Endodontic treatment outcome: effect of the permanent restoration

Nadia M. Chugal, DDS, MS, MPH,[a] Jonathan M. Clive, PhD,[b,†] and Larz S. W. Spångberg, DDS, PhD,[c] Los Angeles, CA, and Farmington, CT
UNIVERSITY OF CALIFORNIA AND UNIVERSITY OF CONNECTICUT

Objective. To investigate the relationship between the presence of the coronal restoration and endodontic treatment success or failure.
Methods. This study comprised 200 endodontically treated teeth with 441 roots. Follow-up examination was conducted 4 ± 0.5 years after completion of endodontic treatment. Outcome criteria were modified from Strindberg.
Results. Teeth/roots restored with permanent coronal restoration (casting or filling) had a higher success rate (80%) than teeth/roots not restored (60%; $P < .01$) in the analysis of aggregate data. However, the results of stratified analysis on key confounding factor (preoperative periapical diagnosis) showed that there is no significant association between the presence of permanent restoration and endodontic outcome. Teeth with preoperative apical periodontitis were less likely to be restored with a crown (23.9%) than teeth without apical periodontitis (76.1%; $P < .01$). Anterior teeth were more likely to be restored with a filling and sooner than the posterior teeth. These associations suggest a treatment selection bias.
Conclusions. Stratified analysis on the key confounding factor reveals that endodontic outcome is driven by the presence of preoperative root canal infection (apical periodontitis). Lack of stratification on key confounding factors inaccurately suggests that presence of permanent restoration contributes to the success of endodontic treatment in the aggregate analysis of grouped data. The choice to restore the tooth as well as the choice and timing of permanent restoration may be the result of a bias in treatment selection. Stratified analysis on key confoundidng factors is the key to valid analysis and accurate results. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:576-82)**

Eradication of microorganisms from an infected root canal system has been demonstrated in numerous studies to be the key to successful endodontic treatment. Endodontic treatment is therefore focused on asepsis and disinfection with preservation of the remaining tooth structure. Conventional clinical practice assumes that endodontically treated teeth are restored to form and function after the completion of endodontic therapy. It is believed that the presence of coronal restoration helps to protect the endodontically treated tooth and root canal system from coronal leakage and reinfection. It is furthermore often assumed that the protective effect is enhanced if the coronal restoration is placed soon after the completion of endodontic treatment. Numerous studies have suggested that unprotected tooth and root canal structures are vulnerable to reinfection.[1-6] Coronal leakage studies generally demonstrated extensive leakage in experimental models in vitro and in vivo.[7]

Much has been written about the effect of permanent coronal restoration on treatment outcome. Safavi et al.[8] reported on the effect of various restorations on periradicular status in a 2-year clinical study with known diagnostic and treatment factors. They observed a tendency toward higher success rate in teeth restored with permanent restoration; the differences, however, did not reach statistical significance. Allen et al.[9] observed that teeth that were permanently restored after orthograde or surgical retreatment had a significantly higher rate of successful outcome compared to the teeth that were not restored.

The effect of various restorative procedures subsequent to endodontic therapy is often missing from most prognosis studies. Several recent studies have addressed the issue of the effect of restoration on endodontic treatment outcome.[10-14] However, the effect of the timely placement of permanent restoration on long-term endodontic treatment outcome has not been addressed.

The purpose of the present study was to investigate the relationship of permanent coronal restoration on endodontic treatment outcome.

[a]Associate Clinical Professor, Program Director, Postgraduate Endodontics, Section of Endodontics, University of California–Los Angeles School of Dentistry.
[b]Biostatistician, Office of Biostatistical Consultation, University of Connecticut Health Center. [†]Deceased.
[c]Professor of Endodontology, University of Connecticut School of Dental Medicine.
Received for publication Feb 28, 2007; returned for revision Apr 5, 2007; accepted for publication Apr 11, 2007.
1079-2104/$ - see front matter

doi:10.1016/j.tripleo.2007.04.011

MATERIALS AND METHODS

Cohort identification and selection of study sample

The study population and the methods have been described in detail previously.[15] Briefly, the study population of this historical prospective cohort study comprised the patients treated at the university postgraduate endodontic clinic during a defined time period.[16] During that time period, a root canal microbiologic culture was routinely taken at several time points in the course of endodontic treatment and was recorded in a data log book. This data log book served as a population base from which we compiled the present study sample. Patients who had a preobturation culture recorded were eligible to enter the study. Identifying patient information was obtained from the patient record.

Inclusion criteria: The availability of complete endodontic, radiographic, microbiologic, and restorative records. Teeth extracted before 4 ± 0.5–year follow-up examination were included in the study if the inclusion criteria were met and the reason for extraction was recorded.

Exclusion criteria: Odontogenic developmental anomalies, teeth with immature roots, root fractures, and missing information or incomplete records.

All patients who met the eligibility criteria were contacted by phone and offered a 4-year follow up examination. Twenty-five percent of the original pool of patients treated who met the study participation criteria were traced. Seventy-five percent of the patients traced consented to a follow-up examination. This represents an 18.7% recall rate at the observation period of 4 ± 0.5 years after obturation. A total of 200 teeth with 441 root canals in 120 patients were evaluated.[15]

Data elements

Comprehensive data were collected and included 117 tooth descriptors.

Diagnostic and treatment information for each of the eligible patients was abstracted from the original patient record retrospectively by the same endodontist.

Endodontic treatment was rendered under controlled conditions and followed standardized protocol. After single-tooth rubber dam isolation, the tooth and rubber dam were disinfected with 30% H_2O_2 and 5% tincture of iodine.[17] Estimated working length was determined using preoperative periapical radiograph and a millimeter ruler and verified with a radiograph. One percent buffered NaOCl (approx. pH 8) was used for irrigation. A minimum 10 mL was used per canal at each session. A sterile aqueous paste of $Ca(OH)_2$ (Calasept; Scania Dental, Svedia, Knivsta, Sweden) was applied with lentulo spiral and packed. In addition, 2% iodine potassium iodide was used for additional disinfection as a final rinse at each treatment session in cases of necrotic pulp with periapical lesion. Before placement of root filling, the canals were irrigated with 70% alcohol and completely dried. The root canals were filled using lateral condensation technique with disinfected guttapercha and AH26 sealer (De Trey Frères, Zurich, Switzerland). Cavit (Espe, Seefeld/Oberbayern, Germany) or IRM (L. D. Caulk Co., Milford, DE) were used for temporary restoration. No cotton pellet was left under the temporary restoration. Occlusion was checked and adjusted.

Following are the definitions of the variables used for the investigation:

Filling includes an amalgam or a resin composite restoration.

Cast restoration includes an onlay, full gold crown, and porcelain fused to metal crown.

Temporary restoration is the presence of an interim restoration or a missing restoration.

Build-up restoration is an amalgam or composite build-up, with or without a post, or a cast post—all as an interim step in the process of fabricating the cast restoration.

Final restoration is the presence of a "filling" or a "cast restoration" at the follow-up examination.

Permanent restoration denotes the presence, of a "filling," "cast restoration," or "build-up restoration" that was placed subsequent to the completion of endodontic treatment.

Final restoration time (FRT) is the time in months between root canal filling and placement of "final restoration."

Build-up restoration time (BUT) is the time in months between root canal filling and placement of a "build-up restoration."

Permanent restoration time (PRT) is the shorter of the 2 time periods FRT and BUT.

Endodontic follow-up examination consisted of a review of history, and a clinical and radiographic examination. Each patient was examined by the same endodontist.

Radiographic evaluation. All endodontic treatment radiographs were viewed by two endodontists under standardized conditions using a magnifying ($\times 2$) Mattson viewer.[18] Radiographic evaluation was blind, i.e., the evaluators were blinded to the preoperative pulp and periapical diagnosis. Format and criteria for radio-

graphic evaluation were identical for treatment and follow-up.

Assessment of periradicular status. Each root was evaluated for the presence of a radiographically detectable periapical pathosis (apical periodontitis) at the time of diagnosis and treatment and at the follow-up examination. This information provided the basis for the periapical status descriptors of each root at the time of diagnosis and treatment (Table I) and at the follow-up examination (Table I, *B* and *C*).

Outcome assessment. Main outcome measure was the absence (success) vs. presence (failure) of periapical pathosis (apical periodontitis). Criteria for the assessment of outcome were adopted from Strindberg (1956).[19] The assessment of outcome was carried out by two of the authors, and an agreement was reached in all cases (modified from Halse and Molven, 1986).[20]

Data analysis and statistical analysis

Data were entered onto the standardized study data collection form, coded for computer entry, and entered into a database (Paradox; Corel, Ottawa, Ontario, Canada). Later on, this database was imported into Excel (Microsoft, Seattle, WA), and the data were analyzed using the SPSS statistical package (SPSS, Chicago, IL).

All data were analyzed ungrouped for total material effects and stratified according to the specified diagnostic categories of periradicular status (Table I) to control for confounding.[15]

Statistical methods

Univariate analysis. The *P* values for tabulated data were computed using chi-square (χ^2) contingency table methods. Means across outcome groups were compared using independent group *t* tests or 1-way analysis of variance or the corresponding nonparametric procedures (Mann-Whitney or Kruskal-Wallis tests).

Multivariate analysis. Logistic regression models were used to evaluate which combination of several independent variables pertaining to endodontic treatment proper best predicted treatment outcome. We used a generalized logistic regression method that included random tooth/patient effects to account for the nonindependence of observations from multiple canals on the same tooth or observations from multiple teeth on the same patient.[21] A *P* value of $<.05$ was considered to be statistically significant.

RESULTS

The primary outcome was success vs. failure. Because the preoperative periapical status exerts primary effect on endodontic outcome,[15,22] data were analyzed grouped and stratified on this factor (Table I, *B*).

Table I. Diagnostic criteria for periradicular status of teeth and roots

A. Clinical Periapical Diagnosis of Teeth (CPDT) and Roots (CPDR). Status descriptors of periradicular status at the time of diagnosis and treatment. Single-rooted teeth were diagnosed according to these criteria. In a multirooted tooth, the clinical periapical diagnosis of the tooth was based on the condition of the most severely affected root. CPDR is a clinical diagnosis assigned to the root, based on clinical findings, including radiographic information of the tooth. Therefore, each root assumes the clinical periapical diagnosis of the most severely affected root of that tooth.

Normal	No clinical symptoms No periradicular sclerosis or rarefaction of bone visible on the radiograph Homogeneous lamina dura enclosing a periodontal ligament of normal width or slightly widened
Acute	Clinical signs and symptoms of inflammation Periradicular sclerosis or rarefaction $\leq$1 mm visible on radiograph Broken or poorly defined lamina dura
Chronic	No clinical signs and symptoms of inflammation or infection Periradicular rarefaction $>$1 mm
Exacerbating	Clinical signs and symptoms of periradicular inflammation and/or infection Periradicular rarefaction $>$1 mm

B. Qualitative Radiographic Diagnosis. Status descriptors of periapical status of a root at the time of diagnosis and treatment and at the follow-up examination. This measures, for each individual root, the radiographic presence of periapical disease. Differentiates between "normal" and "diseased" periapical conditions. Does not discriminate between pulp diagnoses.

Normal periapex	No radiographically discernible periapical changes except for widened periodontal ligament.
Diseased periapex	Presence of any discernible periapical radiolucency.

C. Quantitative Radiographic Diagnosis. Status descriptors of periapical status of a root at the time of diagnosis and treatment and at the follow up examination. The extent of radiographically detectible periapical disease is measured and the largest dimension in millimeters (mm) recorded for each root apex. This diagnosis differentiates between normal periapex, acute, and chronic/exacerbating apical periodontitis. Does not discriminate between pulpal diagnoses.

Normal periapex	No radiographically discernible pathosis except for widened periodontal ligament with intact lamina dura.
Acute apical periodontitis	Periapical radiolucency is present and measures $<$1 mm.
Chronic resorbing and exacerbating apical periodontitis	Periapical radiolucency largest dimension is $>$1 mm.

Reprinted with permission.[22]

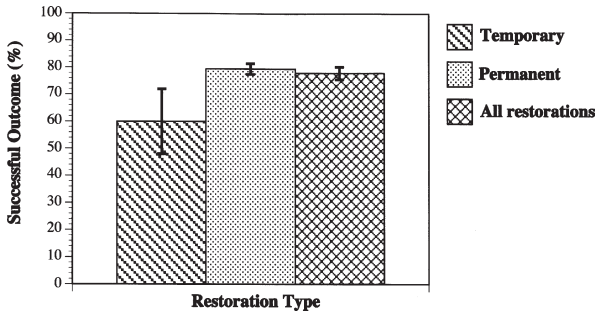

Fig. 1. Treatment outcome (percentage success ± SE) stratified on restoration type. Percentage success is significantly higher for permanent restorations ($P = .013$ by χ^2 test). Data combined across all diagnostic categories.

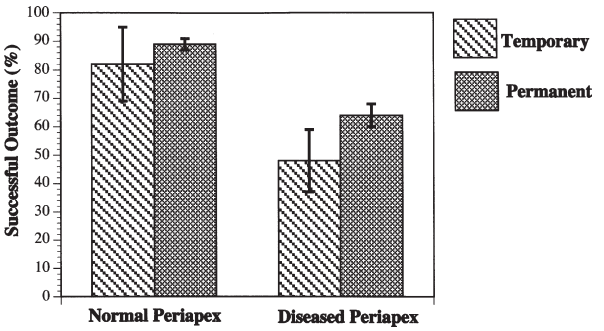

Fig. 2. Percentage successful outcome ± SE for temporary versus permanent restoration stratified on preoperative periapical diagnosis. When controlling for periapical status (normal vs. diseased), there is no statistically significant difference in outcome between permanent and temporary restoration ($P = .17$ by χ^2 test). When controlling for restoration (temporary vs. permanent), success is significantly lower in diseased compared to normal periapex within each type of restoration ($P < .0001$ by χ^2 test).

Effect of restoration

The presence of permanent restoration had a statistically significant effect on endodontic treatment success or failure in the overall analysis of grouped data (Fig. 1; $P = .013$), ignoring other covariates. Forty percent of temporary restoration teeth failed compared with 20.5% of the permanently restored teeth. The difference in success rate of the teeth/roots restored with an amalgam versus composite was not statistically significant, nor was the difference between cast restoration versus filling (amalgam and composite combined).

Effect of preoperative periapical diagnosis and restoration

Of the 166 teeth/roots with preoperative diseased periapical status, 21 (12.6%) still had temporary restorations at 4 ± 0.5 year follow-up examination. In contrast, only 9 (3.8%) of 239 teeth/roots with preoperative normal periapical status had temporary restorations. Therefore, teeth/roots with diseased periapex were more likely to be with temporary restoration at 4 ± 0.5 year follow-up examination than if they had normal periapical status. That is, periapical status (diseased or normal) and restoration status (temporary or permanent) are not independent ($P < .0001$).

Ignoring periapical status, 18 (60%) of the 30 teeth/roots with temporary restorations and 298 (79.5%) of the 375 teeth/roots with permanent restorations were successful, implying that those with permanent restorations have more success than those with temporary restorations (Fig. 1; $P = .013$).

However, controlling for initial periapical status, within each stratum of periapical diagnosis there is no significant association between endodontic success and permanent restoration (Fig. 2; $P = .17$). Controlling for restoration (i.e., within each stratum of restoration), success is significantly lower in teeth/roots with diseased versus normal periapex (Fig. 2; $P < .0001$).

Teeth/roots with preoperative normal periapex were more likely to be restored with a cast restoration (178/234, 76.1%), than teeth/roots with preoperative periapical disease (97/152, 63.8%). The observed difference was statistically significant (Fig. 3; $P = .01$).

Effect of time of placement of final and permanent restoration

There was a statistically significant difference in mean time of placement of final restoration casting versus filling (Table II, *A*; $P < .0001$). Filling also served as a build-up that precedes fabrication of cast restoration. When this was considered, there was no statistically significant difference between build-up restoration time (preceding the final cast restoration) and time of placement of a filling as a final restoration (Table II, *B*).

Teeth/roots with preoperative normal periapex were restored sooner after completion of endodontic treatment with a final restoration than the teeth/roots with apical periodontitis (Table III, *A*; $P = .011$). Likewise, for normal periapex, the permanent restoration time was shorter than for diseased periapex (Table III, *B*; $P = .001$).

DISCUSSION

The findings of the present study show that the critical factor for the endodontic treatment outcome is the preoperative diagnosis and presence of preoperative root canal infection (apical periodontitis). The results of

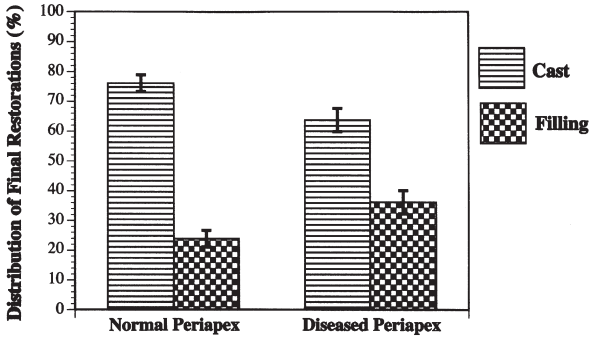

Fig. 3. Distribution of final restoration (cast restoration versus filling) within the strata of preoperative periapical diagnosis (normal versus diseased). A statistically significant association exists between preoperative periapical diagnosis and type of final restoration. ($p = 0.01$ by χ^2 test).

Table II. The time of placement of final restoration and of permanent restoration, overall/grouped analysis

	Casting/ Build-up	*Filling*	
A. Time of placement of "final restoration"	11.01 ± 0.54	5.09 ± 0.52	$P < .0001$
B. Time of placement of "permanent restoration"	6.84 ± 0.37	4.90 ± 0.50	$P = .476$

Mean ± SEM (months); *t* test for equality of means.

Table III. The time of placement of final restoration and of permanent restoration, stratified on preoperative periapical diagnosis (Table I,*B*)

	Normal	*Diseased*	
A. Time of placement of "final restoration"	8.40 ± 0.50	10.65 ± 0.75	$P = .011$
B. Time of placement of "permanent restoration"	5.38 ± 0.32	7.58 ± 0.56	$P = .001$

Mean ± SEM (months); *t* test for equality of means.

this study also show that permanent restoration is not critically important for the successful endodontic outcome. It is important to appreciate that in the overall analysis of grouped data, the presence of permanent restoration may appear to exert statistically significant effect on the outcome of endodontic treatment. However, this aggregate analysis masks significant relationship between preoperative root canal infection and long-term outcome of endodontic treatment. Therefore, when data were stratified on the presence of preoperative apical periodontitis, the results show that there is no significant association between the presence of permanent restoration and endodontic outcome (Fig. 2). Furthermore, the preoperative periapical status, diseased or normal, and restoration choice are not independent. Teeth/roots with preoperative normal periapex had the highest percentage of cast restoration (Fig. 3) and received permanent restoration significantly sooner after obturation than did teeth/roots with preoperative apical periodontitis (Table III**).** Teeth with preoperative apical periodontitis were less likely to be restored with a crown (63.8%) than teeth without apical periodontitis (76.1%; $P < .01$).

It took significantly longer to restore teeth with a cast restoration than a filling as final restoration (Table II). Teeth restored with a casting in many cases had a post and/or a core build-up (permanent restoration) placed before the casting (final restoration). In teeth that received a build-up, there was a delay in the placement of a final cast restoration. Therefore, time of placement of permanent restoration and final restoration were significantly different. The "permanent restoration time" concept was introduced to control for this differential time of placement of a permanent and final restoration. Anterior teeth were more likely to be restored with a filling and sooner than posterior teeth. These associations suggest a treatment selection bias. The choice to restore the tooth as well as the choice and the timing or permanent restoration may be the result of a bias in treatment selection.

This may suggest that the selection of type of final restoration, by the restorative dentist, was affected by the correct assumption that the treatment outcome for teeth with apical periodontitis is less favorable; however, the delay in placement of the final restoration is not in line with current recommendations, based on leakage studies, that the final restoration be placed as soon as possible after the completion of endodontic treatment.

Studies on endodontic prognosis have addressed a wide range of factors in an attempt to accurately forecast the course of endodontic treatment outcome.[19,23-26] It is now an established fact that diagnostic variables and biologic factors such as preoperative pulp and periradicular diagnosis (apical periodontitis) bear the largest effect on the endodontic treatment outcome.[15,22,23,25-28]

The effect of various restorative procedures after endodontic therapy is often missing from prognosis studies. Furthermore, combined effect of endodontic and restorative factors has not been subjected to careful analysis.

Safavi et al.[8] reported on the effect of temporary and permanent restoration on endodontic outcome in a clinical study with known diagnostic and treatment factors. They observed successful results more frequently in teeth with permanent restorations than in teeth with temporary restorations. The differences, however, did not reach statistical significance.

It has been shown that prognosis was better for posterior teeth if they were restored with cast restoration,[29,30] which did not hold true for anterior teeth. That study, however, had several significant shortcomings.[29] The observation period was too wide (1-25 years), criteria for assessment of outcome were not well defined, and known variables that affect endodontic outcome, except for morphologic tooth groupings, were not considered.

In a similar cross-sectional radiographic study, Ray and Trope[11] evaluated the relationship of the quality of root filling and of the coronal restoration and periapical status of endodontically treated teeth. The presence of periradicular osteolysis was equated with failing endodontic outcome. The authors suggested that the quality of the coronal restoration was paramount for endodontic success.

Although it was an important study that raised an important question, it nevertheless was missing some important details. Thus, the presence of periapical osteolysis may have been an indicator of healing as well as failure. Furthermore, the effect of permanent restoration was not (and could not be) tested, because the time lag between endodontic treatment completion and placement of permanent restoration, or if the endodontic treatment was rendered through an existing restoration, was unknown. No clinical data were available to support the radiographic assessment of the quality of the permanent restoration. Bite-wing radiograms were not used for the assessment of margins, although they provide superior imaging compared with periapical radiograms. Given the study design and the fact that preoperative diagnosis was not known and, therefore, data could not be analyzed based on this most important factor, the conclusions, although often quoted, are called into question. Kirkevang et al.[13] found that periapical status of endodontically treated teeth depends on both the quality of the root filling and the quality of restoration, and Tronstad et al.[14] refuted Ray and Trope's findings.

In a radiographic study on prevalence and technical quality of endodontic treatment in an American population, lesser-quality root fillings were more strongly associated with periapical disease then were higher-quality root fillings.[10] Those authors observed no statistically significant difference in the proportion of periapical disease between endodontically treated teeth restored with an amalgam versus other coronal restorations.

Previous studies on endodontic prognosis reported that the major biologic factor influencing the outcome of endodontic treatment is the presence and the extent of preoperative microbiologic insult to the pulp and periapical tissue, as reflected in periradicular diagnosis and the magnitude of periapical pathosis.[15,22,25,31,32] Although several more recent studies have addressed the issue of the association of restoration and endodontic treatment outcome, most of those studies were cross-sectional with little historical knowledge of the endodontic and restorative treatment.[10-14,33] A study on 55 matched pairs with known treatment factors raised the question of importance of coronal leakage.[12] Despite their study results, those authors recommended coronal seal for root fillings.

Recent epidemiologic studies on a large cohort of insured patients investigated the relationship of restoration and endodontic outcome, demonstrating high success rate in teeth restored with cast restoration.[34,35] However, the outcome measure was tooth retention, a measure not comparable to the radiographic evaluation of periradicular status. Therefore, their reported rates are highly skewed toward a high success rate.

There are several issues to keep in mind about the present study. It is not a controlled study with random allocation to study groups (restored vs. not restored) that would allow us to calculate valid outcome rates related to restoration. The present study is retrospective and cross-sectional. Therefore, we cannot claim, as any other cross-sectional study could not, the cause-and-effect relationships. At the same time, we have to recognize that a prospective cohort study with random allocation to "temporary filling" versus "permanent filling" groups is not ethical, and therefore such a study can not be conducted. Study material of "temporary filling" can therefore only be collected by clinical default.

It is also important to note that retrospective or cross-sectional studies often use terms "success and failure" and "periapical health" interchangeably. This is inappropriate and misleading. One can use terms "success and failure" as defined by Strindberg[19] only if one knows the preoperative periapical status and the time when the treatment was completed. Unless these facts are known, one can only describe "presence versus absence" of apical periodontitis, recognizing that this is not synonymous with "success and failure."

The present study was undertaken on clinical material where detailed verifiable endodontic treatment information was available. The density of root fillings was radiographically evaluated as good and the quality of the coronal restoration was clinically assessed and recorded as satisfactory. Careful analysis based on key prognostic factors (preoperative diagnosis) show that the endodontic outcome is critically affected by the presence of preoperative root canal infection (apical periodontitis) and is independent of the type of restoration.

IN MEMORIAM

This paper is dedicated to Dr. Jonathan Clive who passed away before this paper was completed.

This study was supported in part by the Office of Academic Affairs, Veterans Administration, Washington D.C. The authors thank Dr. Jeffrey Gornbein from UCLA Department of Biomathematics for critical assistance with data interpretation and Dr. Angelo Caputo from the School of Dentistry for his invaluable help with graphs and illustrations.

REFERENCES

1. Dow PR, Ingle JI. Isotope determination of root canal failure. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1955;8: 1100-4.
2. Marshall FJ, Massler M, Dute HL. Effects of endodontic treatments on permeability of root dentine. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1960;13:208-23.
3. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. J Endod 1987;13:56-9.
4. Madison S, Swanson K, Chiles SA. An evaluation of coronal microleakage in endodontically treated teeth. Part II. Sealer types. J Endod 1987;13:109-12.
5. Torabinejad M, Ung B, Kettering JD. In vitro bacterial penetration of coronally unsealed endodontically treated teeth. J Endod 1990;16:566-9.
6. Khayat A, Lee SJ, Torabinejad M. Human saliva penetration of coronally unsealed obturated root canals. J Endod 1993;19: 458-61.
7. Madison S, Wilcox LS. An evaluation of coronal microleakage in endodontically treated teeth. Part III. In vivo study. J Endod 1988;14:455-8.
8. Safavi KE, Dowden WE, Langeland K. Influence of delayed coronal permanent restoration on endodontic prognosis. Endod Dent Traumatol 1987;3:187-91.
9. Allen RK, Newton CW, Brown CE Jr. A statistical analysis of surgical and nonsurgical endodontic retreatment cases. J Endod 1989;15:261-6.
10. Buckley M, Spångberg LSW. The prevalence and technical quality of endodontic treatment in an American sub-population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1994; 79:92-100.
11. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995;28:12-18.
12. Riccuci D, Grondhal K, Bergenholtz G. Periapical status of root-filled teeth exposed to the oral environment by loss of restoration or caries. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:354-9.
13. Kirkevang LL, Orstavik D, Horsted-Bindslev P, Wenzel A. Periapical status and quality of root fillings and coronal restorations in a Danish population. Int Endod J 2000;33:509-15.
14. Tronstad L, Asbjornsen K, Doving L, Pedersen I, Eriksen HM. Influence of coronal restorations on the periapical health of endodontically treated teeth. Endod Dent Traumatol 2000;16: 218-21.
15. Chugal NM, Clive JM, Spångberg LS. A prognostic model for assessment of the outcome of endodontic treatment: effect of biologic and treatment variables. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:342-52.
16. Mausner J, Kramer S. Mausner and Bahn. Epidemiology—an introductory text. 2nd ed. Philadelphia: W. B. Saunders; 1985. ch. 7.
17. Möller A. Microbiological examination of root canals and periapical tissues of human teeth. Microbiological studies. Odontol Tidskr 1966;74(Suppl):1-380.
18. Mattson O. A magnifying viewer for photofluorographic films. Acta Radiol 1953;39:412-19.
19. Strindberg LZ. The dependence of the results of pulp therapy on certain factors. Acta Odont Scand 1956;14:1-175.
20. Halse A, Molven O. A strategy for the diagnosis of periapical pathosis. J Endod 1986;12:534-8.
21. Diggle PJ, Liang K-Y, Zeger SL. The analysis of longitudinal data. New York: Oxford University Press; 1994. p. 169-89.
22. Chugal NM, Clive JM, Spångberg LS. A prognostic model for assessment of the outcome of endodontic treatment: some biologic and treatment factors associated with outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;96:81-90.
23. Storms JL. Factors that influence the success of endodontic treatment. J Can Dent Assoc 1969;35:83-97.
24. Kerekes K, Tronstad L. Long-term results of endodontic treatment performed with a standardized technique. J Endod 1979; 5:83-90.
25. Sjögren U, Hågglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. J Endod 1990; 16:498-504.
26. Lin L, Skribner J, Gaengler P. Factors associated with endodontic treatment failures. J Endod 1992;18:625-7.
27. Seltzer S, Bender IB, Smith J, Freedman I, Nazimov H. Endodontic failures—an analysis based on clinical, roentgenographic, and histologic findings. Part I. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1967;23:500-16.
28. Seltzer S, Bender IB, Smith J, Freedman I, Nazimov H. Endodontic failures—an analysis based on clinical, roentgenographic and histologic findings. Part II. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1967;23:517-30.
29. Sorensen JA, Martinoff JT. Intracoronal reinforcement and coronal coverage: a study of endodontically treated teeth. J Prosthet Dent 1984;51:780-4.
30. Sorensen JA. Preservation of tooth structure. J Cal Dent Assoc 1988;16:15-22.
31. Sundqvist G. Bacteriological studies of necrotic dental pulps. Umeå University Odontological Dissertations, No. 7. 1976.
32. Byström A, Happonen R-P, Sjögren U, Sundqvist G. Healing of periapical lesions of pulpless teeth after endodontic treatment with controlled asepsis. Endod Dent Traumatol 1987;3:58-63.
33. Siqueira JF, Rocas IN, Alves FR, Campos LC. Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:369-74.
34. Lazarski MP, Walker WA, Flores CM, Schindler WG, Hargreaves KM. Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. J Endod 2001;27:791-6.
35. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. J Endod 2004;30:846-50.

Reprint requests:

Nadia M. Chugal, DDS, MS, MPH
Sections of Endodontics, A3-075 CHS
UCLA School of Dentistry
10833 Le Conte Avenue
Los Angeles, CA 90095-1668
nchugal@ucla.edu