of periapical rarefaction were associated with reduced probability of success.

INTRODUCTION

Many clinical factors affect outcomes after root canal treatment; the extent of root filling and the status of periapical tissue are the most critical of these, as reported previously.[1–7] The extent of root filling is indicative of treatment accuracy, while conversely, the extent of periapical tissue destruction is an important indicator of the correct treatment choice. Indeed, when large radiolucent areas are found at the apex, apical curettage or apicoectomy may be indicated depending on the sizes and shapes of these areas.

Increased conformity between root filling and root apex, as well as reduced periapical tissue destruction, are important in improving outcomes. However, there is an argument that underfilling of root canals is better than overfilling; conversely, overfilling is regarded as an ideal approach, in cases involving radiolucency.[8] This may be attributed to differences in the interpretation of dental X-ray images as well as in criteria used to define treatment outcomes.

In the present study, eccentric projections were combined with conventional orthoradial X-ray projections among subjects who previously underwent root canal treatment, and the root filling extent and periapical status of each root were evaluated in detail.

METHODS

The outcomes of root canal therapy were examined in a small cohort of patients treated by the same dentist (KK). The original therapy followed conventional procedures, with enlargement and preparation of the root canal, followed by the application of a disinfectant

drug (tricresol formalin). The root canal was confirmed to be clean and free of both exudate and putrid odor; then, root filling was performed using a lateral condensation technique with gutta-percha point and a sealant (zinc oxide eugenol cement).

Follow-up clinical and X-ray examinations were performed approximately 2–4 years later to assess treatment outcomes. Dental X-rays were taken in both an eccentric projection and a conventional orthoradial projection by using the bisecting angle technique; this allowed the tooth root and periapical area to be clearly distinguished. Specifically, orthoradial and distoeccentric projections were applied to single- and double-rooted teeth (i.e., maxillary first premolars), whereas orthoradial, distoeccentric, and mesioeccentric projections were applied to multirooted teeth (i.e., mandibular and maxillary molars). Orthoradial and eccentric projection films were simultaneously placed on a viewer with a color temperature of 5000 K per tooth to assess and record the root filling extent (overfilling, adequate filling, or underfilling) and the apical periodontal status for each root (Fig. 1 A–C).

The straight distance from the apex to the tip of the gutta-percha was measured on the orthoradial projection radiograph taken at follow-up to assess the extent of the root fillings. Underfilling was defined as a distance of at least 1.6 mm to the crown side, adequate filling as a distance of 0–1.5 mm, and overfilling as the presence of proptosis from the apical foramen. In addition, the periapical statuses of each root immediately after therapy and at follow-up were classified into four groups: normal (constant width of the periodontal ligament space, nearly identical to that of the lateral root/healthy adjacent teeth); widening of the periodontal ligament space (enlarged periodontal space to ≤1 mm); small radiolucent findings (radiolucency of the apex with a maximum diameter of ≤4 mm); and large radiolucent findings (radiolucency with a maximum diameter of >4 mm).

The treatment outcome was the radiological classification at the time of follow-up examination. When calculating the treatment success rate, both normal and widened periodontal ligament spaces were regarded as good outcomes (Fig. 2 A–E).

Statistical analysis

For all statistical analyses, program package BMDP/P3F (Kyushu University Data Processing Center)[11] was used. The extent of root filling and the periapical statuses immediately after treatment and at follow-up were recorded, counted for each root, and placed in a contingency table. A log-linear model[9] was then used to obtain a saturation model, based on the following formula:

$$\log_e F_{ijk} = \mu + \lambda_i^F + \lambda_j^X + \lambda_K^S + \lambda_{ij}^{FX} + \lambda_{jk}^{XS} + \lambda_{ik}^{FS} + \lambda_{ijk}^{FXS}$$

where F_{ijk} is the frequency of each cell in the contingency table; μ is the overall average;

$\lambda_{i,}^{F}, \lambda_{j}^{X}, \lambda_{K}^{S}$ are the main effects; $\lambda_{ij}^{FX}, \lambda_{jk}^{XS}, \lambda_{ik}^{FS}$ is the primary interactive effects; and λ_{ijk}^{FXS} are the secondary interactive effects. The indices F, X, and S indicate the overfilling, adequate, and underfilling statuses, respectively (at either the time of root canal filling or follow-up).

For each parameter (λ), the numerical values, significance, model fitness, and residue for deviations from the model were examined, if they decreased in the hierarchical model.[10] During this process, the effect of periapical status at the time of treatment on the interaction between root filling extent and treatment outcomes (radiographic findings at follow-up) was studied.

RESULTS

Data were used for 39 patients (13 males and 26 females), including 202 roots from 161 teeth (68 anterior teeth, 57 premolar teeth, and 36 molar teeth), who underwent root canal treatment at Kyushu University Dental Hospital. The average number of treatment sessions was 2.7 per tooth root, and the average follow-up was 3 years 2 months (standard deviation, 1 year 4 months). Two patients with radiolucency at the apex on follow-up X-rays complained of uncomfortable sensations or dull pain near the affected root. No other patients exhibited subjective or objective symptoms.

Table 1: Root filling extent, periapical status, and radiographs at the time of follow-up re-examination
(numerical values indicate numbers of root canal cases)

Radiograph at filling	Root filling extent	Radiograph at re-examination			
		Normal	Widening	Small	Large
Normal	Under	34	5	1	0
	Adequate	60	11	1	0
	Over	2	0	1	2
Widening	Under	9	7	0	0
	Adequate	24	13	0	1
	Over	5	5	0	0
Small	Under	0	1	0	0
	Adequate	5	1	1	0
	Over	1	0	3	0
Large	Under	1	1	0	0
	Adequate	1	3	0	0
	Over	1	2	0	0
Total		143	49	7	3

Table 1 summarizes the results: 59 roots were underfilled, 121 were adequately filled, and 22 were overfilled. Concerning widening of the periodontal ligament space, 117 roots were normal, 64 were widened, and 21 exhibited radiolucency. Based on these findings, the proportion of

roots with favorable outcomes was 95% (192/202).

The model that most concisely expressed the content was the conditional independence model. This included the primary interaction between filling extent and radiological findings at follow-up examination, as well as that between radiological findings during treatment and radiological findings at the time of follow-up examination. The formula was as follows:

$$\log_e F_{ijk} = \mu + \lambda^F + \lambda^X + \lambda^S + \lambda^{FS} + \lambda^{XS}$$

(degree of freedom = 24, likelihood ratio statistic χ^2_{ML} = 22.57, P = 0.54: χ^2 = 22.87, P = 0.53). Based on the parameter values (λ) estimated for this model, there was a positive association between adequate root filling and normal radiological findings at the time of follow-up examination (λ^{FS}/σ = 2.9, P < 0.05), as well as between overfilling and small radiolucent findings (λ^{FS}/σ = 2.0, P < 0.05). However, overfilling was negatively associated with normal radiological findings (λ^{FS}/σ = −4.1, P < 0.01) (Table 2).

Table 2: Standardized parameter values of the primary interaction between root filling extent and radiographs at re-examination (treatment outcome)

Root filling extent	Radiograph at re-examination			
	Normal	Widening	Small	Large
Under	1.714	0.416	-0.581	-0.593
Adequate	2.876	1.051	-1.278	-0.918
Over	-4.089	-1.337	2.043	1.660
Red: significant association				

Among the primary interaction parameters between the radiological findings from baseline to follow-up, there were positive associations between normal findings at baseline and follow-up, widening of the space at baseline and follow-up, and small radiolucent findings at baseline and follow-up (λ^{xS}/σ = <3.7, 2.2, 2.8, respectively; P < 0.05). However, there was a negative association between the large radiolucent findings at baseline and

Table 3: Standardized parameter values of the primary interaction between periapical status and radiographs at re-examination (treatment outcome)

Radiograph at root filling	Radiograph at re-examination			
	Normal	Widening	Small	Large
Normal	3.755	-1.077	-0.757	-0.679
Widening	1.583	2.198	-1.731	-0.293
Small	-1.592	-1.789	2.813	0.144
Large	-2.042	0.986	0.147	0.619
Red: significant association				

normal radiological findings at follow-up ($\lambda^{xS}/\sigma = -2.0$, $P < 0.05$) (Table 3).

Finally, the differences between the adapted model and the observed values were compared using the standardized residual [i.e., (observed value − expected value)/$\sqrt{\text{expected value}}$]. Only one value was significantly greater than the 5% normal deviation. This was seen for overfilled teeth with roots that had large radiolucent areas at the apex; these teeth showed normal radiological findings at the time of follow-up examination (Table 4).

Table 4: Values of standardized residual showing differences between adapted conditional independence model and observation values

Radiograph at filling	Root filling extent	Radiograph at re-examination			
		Normal	Widening	Small	Large
Normal	Under	0.802	0.181	0.453	-0.315
	Adequate	0.038	0.633	0.098	-0.617
	Over	-1.751	-1.398	-0.400	0.757
Widening	Under	-0.772	-0.075	0.261	-0.075
	Adequate	0.022	-0.251	0.057	0.730
	Over	1.513	0.559	-0.231	-0.580
Small	Under	-1.193	0.477	-0.683	0.289
	Adequate	0.404	-0.296	-0.184	0.000
	Over	1.272	-0.096	0.604	-0.204
Large	Under	0.094	-0.462	0.261	0.289
	Adequate	-0.767	-0.292	0.057	0.000
	Over	2.026	1.149	-0.231	-0.204

Red: significantly greater than 5% normal deviation

DISCUSSION

The outcomes of root canal therapy are primarily determined by the presence or absence of clinical symptoms and radiographic findings. Radiographs provide an objective measure and yield extensive information; notably, correct interpretation of radiographs is critical in determining success or failure. However, radiographs are limited in that they are two-dimensional planar images that may not accurately represent the root and periapical statuses. With regard to double-rooted and multirooted teeth, overlapping of the root images may occur, such that the roots are difficult to distinguish. To compensate for this inability and to acquire a three-dimensional view of the apex, mesioeccentric projection with or without

distoeccentric projection, coupled with conventional orthoradial projection, were used in the present study. By comparing and observing these radiographs, the statuses of the teeth roots and their surrounding tissues could be determined in greater detail.

According to Kerekes and Rowe (1982),[12] whereas the acquisition of radiographs from various angles can result in reliable evaluation of root filling, radiographs acquired solely from the buccolingual direction can result in over-evaluation. This problem can be resolved by the acquisition of simultaneous radiographs in distoeccentric projection, with or without mesioeccentric projection.

The occurrence of distortion may be increased in radiographs taken in eccentric projection, compared with those taken in orthoradial projection; thus, root filling extent at follow-up was assessed using radiographs taken in orthoradial projection in this study. According to Kawaguchi and Yonezawa (1976),[13] the use of radiographs in orthoradial projection and 20° mesioeccentric or distoeccentric projection showed no significant differences in root filling extent between images. Similarly, in the present study, there was no difference in the extent of filling observed between orthoradial and eccentric images. In contrast, there was a difference between orthoradial and eccentric radiographs with regard to the assessment of periapical status. Indeed, if one image showed that the periodontal ligament space was normal, the other image often showed a widening of that space; the reverse relationship was also observed. In such cases, the recorded outcome was widening of the periodontal space.

When analyzing clinical findings and treatment outcomes, multivariate analyses are typically used to clarify relationships between factors that influence each other. To process classification data, such as treatment-related factors and treatment outcomes, multiple regression or discriminant analysis can be used.[7] Log-linear modeling can reveal interactions between variables that cannot otherwise be evaluated directly by multiple regression or discriminant analysis methods, which is useful when analyzing contingency tables. Mackowiak et al. (1980)[14] applied this log-linear modeling approach to the analysis of cases of bacteremia. Depending on the amount of data that must be assessed, a simple model is desirable; thus, it is necessary to determine whether the model used in a given study can be applied to different samples with different follow-up periods.

At the time of follow-up examination, there was a high number of normal radiological findings in the group with adequate root filling, whereas there was a small number of normal findings in the group with overfilling. The findings in the group with overfilling should therefore be considered inferior because overfilling causes injury to the periapical tissues.

Thus, it is more difficult to tightly seal the apical foramen in the group with overfilling than in the group with underfilling or adequate filling. According to Barbakow et al. (1981),[15] when solely considering cases with radiolucent findings, treatment success did not appear to be influenced by the radiographic position of the root filling. Furthermore, Molven and Halse (1982)[16] investigated outcomes after 11–16 years among patients with overfilling; they reported that 80% of protruding fillers had been absorbed and that 80% of apical lesions had disappeared. Thus, depending on the patient and assessment period, the outcomes of overfilling are not necessarily poor; this suggests a need for further investigation of such outcomes.

Radiolucent findings regarding areas surrounding the apices of teeth tend to be associated with poor outcomes. Associated roots exhibit increased frequencies of bacterial infection in the root canal, as well as infection with a deeper invasive depth relative to that of roots without apical radiolucency.[17] The development of granulomatous inflammatory tissue or epithelium within the lesion has also been recognized as a radiolucent finding.[18,19] Despite removal of the source of disease in the root canal, a considerable amount of time is needed to achieve cure. Overall, these factors appear to contribute to poor treatment outcomes.

Although overfilled tooth roots tended to have poor outcomes in this study, those with large radiolucent findings at the root apex tended to have better outcomes. Consistent with the report by Bhasker (1972),[20] stimulation of the tissue surrounding the apical foramen (e.g., due to excessive filling and instrumentation) may cause acute inflammation and epithelial destruction, as well as disappearance of granulomatous inflammatory tissue.

CONCLUSION

Most outcomes were favorable (95%). First, treatment outcomes were significantly associated with both root filling extent and radiological findings during treatment. Second, treatment outcomes were good when root filling was adequate, but were poor when overfilling occurred. Third, there were no changes from baseline to follow-up when the periapical space was normal, widened, or exhibited small radiolucent findings. However, roots with large radiolucent findings at the time of root canal filling tended to improve over time, such that they became normal.

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to Prof. Hisashi Nagasawa for his guidance and review. In addition, I would like to thank Enago (www.enago.jp) for performing English

language review.

References

1) Molven, O. : The frequency, technical standard and results of endodontic therapy. Thesis, Bergen, 1974.
2) Bergenholtz, G., Lekholm, U., Milthon, R. & Engstrom, B. : Influence of apical overinstrumentation and overfilling on re-treated root canals, J. Endod. 5 : 310~314,1979.
3) Barbakow, F.H., Cleaton-Jones, P.E. & Friedman, D. : An evaluation of 566 cases of root canal therapy in general dental practice. 2. Postoperative observations, J. Endod., 6 : 485~489, 1980.
4) Heling, B. & Kischinovsky, D. : Factors affecting successful endodontic therapy, J. Br. Endodo. Soc., 12: 83~89, 1979.
5) Bergenholtz, G., Lekholm, U., Milthon, R., Heden, G., Odesjo, B. & Engstrom,B. : Retreatment of endodontic fillings, Scand. J. Dent. Res., 87 : 217~224, 1979.
6) 白井夏野、高城利光、森谷浩司、鳥居　肇、斎藤正人、長田　保、：CHLOROPERCHA をシーラーとして用いた根管充填の遠隔成績、　日本歯科保存学雑誌、25 : 159~169, 1982.
7) 小嶋一敏：根管治療後の不快症状ならびに治療成績に対する臨床要因の影響、日本歯科保存学雑誌、24 : 301~316, 1981.
8) 八幡昌介：感染根管治療の予後成績について、日本歯科保存学雑誌、17 : 257~274, 1974.
9) エベリット、B.S.　山内光哉監訳：質的データの解析―カイ二乗検定とその展開、新曜社、1980.
10) Haberman, S.J. : Analysis of Qualitative Data. Volume 1 Introductry Topics, Academic Press, pp197~233, 1978.
11) Dixon, W.J. & Brown, M.B. (ed.) : BMDP Biomedical Computer programs P-seris, P3F Multiway frequency tables—The log-linear model, University of California Press, pp297~332, 1979.

12) Kerekes, K. & Rowe, A.H.R. : Thermomecanical compaction of Gutta-percha root filling, International Endodontic Journal, 15:27~35, 1982.

13) 川口叔宏、米沢範子：X線写真像によるリーマーの根尖到達度の判定（模型実験）、日本歯科保存学雑誌、19 : 111~118, 1976.

14) Mackowiak, P.A., Browne, P.H. Southern, P.M. Jr. & Smith, J.W. : Polymicrobial sepsis : An analysis of 184 cases using log linear models, Am. J. Med. Sci.,280:73~80, 1980.

15) Barbakow, F.H., Cleaton-Jones, P.E. & Friedman, D. : Endodontic treatment of teeth with periapical radiolucent areas in a general dental practice, Oral Surg., 51 : 552~559, 1981.

16) Molven, O. & Halse, A. : Long-term result of apical overfilling of root canals, Journal of Dental Research, 61 : 573, 1982.

17) Eggink, C.O. : The value of the bacteriological culture in endodontics 1. The influence of infection during and after treatment, International Endodontic Journal, 15: 79~86, 1982.

18) Weiner, S., McKinney, R.V., & Walton, R.E. : Characterization of the periapical surgical specimen, Oral Surg., 53: 293~302, 1982.

19) Block, R.M. Bushell, A., Rodrigues, H. & Langeland, K. : A histopathologic, histobacteriologic, and radiographic study of periapical endodontic surgical specimens, Oral Surg., 42: 656~678, 1976.

20) Bhaskar, S.N. : Nonsurgical resolution of radicular cysts, Oral Surg., 34: 458~468, 1972.

Jap. J. of Cons. Dent. 25(3):658–666,1982

APPENDIX

This paper is an English translation of original paper in Japanese. If you need original work, please specify the destination and contact me.