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CLINICAL RESEARCH

Endodontic Treatment Outcomes in a Large Patient Population in the USA: An Epidemiological Study

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Outcome assessment of endodontic treatment is critical for appropriate case selection and treatment planning. However, reports on outcomes of nonsurgical endodontic treatment vary considerably. Epidemiological studies done in a large patient population and over a long follow-up period can provide the clinician with useful tools for clinical decision-making and assessment of tooth prognosis. In this study, outcomes of initial endodontic treatment done in 1,462,936 teeth of 1,126,288 patients from 50 states across the USA was assessed over a period of 8 yr. Treatment was done by private general practitioners and endodontists participating in the Delta Dental Insurance plan that insures approximately 14 million individuals in the USA. Overall, 97% of teeth were retained in the oral cavity 8 yr after initial nonsurgical endodontic treatment. The combined incidence of untoward events such as retreatments, apical surgeries, and extractions was 3% and occurred mostly within 3 yr from completion of treatment. Analysis of the extracted teeth revealed that 85% had no full coronal coverage. A significant difference was found between covered and noncovered teeth for all tooth groups tested ($p < 0.001$). In conclusion, it appears that initial nonsurgical endodontic treatment is a predictable procedure with high incidence of tooth retention after 8 yr.

During the past 50 yr, a number of studies attempted to assess the outcome of endodontic treatment (1, 2). Treatment outcomes varied considerably among the studies and yielded success rates ranging from about 30 to 98% (1). Criteria for assessing success and failure also varied. Outcomes were assessed either by radiographic changes, functionality of the tooth involved and/or by presence of signs and symptoms. Because of lack of standardization, these studies varied considerably in design, treatment protocols, and methodology as well as in recall rates and duration of the observation periods (3) (Table 1).

Another approach to assess the outcome of endodontic therapy is through epidemiological methods. These methods enable the analysis of large cohorts of patient populations as well as multiple treatment variables, providing the clinician with more tools for clinical decision-making and assessment of tooth prognosis. Majority of the epidemiological studies reported in the endodontic literature was conducted in European populations and assessed mainly the prevalence of periapical disease after initial treatment (4). Few epidemiological studies assessed endodontic treatment outcomes in American populations. One study focused on Washington State population and assessed the outcomes of initial treatment in 44,613 patients (5). It was found that about 94% of the teeth remained functional after 3.5 yr. Another epidemiological study, in a dental school patient population, analyzed radiographically the quality of endodontic treatment as related to the prevalence of periapical disease (6). Direct correlation was found between the quality and standards of endododntic treatment and the presence or absence of periapical disease during the follow-up period.

Despite the numerous studies, data obtained from significantly large patient populations regarding endodontic treatment outcomes as well as the occurrence of untoward events such as retreatment, apical surgery and extraction is insufficient. These data play an important role in case selection and treatment planning. It also enables the clinician to make more predictable evidence-based decisions regarding the long-term prognosis of endodontic treatment allowing the patient to retain their natural dentition in function.

The purpose of this study was to analyze retrospectively the outcomes of initial endodontic treatment, and tooth retention over a period of 8 yr in a large patient population from 50 states across the USA.

MATERIALS AND METHODS

Data for this study were obtained from the Delta Dental Insurance Data Center located in Seattle, WA. This company insures

approximately 14 million individuals in 50 states across the USA. It has maintained a computerized database of its claims since 1993.

The protocols and guidelines of evidence-based medicine for prognosis and outcome analysis as suggested by Sackett et al. were followed (7). These included analysis of a large patient population, common point for analysis initiation, long follow-up period, blind outcome criteria and less than 5% loss in patient pool. Subsequently, a large sample of patient population assembled at a common point in the course of endodontic therapy was analyzed. This point was determined as the completion date of the initial nonsurgical root canal treatment (NSRCT) as reported to the Delta Dental Data Center. The patient's treatment data were collected continuously for 8 yr in the database and outcome criteria were applied blindly because none of the dentists submitting the claims were aware that the data would be used for an endodontic outcome analysis in the future.

Patients included in this study were enrolled in the dental plan for a continuous period from 1995 to 2002. Private general practitioners and endodontists performed the endodontic treatments. From a pool of 14 million individuals, a total of 1,126,288 patients had initial root canal therapy done that met the above-mentioned inclusion criteria for this study. A total of 1,462,936 NSRCT procedures done in these patients were analyzed by making a query for the specific ADA procedure code. Procedure 3310 is the ADA code for initial NSRCT in maxillary and mandibular anterior teeth and includes central and lateral incisors and canines. Procedure 3320 is the code for initial NSRCT in maxillary and mandibular first and second premolars. Procedure 3330 is the code for initial NSRCT in maxillary and mandibular first, second, and third molars.

The occurrence of untoward events was analyzed by making a query for the ADA procedure codes 3346, 3347, 3348, 3410, 3421, 3425, 7110, 7120, and 7210. Procedures 3346 is the ADA code for nonsurgical retreatment in maxillary and mandibular anterior teeth, procedure 3347 is the code for nonsurgical retreatment in maxillary and mandibular premolars and procedure 3348 is the code for nonsurgical retreatment in maxillary and mandibular molars. Procedures 3410 is the ADA code for apical surgery in maxillary and mandibular anterior teeth, procedure 3421 is the code for apical surgery in maxillary and mandibular premolars and procedure 3425 is the code for apical surgery in maxillary and mandibular molars. Procedures 7110, 7120, and 7210 are the ADA codes for tooth extraction as related to the degree of difficulty of the procedure.

After completion of initial NSRCT, the teeth were tracked in the database during the entire period and the percentage of teeth that were retained, or presented untoward events, was recorded. The differences between the groups were statistically analyzed using the χ^2 test at 95% level of confidence.

TABLE 1. Variability of factors in studies of endodontic treatment outcome

Factor	Variable
Tooth type	Anterior, premolar, molar
Sample size	10 to 4700
Operator	Students, general practitioners, specialists
Asepsis	Use of rubber dam
Intracanal medication	IKI, $Ca(OH)_2$, CMPC, none
Canal Irrigant	Saline, Chlorhexidine, NaOCl (various concentrations)
Coronal coverage	No, yes, unknown
Recall rate	12% to 100%
Observation period	6 months to 27 years
Technique	Standardized, step back, rotaries
Apical enlargement	Various sizes
Apical extent of filling	Short, flush with apex, long
Treatment sessions	One, two, more
Bacterial Culturing	Yes, no
Control group	Yes, no

RESULTS

A total of 1,462,936 teeth were evaluated in this study and included 309,979 anterior teeth (21%), 390,343 premolars (27%), and 762,614 molars (52%). At the end of the 8-yr observation period, a total of 1,420,963 teeth (97.1%) were retained in the oral cavity.

Anterior Teeth

At the end of the observation period, 302,018 of anterior teeth (97.43%) were retained and 7961 (2.57%) were extracted. Of all treated teeth, 1019 (0.33%) underwent nonsurgical retreatment and 3767 (1.2%) underwent apical surgery (Table 2). Most untoward events occurred during the first 3 yr. During this period, 870 teeth were retreated (85%), 3607 teeth underwent apical surgery (96%), and 6723 teeth were extracted (84%) (Fig. 1).

Premolars

At the end of the observation period, 379,854 premolar teeth (97.32%) were retained and 10,489 (2.68%) were extracted. Of all treated teeth, 1197 (0.31%) underwent nonsurgical retreatment and

TABLE 2. Outcome of initial non-surgical root canal treatments in maxillary and mandibular anterior teeth (n = 309,979)

Months (Year)	0–12 (1)	12–24 (2)	25–36 (3)	37–48 (4)	49–60 (5)	61–72 (6)	73–84 (7)	85–96 (8)	Cumulative total
RETX									
n (%)	432 (0.14)	256 (0.08)	182 (0.06)	99 (0.03)	42 (0.01)	8 (0.00)	0 (0)	0 (0)	1019 (0.33)
Apico									
n (%)	2874 (0.93)	508 (0.16)	225 (0.07)	108 (0.03)	45 (0.01)	7 (0.00)	0 (0)	0 (0)	3767 (1.2)
Extr.									
n (%)	2968 (0.96)	2243 (0.72)	1512 (0.49)	814 (0.26)	352 (0.11)	67 (0.02)	4 (0.00)	1 (0.00)	7961 (2.57)

2216 (0.5%) underwent apical surgery (Table 3). Most untoward events occurred during the first 3 yr. During this period, 1019 teeth were retreated (85%), 2041 teeth underwent apical surgery (92%), and 9156 teeth were extracted (87%) (Fig. 2).

Molars

At the end of the observation period, 738,874 molar teeth (96.89%) were retained and 23,740 (3.11%) were extracted. Of all treated teeth, 3568 underwent nonsurgical retreatment (0.47%), and 3404 teeth underwent apical surgery (0.45%) (Table 4). Most untoward events also occurred during the first 3 yr. During this period, 2890 teeth were retreated (81%), 3115 underwent apical surgery (89%), and 20,985 teeth were extracted (88%) (Fig. 3).

Coronal Restoration and Tooth Retention

Of the 41,973 extracted teeth, 35,697 (85%) had no full coronal coverage (Table 5). Statistically, a significant difference was found between the teeth with crown, and teeth with no crown for all tooth groups tested ($p < 0.001$). Teeth with no crown were classified as teeth that were either not restored at all, or restored with large, multiple-surface amalgam or composite restorations. The number of extracted teeth with no crown was 4.8-fold higher in anterior teeth, 5.8-fold higher in premolars, and 6.2-fold higher in molars as compared to teeth with crown (Table 5).

DISCUSSION

Endodontic treatment outcomes are related to treatment expectations (1). Often, the many endodontic outcome studies published in the literature vary in their results regarding the incidence of success and failure of initial endodontic therapy. While in several studies treatment success is measured by radiographic and clinical normalcy, others refer only to clinical normalcy (2, 3).

In this study, we attempted to analyze the outcomes of initial endodontic treatment from an epidemiological perspective considering tooth retention in the oral cavity as evidence of treatment success and the occurrence of untoward events as treatment failure. Observation of a large patient population over an 8-yr period revealed a high retention rate of teeth after initial endodontic treatment regardless of the etiology, specific treatment technique, tooth group, or special patient characteristics. Overall, about 97% of teeth were retained in the oral cavity for 8 yr after completion of the initial nonsurgical endodontic treatment. Our findings agree with other follow-up studies indicating that the chance of endodontically treated teeth to remain functional over time is 91 to 97% (1). From an epidemiological point of view, our results are comparable to those of Lazarski et al. (5) who reported an incidence of 94% of teeth being functional 3.5 yr after initial endodontic treatment. Our slightly higher tooth retention rate could be because of the larger patient population and longer follow-up period. Moreover, several studies have indicated that the degree of healing of endodontic disease after treatment increased over time (8–11) and in some cases it might take a long time after initial therapy (12, 13).

It is interesting to note that most endodontic clinical failures requiring additional intervention such as orthograde retreatment, apical surgery, or extraction were recognized within the first 3 yr (Figs. 1–3). This is in agreement with the observations of Nobuhara and Del Rio (14) who found that the majority of apical surgeries were performed within the first 2 yr after completion of orthograde endodontic therapy. It is most likely that such failures may have resulted from unresolved sign and symptoms, failing restorative treatment, root fractures, and/or iatrogenic causes. However, this specific information could not be obtained from the Delta Dental database.

Less than 0.5% of all treated teeth underwent nonsurgical retreatment during the 8- yr observation period. Incidence of retreat-

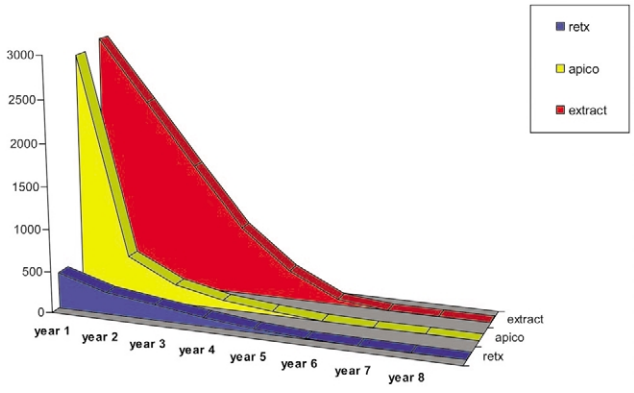

FIG 1. Number of untoward events in maxillary and mandibular anterior teeth per year of follow-up observation (n = 12,747).

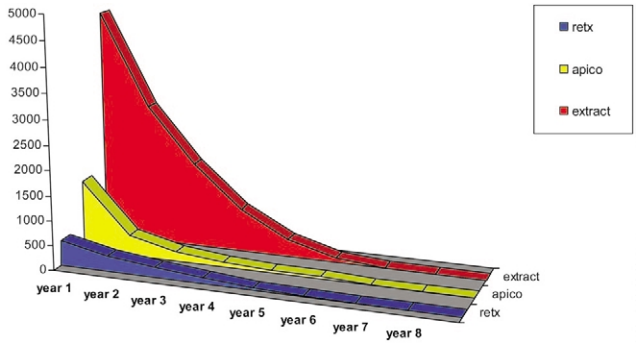

FIG 2. Number of untoward events in maxillary and mandibular premolar teeth per year of follow-up observation (n = 13,902).

TABLE 3. Outcome of initial non-surgical root canal treatments in maxillary and mandibular premolar teeth (n = 390,343)

Months (Year)	0–12 (1)	12–24 (2)	25–36 (3)	37–48 (4)	49–60 (5)	61–72 (6)	73–84 (7)	85–96 (8)	Cumulative total
RETX,	501	313	205	120	38	18	2	0	1197
(%)	(0.13)	(0.08)	(0.05)	(0.03)	(0.01)	(0.00)	(0)	(0)	(0.31)
Apico,	1429	418	194	87	47	40	1	0	2216
(%)	(0.37)	(0.11)	(0.05)	(0.02)	(0.01)	(0.00)	(0)	(0)	(0.56)
Extract,	4642	2804	1710	877	361	82	9	4	10,489
(%)	(1.19)	(0.72)	(0.44)	(0.22)	(0.09)	(0.02)	(0.00)	(0)	(2.68)

TABLE 4. Outcome of initial non-surgical root canal treatments in maxillary and mandibular molar teeth (n = 762,614)

Months (Year)	0–12 (1)	12–24 (2)	25–36 (3)	37–48 (4)	49–60 (5)	61–72 (6)	73–84 (7)	85–96 (8)	Cumulative total
RETX,	1249	998	643	425	198	50	2	3	3568
(%)	(0.16)	(0.13)	(0.08)	(0.03)	(0.01)	(0.00)	(0)	(0)	(0.47)
Apico,	2084	706	325	178	81	26	4	0	3404
(%)	(0.27)	(0.09)	(0.04)	(0.02)	(0.01)	(0.00)	(0)	(0)	(0.45)
Extr,	11378	6103	3504	1842	732	163	16	2	23,740
(%)	(1.49)	(0.80)	(0.46)	(0.24)	(0.10)	(0.02)	(0.00)	(0)	(3.11)

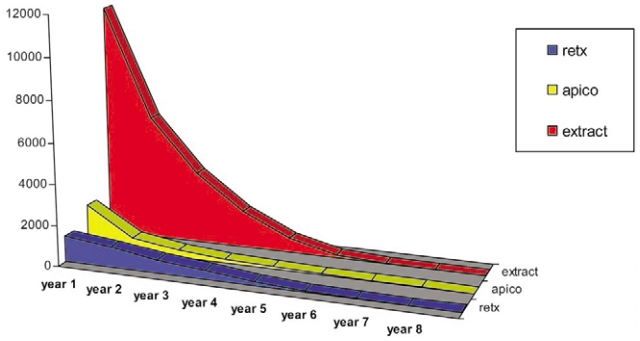

FIG 3. Number of untoward events in maxillary and mandibular molars teeth per year of follow-up observation (n = 30,712).

TABLE 5. Distribution of extracted teeth in relation to coronal coverage

	Crown with post	Crown without post	No Crown
Anterior,	770	574	6565
(%)	(9.7)	(7.3)	(83)
Premolars,	752	808	8879
(%)	(7.2)	(7.7)	(85.1)
Molars,	925	2447	20253
(%)	(3.9)	(10.4)	(85.7)

ment was comparable in all tooth groups showing a similar behavior pattern like the other untoward events, mostly occurring at the initial stages of the follow-up period. Although our study could not determine the presence or degree of apical periodontitis associated with the analyzed teeth, it seems that the majority of initial nonsurgical root canal treatments were successful in addressing the symptoms of endodontic disease enhancing patient motivation for tooth retention.

Of the teeth requiring apical surgery, anterior teeth were the predominant group (1.2%) followed by premolars (0.56%) and molars (0.45%). This may be a result of several reasons. Firstly, it has been shown that periapical cyst formation was more frequent in the anterior segments of the jaws, especially in the maxilla (15–16). Some of these lesions may not respond to nonsurgical endodontic therapy thus requiring surgical removal (17). Secondly, radiographic appearance of periapical lesions may be more evident in areas where the lesion could readily affect the integrity of the cortical bone (18). Thirdly, decisions for case selection could have been affected because most practitioners would probably be more comfortable performing apical surgery in the anterior rather than posterior dentition because of better visibility and easier access.

Our analysis of the teeth extracted during the follow-up period revealed that more than 83% had no full coronal coverage. This group included teeth without any coronal restoration or teeth with large, multiple-surface amalgam or composite restorations. The number of extracted teeth without full coronal coverage was five to six times higher than fully covered teeth. Our results agree with others reporting that endodontically treated teeth without full coronal coverage were lost at a rate six times greater than fully covered teeth (19). This implies that the restorative phase after initial endodontic treatment most likely effects the survival rate of endodontically treated teeth, specially in the posterior dentition.

Several studies have shown the importance of coronal protection for the long-term survival of endodontically treated teeth. Vire (20) found that 59% of extractions of endodontically treated teeth occurred because of restorative or prosthetic failure and crown fractures. Fennis (21) suggested that endodontically treated teeth were more susceptible to unfavorable subgingival fracture and recommended cuspal coverage in all cases. Lagouvardous (22) found that 83% of fractured endodontically treated teeth had three or more restored surfaces. The majority of factures (84%) occurred below or at the crestal bone level contributing to the poor prognosis of the tooth. Hansen (23), in a 20 yr retrospective study, found that amalgam without cuspal coverage was not adequate for coronal restoration of endodontically treated teeth and concluded that cuspal coverage was critical for their long-term prognosis. Reeh (24) showed that the endodontic access cavity caused only 5% decrease in tooth stiffness while MOD preparation decreased stiffness by more than 60%. Therefore, it is the cumulative loss of tooth structure from caries, restorative as well as endodontic procedures that might increase the possibility of fracture of teeth without full coronal coverage.

Most of the extracted teeth with full coronal coverage had no post. No significant differences were found between teeth with and without post. This is in agreement with Sorensen and Martinoff (25) who suggested that the role of the core is more critical than the post for the long-term success of endodontically treated teeth. It is therefore recommended that teeth undergoing endodontic treatment be restored as soon as possible to prevent coronal leakage or coronal fracture. If the tooth does not require a post, a core should be placed upon completion of canal obturation or soon thereafter. Final restoration with full cuspal coverage should be done if the tooth has lost three or more surfaces.

In conclusion it is apparent that nonsurgical endodontic treatment is a predictable procedure with an excellent long-term prognosis and 97% tooth retention rate. Multiple factors may affect the outcome of treatment, but in this study it was not possible to account for all such factors nor was it possible to analyze the characteristics of other untoward events such as postoperative pain or presence or absence of periapical inflammation. However, the high tooth retention rate after 8 yr may well be associated with tooth functionality and patient comfort. In fact, it was reported that the vast majority of patients (97%) reported improved quality of

life and satisfaction with their decision to have endodontic treatment rather than extraction (26).

With regard to retention rate of teeth, the trend of endodontic outcomes found in the large patient population used in this study, can be useful to the clinician for a rational evidence-based case selection and endodontic treatment decision-making.

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