

# Epidemiological Evaluation of the Outcomes of Nonsurgical Root Canal Treatment in a Large Cohort of Insured Dental Patients

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**Selected outcomes following initial nonsurgical root canal treatment (NSRCT) procedures were retrospectively assessed using an insurance company database of 110,766 nonsurgical root canal procedures that were completed by endodontists and their referring general dentists. A subset of 44,613 cases, with a minimum required follow-up time of 2 yr, showed incidences of extraction, retreatment and periradicular surgery equal to 5.56%, 2.47%, and 1.41%, respectively. The incidence of subsequent extraction increased with patient age. Teeth that were not restored after root canal therapy were significantly more likely to undergo extraction than restored teeth. Although the practice pattern for endodontists consisted of a significantly higher proportion of molars (48% more;  $p < 0.001$ ) and a smaller proportion of anterior teeth (43% less;  $p < 0.001$ ) than general dentists, both groups of providers had comparable rates of untoward events. These data strongly support the hypothesis that the specialist practice provides similar rates of clinical success compared with other providers, even when treating significantly more complex NSRCT cases. Overall, 94.44% of nonsurgical root canal treated teeth remained functional over an average follow-up time of 3.5 yr. These results are an important indication of the benefits of endodontic treatment when provided in an integrated health care delivery system of endodontists and their referring general dentists.**

The outcomes of nonsurgical root canal treatment (NSRCT) have classically been studied using clinical signs and symptoms, radiographic interpretation, and histopathological evaluation of excised tissue. Such intensive investigation parallels clinical practice and provides detailed information on selected cases. Another method

of studying outcomes is through the use of epidemiological methods. Such techniques allow for the concomitant study of very large cohorts and multiple variables; however, the epidemiological approach has not been utilized as extensively in endodontic research. One review found only 16 epidemiological studies over a recent 6-yr period in three major endodontic journals (1).

Understanding outcomes of NSRCT is an important aspect of the specialty; not only does it permit evaluation of clinical techniques, but it also allows for the development of criteria to further improve diagnostic, treatment, and posttreatment recommendations. In general, outcome studies can be designed using one of two major approaches: prospective or retrospective. Prospective studies allow for the randomization of test subjects, standardization of techniques and sampling methods, and the simultaneous study of multiple variables. However, the low failure rate and long follow-up times needed in endodontics makes prospective studies often underpowered and very expensive to conduct.

Alternatively, retrospective studies have the advantages of larger study populations, longer follow-up periods, and often are shielded from bias because data were often collected for reasons other than the study question. However, a major limitation is the inability to randomize and standardize the experiment, which necessitates both careful interpretation and tentative application of results to the general population. Furthermore, important data may not have been collected, thus limiting the scope of analysis.

Previous studies of the outcomes of NSRCT have focused on traditional clinical parameters of success. Using defined clinical and radiographic evaluation criteria, endodontic success rates in larger studies have ranged between 53% (2) and 93% (3). In contrast, other studies have evaluated untoward events after root canal therapy, a term operationally defined as a composite measure of extraction, retreatment, or apical surgery. As defined, an untoward event is a composite measure of multiple procedures indicated by any of several clinical conditions. An advantage of using this measure in retrospective studies is that it allows a robust comparison of the outcomes of NSRCT. Furthermore, the large cohort of patients available in retrospective studies permits evaluation of the predictive value of other factors on the occurrence of an untoward event. Larger studies also allow for the evaluation of overall health care delivery in a defined population. As defined, untoward events following NSRCT are affected by three important factors: preexisting factors, such as root fractures and periodontal

disease; postendodontic factors, such as improper restoration or crown fractures; and endodontic factors, such as poor initial therapy or anatomic irregularities.

Other studies have evaluated untoward events following NSRCT. One investigation found that 55% of teeth following NSRCT were retained over a 17-yr period by Dutch servicemen (4). Similarly, a recent case-control study analyzed reasons for tooth loss after nonsurgical root canal therapy. Of interest, this study selected its cases and controls from a large insurance company database. A total of 96 extraction cases and 120 control cases provided evidence that number of proximal contacts, age, history of facial injury, number of missing teeth, and abutment status were all correlated with the eventual extraction of teeth following NSRCT (5). Another study classified 59.4% of extractions following NSRCT procedures as due to prosthetic failure, 32% as due to periodontal failure, and 8.6% as due to endodontics failure, mostly instrument separation (6). Based on these findings, extraction following NSRCT procedure is a composite measure of multiple types of failure. As such, the incidence of untoward events allows for a robust comparison of NSRCT outcomes; furthermore, by using a large cohort of patients, multiple other factors can be included in the analysis.

Although no single study will be able to address all of these issues, the present study determined the occurrence of untoward events following NSRCT using an epidemiological approach, a caseload of more than 100,000 NSRCT procedures, and the ability to track subsequent procedures performed on these teeth. The following questions were addressed using untoward events following NSRCT as the major study endpoint:

1. What is the incidence of untoward events following initial NSRCT? Are there patient factors that impact the incidence of untoward events following NSRCT?
2. How does the type, or lack, of subsequent restoration affect the incidence of untoward events following NSRCT?
3. Do the patterns of treatment differ between endodontists and nonendodontists? Do nonendodontists tend to refer their cases requiring nonsurgical or surgical retreatment?

It is important to recognize that an epidemiological study using insurance data provides an integrated, overall measure of health-care delivery. In the present study, the health care model consists of patients treated in an integrated system of endodontists and their referring general dentists. Accordingly, neither the outcome data nor the present experimental design permits direct comparisons between groups of providers because there is no attempt to stratify cases by preendodontic factors, postendodontic factors, or even by complexity of the endodontic case. However, the database does provide an opportunity to evaluate the effects of known variables (e.g. gender, age, postendodontic restorations) on the incidence of untoward events following NSRCT. As such, it provides a robust evaluation of the efficacy of dental health care delivery in an integrated setting of endodontists and their referring general dentists.

## MATERIALS AND METHODS

Data for this study were obtained from Washington Dental Service, affiliated with Delta Dental Plans Association, Seattle, WA. This plan insures approximately 1.5 million patients and has maintained a computerized database of its claims since 1993. These data, therefore, are derived from a private practice environ-

ment consisting of general dentists, endodontists, and other dental specialists with patients enrolled in a dental insurance program.

Patients included in this study were enrolled in the dental plan for a continuous period commencing January 1, 1993, and ending December 31, 1998. From the 1.5 million total patients, approximately 586,000 met this criterion for inclusion. The query of the database for endodontic ADA procedure codes 3310, 3320, 3330, and 3340 produced 110,766 initial NSRCT procedures performed during this 5-yr period. These teeth were then followed for subsequent procedures attributed to them within the database.

The following information was collected for each NSRCT procedure: patient identification number, tooth number, date of endodontic procedure, patient age, patient gender, practitioner identification number, and practitioner specialty status. Endodontic specialists were practitioners who had completed an accredited endodontic training program. The following was collected for each subsequent procedure: patient identification number, practitioner identification number, practitioner specialty status, tooth number, and up to three separate procedure codes per subsequent treatment date, with a maximum of five subsequent treatment dates. This allowed the collection of information on up to 15 subsequent procedures that were attributed to the tooth after NSRCT was performed.

Based on the available data, teeth with an NSRCT procedure were evaluated for subsequent untoward events yielding an insurance claim, namely extraction, retreatment, or apical surgery, during the available follow-up time. Additionally, to increase the effective follow-up period, the data were further refined into a subset that included only teeth with greater than 2 yr of potential follow-up within the database. This subset provided a longer mean follow-up period to assess the incidence of untoward events.

The following analyses were performed for both the main and subset cohorts:

### I. Summary Analysis

- A. Overall numbers and types of procedures performed by endodontists and nonendodontists
- B. Incidence of untoward events following an NSRCT procedure; patterns of treatment and referral for subsequent retreatment and apical surgery procedures; further analyses based on tooth position, patient age, and patient gender

### II. Predictive value of restorations on incidence of untoward events

- A. The following categories were used for analysis:
  1. Teeth that had received only an amalgam or resin restoration subsequent to NSRCT, excluding single-surface restorations because these were likely to have preexisting full-coverage restorations
  2. Teeth that had received any type of single-unit full-coverage restoration
  3. Teeth that were included in any type of multi-unit full-coverage restoration
  4. Teeth that showed no subsequent restoration code

### III. Predictive value of subsequent build-up on incidence of untoward events

- A. The following categories were used for analysis:
  1. Single-unit restoration with some type of post and core
  2. Single-unit restoration with some type of build-up, but no post and core
  3. Single-unit restoration with no build-up or post and core
  4. Multi-unit restoration with some type of post and core

5. Multi-unit restoration with some type of build-up, but no post and core
  6. Multi-unit restoration with no build-up or post and core
- IV. Predictive value of post and core restorations on incidence of untoward events
- A. The following categories were used for analysis:
1. All teeth with subsequent cast post and core
  2. All teeth with subsequent prefabricated post and cores

Data were analyzed using SAS statistical software (SAS Institute, Cary, NC). Student's *t* test and  $\chi^2$  analyses were used to determine the significance of differences that were found between groups. For trend analyses, the Mantel-Haenszel method of assessing multiple contingency tables was used.

## RESULTS

Of the 110,766 NSRCT cases, 1,224 were excluded from the analysis because of missing tooth or practitioner identification numbers, leaving 109,542 cases. Nonendodontists performed 72,424 cases (66.12%), and endodontists performed 37,118 cases (33.88%). The overall incidence of untoward events following an NSRCT procedure was 6.40%: 3.56% of all cases were subsequently extracted, 1.84% were nonsurgically retreated, and 1% underwent periradicular surgery. The mean follow-up period in this cohort was 22.0 months for teeth that did not suffer a subsequent untoward event and 14.7 months for teeth that suffered a subsequent untoward event; the longest follow-up time for either group was 72 months.

Based on the desire to maximize the effective follow-up period, a subset was created that consisted of all endodontic procedures with 2 yr or more of potential follow-up in the database. Of the 109,542 NSRCT cases that met the initial criteria for inclusion, 44,613 cases met this more stringent criterion (Table 1). Nonendodontists performed 29,895 cases (67.01%), and endodontists performed 14,718 cases (32.99%). The overall incidence of untoward events following NSRCT was 9.44%: 5.56% of all cases were subsequently extracted, 2.47% were nonsurgically retreated, and 1.41% underwent periradicular surgery. Of the 5.56% extracted teeth, 0.45% were first retreated nonsurgically and/or surgically before being extracted. The mean follow-up period was 41.9 months for teeth that did not suffer a subsequent untoward event and 20.0 months for teeth that suffered a subsequent untoward event; the longest follow-up time for either group was 72 months.

The case distribution in the typical endodontic specialty practice participating in this plan was 12.13% anterior, 18.67% premolar, and 69.18% molar. The typical nonendodontic practice distribution was composed of a significantly different mix of tooth types, with 21.08% anterior, 32.13% premolar, and 46.79% molar cases ( $p < 0.001$ ).

Incidence of extraction for anteriors (5.05%), premolars (5.53%), and molars (5.75%) showed a trend for increased extraction with posterior teeth ( $p < 0.02$ ). Of interest, anteriors tended to undergo subsequent apical surgery (2.94%) more often than premolars (1.31%) or molars (1.10%) ( $p < 0.001$ ).

The treatment patterns for cases in this data set that were initially performed by nonendodontists and endodontists are shown in Figs. 1 and 2, respectively. For nonendodontist cases, 44.11% of the cases that required retreatment and 43.83% of the cases that required periradicular surgery were referred to endodontists. Incidence of extraction after retreatment was statistically indistinguish-

able for procedures that were performed by nonendodontists (6.67%) and endodontists (7.53%) ( $p =$  not significant). However, there were significantly more extractions performed after periradicular surgery by nonendodontists (25.56%) than by endodontists (7.47%) ( $p < 0.001$ ).

For endodontist cases, 86.72% of the cases that required retreatment and 89.04% of the cases that required periradicular surgery were also performed by an endodontist. Too few retreatment cases were performed by nonendodontists to allow for statistical analysis, although subsequent extraction rates were comparably low (3.13% and 5.26%). However, there were significantly more extractions performed after periradicular surgery by nonendodontists (48.72%) than by endodontists (11.04%) ( $p < 0.001$ ).

## Role of Patient Age and Gender

Of the 44,613 NSRCT cases with the minimum 2-yr follow-up, 11,611 were excluded because of missing or invalid patient gender and/or age, leaving 33,002 cases. Of the remaining cases, 16,562 (50.23%) patients were female and 16,440 (49.77%) patients were male. Only patients between the ages of 14 and 90 years were included in the analysis. The average female patient was 41.81 yr old at the time of initial root canal therapy, compared with male patients who were significantly older at 43.40 yr ( $p < 0.001$ ). Females and males experienced similar incidence of extraction and other untoward events after root canal therapy. Females showed a 5.56% incidence of extraction and males a 5.69% incidence of extraction ( $p =$  not significant).

Patient age at the time of the NSRCT procedure seems to be a risk factor for experiencing an untoward event. As stated earlier, the total population of female cases had a mean age of 41.81 yr at the initiation of NSRCT; however the subpopulation of those females who subsequently experienced an untoward event had a mean age at the initiation of NSRCT of 44.36 yr ( $p < 0.001$ ). A similar pattern was observed for males: the total population of male cases had a mean age of 43.30 yr at the initiation of NSRCT; however the subpopulation of those male patients who subsequently experienced an untoward event had a mean age at the initiation of NSRCT of 46.47 yr ( $p < 0.001$ ). Taken together, the incidence of subsequent extraction for both genders increased 1% to 2% each decade until reaching a plateau after age 60 years.

## Role of Subsequent Restoration

Of the NSRCT cases with a minimum 2-yr follow-up, 34,525 fell into one of these restoration categories: amalgam/resin (4,684 cases), single-unit full coverage (18,365 cases), multi-unit full coverage (1,452 cases), and no restoration (10,024 cases). The incidence of extraction differed among these groups: single-unit restorations (2.54%), multi-unit restorations (4.20%), amalgam/resin restorations (6.28%), and teeth with no subsequent restoration code (11.21%). Statistical analyses showed all groups to be significantly different from each other ( $p < 0.001$ ).

## Role of Subsequent Build-Up

Of the NSRCT cases with a minimum 2-yr follow-up, 19,817 fell into one of these build-up categories: single-unit with post and core (5,812 cases), single-unit with build-up but no post and core (6,774 cases), single-unit with no build-up or post and core

TABLE 1. Subset analysis of 44,613 nonsurgical root canal therapy cases with a minimum follow-up time of 2-yr

Untoward event				
	Anterior	Premolar	Molar	Overall
Extraction	5.05%	5.53%	5.75%	5.56%
Retreatment	2.30%	2.18%	2.68%	2.47%
Periradicular surgery	2.79%	1.24%	1.03%	1.41%
Practitioner analysis				
	Anterior	Premolar	Molar	
Types of cases				
Endodontists	12.13%	18.67%	69.18%	
Nonendodontists	21.08%	32.13%	46.79%	
	<i>n</i>	Extraction	Retreatment	Periradicular Surgery
Treatment patterns				
Endodontists	14,718	5.91%	1.48%	2.05%
Nonendodontists	29,895	5.39%	2.96%	1.09%
Patient analysis				
	<i>n</i>	Incidence of Extraction		
Gender				
Male	16,440	5.69%		
Female	16,562	5.56%		
	Mean Age at Time of NSRCT	Mean Age at Time of NSRCT if Subsequently Extracted		
Age				
Male	43.40 yr	46.47 yr		
Female	41.81 yr	44.36 yr		
	<i>n</i>	Incidence of Extraction		
Restoration analysis				
subsequent restoration				
Amalgam or Resin Only	4,684	6.28%		
Full-coverage, Single-Unit	18,365	2.54%		
Full-coverage, Multi-Unit	1,452	4.20%		
No Restoration Recorded	10,024	11.21%		
Subsequent build-up				
Single-unit with post and core	5,812	2.98%		
Single-unit with build-up, but no post and core	6,774	2.20%		
Single-unit with no build-up or post and core	5,779	2.49%		
Multi-unit with post and core	659	3.95%		
Multi-unit with build-up, but no post and core	395	4.81%		
Multi-unit with no build-up or post and core	398	4.02%		
Subsequent post and core				
Cast post and cores	1,649	5.10%		
Prefabricated posts	17,252	3.84%		

(5,779 cases), multi-unit with post and core (659 cases), multi-unit with build-up but no post and core (395 cases), and multi-unit with no build-up or post and core (398 cases). The incidence of extraction for each single-unit group is as follows: single-unit with post and core (2.98%), single-unit with build-up but no post and core (2.20%), and single-unit with no build-up or post and core (2.49%). The incidence of extraction was as follows in the multi-unit category: multi-unit with post and core (3.95%), multi-unit with build-up but no post and core (4.81%), and multi-unit unit with no build-up or post and core

(4.02%). In general, single-unit restorations had a lower incidence of extraction than multi-unit restorations (2.54% versus 4.20%,  $p < 0.001$ ).

#### Comparison of Post and Core Restorations

After NSRCT was performed, 8,901 teeth had post and cores placed; cast post and cores accounted for 1,649 cases (18.53%) and prefabricated post and cores for 17,252 cases (81.47%). The pre-

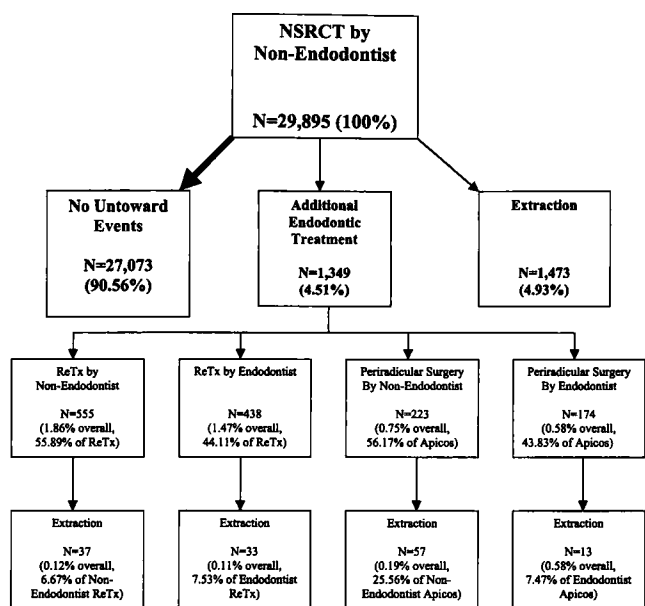


Fig. 1. Treatment patterns for nonsurgical root canal procedures initially performed by nonendodontists.

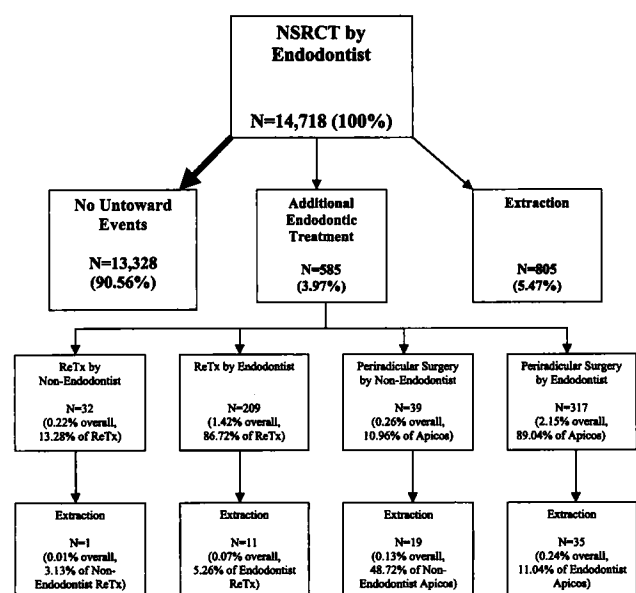


Fig. 2. Treatment patterns for nonsurgical root canal procedures initially performed by endodontists.

fabricated post and core group showed lower incidence of extraction (3.84%) than the cast post and core group (5.10%) ( $p < 0.02$ ).

### DISCUSSION

Endodontic outcomes are difficult to study for several reasons. One of the greatest challenges in determining the outcome of a nonsurgical root canal treatment procedure is the fact that nonendodontic factors, such as the quality of the subsequent restoration, often are major, and at times singular, contributors to the long-term health, retention, and function of teeth after NSRCT (6, 7).

The nature and size of the database in the present study compelled the operational definition of untoward events following

NSRCT as the dependent variable. It is important to realize that this dependent variable is not a proxy for NSRCT failure, because the operational definition of an untoward event includes extraction, retreatment, and periradicular surgery. Untoward events can occur because of both preexisting factors (e.g. root fracture) and post-endodontic factors (e.g. quality of restoration), as well as NSRCT failure. However, the incidence of untoward events after NSRCT is a valuable measure because it provides an integrated measure of overall oral health care delivery to this large population base. Similarly, many nonuntoward events cannot be accounted for in the data; lingering pain and continued periapical pathosis are two such clinically important events that comprise adverse NSRCT outcomes, yet are not necessarily detected by these methods.

The large size of this study population renders inconsequential many potential sources of bias and confounding, although certain factors should be borne in mind while interpreting these results. One notable aspect of this study is its study base. Dental patients who are continuously insured are likely to suffer from different disease patterns than the general population and probably receive different modes of treatment than those who are uninsured.

Probably most important to this analysis, however, is the private practice source of cases treated without any coordination with this study. As discussed above, there are benefits to such an arrangement, including the removal of biases, such as information bias and observer bias and the applicability of results to the everyday practice of endodontists and their referring general dentists. However, this design also incorporates the following features:

1. Endodontic diagnosis, treatment, and follow-up were provided without any standardization among providers.
2. Treatment and referral patterns, although indicative of private practice, were neither standardized nor did they necessarily follow an idealized model of care.
3. Data were collected for insurance reimbursement and did not include information on pretreatment diagnosis, case complexity, patient socioeconomic status, or other factors that may be important to endodontic outcomes.
4. It is possible that some procedures may have been performed but not submitted to the insurance company.

Despite these limitations, we believe that the present results are an important indication of the benefits of endodontic treatment when provided in an integrated health care delivery system of endodontists and their referring general dentists; 94.44% of cases remained functional after an average follow-up time of 3.5 yr. It is equally important to recognize the fact that the study limitations are not conducive to direct comparisons between groups of providers. For example, even though the endodontic practice pattern consisted of a significantly higher proportion of molars (48% more;  $p < 0.001$ ) and a smaller proportion of anterior teeth (43% less;  $p < 0.001$ ) than general dentists, both groups of providers had comparable rates of untoward events. These data strongly support the hypothesis that the specialist practice provides similar rates of clinical success compared with other providers, even when treating significantly more complex endodontic cases.

An analysis of treatment patterns provides insight into the patients experiencing an untoward event. Of the 29,895 NSRCT cases performed by nonendodontists, 1,390 (4.65%) required subsequent retreatment or periradicular surgery. Of these cases, 612 (44.03%) were referred to endodontists for these subsequent procedures. In contrast, of the 597 cases performed by endodontists that required subsequent retreatment or periradicular surgery, 526

(88.11%) remained under the care of an endodontist for the subsequent procedure.

Although the incidence of extraction after retreatment was similar for endodontists and nonendodontists, a striking finding was the significantly higher incidence of extraction after periradicular surgery by nonendodontists: between 25% and 49% of nonendodontist periradicular surgery cases were subsequently extracted, as opposed to between 7% and 11% of endodontist periradicular surgery cases. On average, the results indicate that the failure rate was more than 3-fold greater when apical surgery was performed by nonendodontists compared with endodontists. A prospective study would be required to determine the source of this variation in untoward postsurgical events between these groups of providers.

Perhaps equally interesting were the findings concerning the roles of patient age and subsequent restoration on the incidence of extraction. Several investigators have studied patient age as a predictor of endodontic failure, and both positive (8) and negative (9) associations have been found. However, one recent study also using tooth loss as its dependent variable found that older patients were 1.4 times as likely per 10-yr increase in age to undergo an extraction procedure after root canal therapy (5). Considering the aging U.S. population and declining rates of edentulism, these findings that older patients have an increased risk of tooth loss following NSRCT procedures merits further investigation. One possible explanation may be the increased prevalence of preexisting apical periodontitis with age, which has frequently been associated with decreased endodontic success (1, 10). Patient gender was not associated with extraction following NSRCT, although it is notable that males tended to receive treatment at a significantly later age than females.

Similarly, prior studies have shown the importance of subsequent restoration on tooth retention following NSRCT procedures. In this study this effect was dramatic, with the incidence of extraction increasing more than 4-fold (from 2.54% to 11.21%) when no subsequent restoration code was attributed to the tooth after NSRCT was performed. Single and multi-unit full-coverage restorations provided the highest tooth retention rates, followed by amalgam or resin-only restorations. Build-up and post categories showed little variation between groups.

Multiple factors that were both present and absent from this analysis should be included in a prospective study on NSRCT outcomes. Notably absent from the present study are patient medical/social factors, preoperative diagnostic information, case complexity information, stratified allocation based on treatment complexity, randomized allocation of treatment, and blinded parametric clinical and radiographic follow-up information. Furthermore, a prospective study will benefit from standardized evaluators, recorded techniques, and standardized allocation of cases among providers. The latter will be critical if operator training and experience are factored into the analysis. Based on the large number of retreatment procedures (both nonsurgical and surgical) performed today, an analysis of these more advanced techniques may also provide valuable information on the practice of modern endodontics. Factors included in the present analysis and potentially important for a prospective study include detailed informa-

tion on subsequent restoration and patient demographic information.

Overall, it was found that the incidence of extraction subsequent to NSRCT among a group of 109,542 private practice patients was 3.56% over a mean 14.7 months; a subset of 44,613 patients with a minimum potential follow-up of 2 yr showed an extraction incidence of 5.56% over a mean 20.0 months. Increased patient age, lack of subsequent restoration, and nonendodontist-performed periradicular surgery were associated with greater incidence of extraction.

Using this and previous studies as a benchmark, a prospective study of NSRCT outcomes would allow for the randomization of test subjects, standardization of techniques and sampling methods, and the simultaneous study of multiple variables. However, the low failure rate and long follow-up times needed in endodontics would require careful study design, including rigorous power analyses to ensure the significance of results.

Based on Vire's (6) work, which showed an 8.6% incidence of extraction resulting from true endodontic failure, the overall incidence of extraction found in the present study (5.56%) translates into an NSRCT failure rate of approximately 0.48%. Thus, we can see that NSRCT therapy that is provided in an integrated health care delivery model of endodontists and general dentists is an excellent and predictable system for the retention of diseased teeth.

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