The effect of diabetes mellitus on endodontic treatment outcome

Data from an electronic patient record

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Nonsurgical endodontic treatment has two main objectives: the prevention and the treatment of periradicular lesions. The prevention of a periradicular lesion is achieved by excising vital, irreversibly inflamed dental pulp or noninflamed pulp treated for restorative reasons, and then preparing and obturating the canal space. During the treatment of pre-existing periradicular lesions, the added step of minimizing or significantly reducing microbial irritants in the endodontic system must be achieved for optimal prognosis. Despite the best attempts at eliminating microbial presence in cases with periradicular lesions, studies have shown that the prognosis of treatment in these cases is about 10 to 20 percent less than in cases with no lesions.[1-3]

The findings associate diabetes with a decrease in the success of endodontic treatment in cases with preoperative periradicular lesions.

Treatment outcome in endodontics usually is assessed by several parameters. These include the resolution of signs and symptoms of pulpal and periradicular pathosis and the ability to adequately prepare, obturate and coronally seal the endodontic system, as determined from the postoperative radiograph. More importantly, however, the treatment outcome should be determined at annual or semiannual follow-up examinations for at least two to four years when it is established that no new periradicular lesions have developed and that any pre-existing lesions have completely healed, regardless of signs and symptoms.

ABSTRACT

Background. The authors used a custom-built electronic record system to investigate endodontic diagnostic and treatment outcome data in patients with and without diabetes.

Methods. The medical histories and endodontic treatment data for nonsurgical endodontic patients treated in predoctoral and postgraduate specialty clinics were entered into an electronic record system. A total of 5,494 cases (including 284 cases in patients with diabetes) were treated, and 540 cases (including 73 cases in patients with diabetes) had follow-up data two years or more postoperatively. The authors performed univariate and multivariate analyses to determine important factors affecting endodontic diagnosis and treatment outcome.

Results. Patients with diabetes had increased periodontal disease of teeth with endodontic involvment compared with patients who did not have diabetes. There was a trend toward increased symptomatic periradicular disease in patients with diabetes who received insulin, as well as flare-ups in all patients with diabetes. Two years or longer postoperatively, 68 percent of cases followed were successful. Older age, the absence of preoperative lesions, the presence of permanent restorations and longer postoperative evaluation periods all were associated with a successful outcome. A multivariate analysis showed that in cases with preoperative periradicular lesions, a history of diabetes was associated with a significantly reduced successful outcome.

Conclusions. Patients with diabetes have increased periodontal disease in teeth involved endodontically and have a reduced likelihood of success of endodontic treatment in cases with preoperative periradicular lesions.

Clinical Implications. Patients with diabetes who are treated endodontically should be assessed carefully and be treated with effective antimicrobial root canal regimens, particularly in cases with preoperative lesions.

Diabetes mellitus, or DM, is a major source of morbidity and economic expense in the United States. Approximately 16 million people have DM, of which nearly 1 million have insulin-dependent DM, or IDDM.[4] People with diabetes are considered to be at a significantly higher risk of systemic infection[5,6] and hospitalization due to infectious disorders (particularly septicemia and respiratory disorders)[7-9] than are people who do not have diabetes.

Few data, however, are available on the pathophysiology and clinical progression of periradicular lesions or the prognosis of endodontic treatment in patients with DM. An earlier report indicated that lesions will not heal if diabetes is not controlled and that the lesions will increase in size despite endodontic treatment.[10] In a Swedish population, residents with long-duration IDDM were found to have an increased prevalence of endodontically treated teeth with periradicular lesions compared with residents who had short-duration IDDM or age- and sex-matched people who did not have diabetes.[11] In a clinical study, radiographic healing of periradicular lesions after endodontic treatment was closely monitored in 12 patients with low-plasma glucose (70-89 milligrams per deciliter) and 13 patients with high-plasma glucose (90-110 mg/dL).[12] Blood glucose was measured two hours postprandially at the time of endodontic treatment. After 30 weeks, the periradicular radiolucencies in the patients in the low-glucose groups were reduced by an average of 74 percent compared with a reduction of only 48 percent in the patients in the high-glucose group. In streptozocin-induced hyperglycemic rats, induced periradicular lesions were larger than lesions in normoglycemic controls.[13] No significant infections and no mortality among the hyperglycemic rats were reported in that study. However, Fouad and colleagues[14] and Ueta and colleagues[15] have shown that the presence of DM may make the host more susceptible to severe endodontic infections with significant morbidity.

Our objectives in conducting this study were to investigate a number of endodontic treatment parameters and the factors affecting the endodontic treatment outcome of patients with and without diabetes in a dental school patient population that were documented in an electronic patient record.

The Endodontic Electronic Record has been used to document treatment information for patients who received an endodontic evaluation and treatment.

MATERIALS AND METHODS

Endodontic Electronic Record system. The Endodontic Electronic Record, or EER, has been used to document treatment information for patients who received an endodontic evaluation and treatment in the predoctoral and postgraduate endodontology clinics at the School of Dental Medicine, University of Connecticut Health Center in Farmington. The EER is a secured client/server relational database system we developed using FileMaker Pro for Windows/Macintosh, versions 3 through 5.5 (FileMaker, Santa Clara, Calif.) that runs on the health center's local area network. The system is accessed chairside by providers who enter patients' medical histories, endodontic diagnoses, treatment and follow-up data.

Data for predoctoral students' patients are verified and cosigned electronically by the supervising instructors during the clinic session. Full-time faculty members periodically review postgraduate students' cases, using the electronic interface in their offices. The system, which also contains digitized radiographs of the treatment, organizes endodontic follow-up examinations and contains data on treatment outcomes for those cases for which patients returned for follow-up examination.

Endodontology faculty (who include a number of part-time endodontists from the community) and postgraduate students are calibrated at least once annually on record entries. Predoctoral students receive didactic instruction on record entries and have to demonstrate a competency by entering data for a simulation case before they can start entering actual patient data.

Patient data. The patient cohort included in this study consisted of all patients receiving nonsurgical endodontic treatment who were treated by predoctoral students (starting in January 1995) and postgraduate students (starting in January 1997) at the School of Dental Medicine, University of Connecticut Health Center through mid-October 2001. We restricted the study to those patients for whom the medical history (as reported by the patient at the time of treatment

and updated at the time of follow-up examinations) and endodontic diagnostic and treatment information were available. We obtained special permission from the institutional review board of the University of Connecticut Health Center to download and use anonymous information on these patients for this study.

We included history of DM as an independent variable. Since the inception of the EER, we generally designated history of diabetes as IDDM or noninsulin-dependent DM, or NIDDM. The current classification of type 1 and type 2 DM, however, distinguishes the two types by factors other than the just treatment with insulin,[16] since a number of patients with type 2 diabetes are treated with insulin. Nevertheless, information on whether patients whose data were entered before the new classification was adopted belonged to type 1 or type 2 was not available, so we categorized the patients using the older designations of IDDM, NIDDM or without diabetes in this report. Information on fasting blood glucose levels or glycated hemoglobin values, which would indicate the degree of glycemic control of the patients with diabetes, was not available.

BOX

DEFINITIONS OF OUTCOME CATEGORIES.

OUTCOME CATEGORY	DEFINITION
Success	— A tooth that had no preoperative periradicular radiolucency of endodontic origin and continued to show no radiographic or clinical abnormalities at the time of follow-up. — A tooth that had a preoperative periradicular radiolucency but showed bone deposition or no apical rarefaction. The periodontal ligament space was intact or up to twice the width of neighboring teeth at the time of follow-up examination.
Failure	— Periradicular pain, swelling or a sinus tract related to the tooth being evaluated. — A periradicular radiolucency that had developed after completion of treatment. — A preoperative lesion had not resolved or had partially resolved in three to four years with or without pain, swelling, a sinus tract or deep isolated probing of endodontic origin.
Uncertain	A lesion that has healed partially at six months to three years with no symptoms. Within three to four years from the date of completion of treatment, the outcome of all cases is determined to be either a success or a failure.

Treatment and follow-up protocols. Predoctoral and postgraduate endodontology students performed nonsurgical endodontic treatment. Cases with vital pulp were completed in a single visit if time allowed; if not, they were completed in multiple visits, and a calcium hydroxide paste was placed as intracanal medicament between visits. All cases with a necrotic pulp were completed in at least two visits, and a calcium hydroxide paste was placed as an intracanal medicament between visits. Nonsurgical retreatments were performed mostly by postgraduate students using the multivisit protocol. Patients generally did not receive supplementary antibiotics unless they had to receive antibiotics before treatment for a systemic reason or if they had a spreading periradicular infection, characterized by fever, malaise, lymphadenopathy or diffuse extraoral swelling. After completion of treatment, a predoctoral student or general dentistry resident restored the tooth involved, or the patient was referred back to the referring dentist for restoration. The protocol for follow-up examinations was that the first examination was at six months postoperatively, followed by annual examinations for two to four years, depending on the availability of the patient and the ability to determine the treatment outcome with certainty.

At the time of the follow-up examinations, the follow-up provider (who may or may not have been the same as the treatment provider) determined whether the treatment was successful, had failed or had an uncertain outcome. Predoctoral providers made this determination after consulting with the supervising endodontology instructor, who cosigned the computer entry. Furthermore, in uncertain or failed cases, providers documented the most likely cause of failure or uncertainty. As noted previously, all instructors and providers were calibrated at least once annually on the definitions of the three outcome categories (Box).

Statistical analysis. We examined two main categories of data in this study: diagnostic data and treatment outcome data. We compared both sets of data in patients with IDDM or NIDDM or without diabetes. Whenever we determined that the sample size of the two groups of patients with diabetes was small, we combined both groups. We

TABLE 1

PATIENT POPULATION.

PATIENT GROUP	TOTAL NO. OF PATIENTS (%)	TOTAL NO. CASES OF ENDODONTIC PROCEDURES AVAILABLE (%)	NO. OF COMPLETED NONSURGICAL ENDODONTIC TREATMENT CASES (%)	NO. OF NONSURGICAL ENDODONTIC TREATMENT CASES WITH ANY FOLLOW-UP (%)	NO. OF NONSURGICAL ENDODONTIC TREATMENT CASES WITH FOLLOW-UP TWO YEARS OR MORE (%)*
IDDM†	58 (1)	97 (1)	70 (1)	35 (2)	17 (3)
NIDDM‡	184 (4)	297 (4)	214 (4)	129 (7)	56 (10)
Without Diabetes	5,002 (95)	7,122 (95)	5,210 (95)	1,656 (91)	467 (86)
TOTAL	**5,244**	**7,516**	**5,494**	**1,820**	**540**

* Figures include all cases that failed at any time, and the nine cases that failed owing to vertical root fractures and were eliminated from analysis of outcome data.
† IDDM: Insulin-dependent diabetes mellitus.
‡ NIDDM: Noninsulin-dependent diabetes mellitus.

examined data in the three patient categories by case (defined as a procedure on a tooth). The variables for diagnostic data included the associated periodontal disease of the teeth examined or treated endodontically, the presence of symptomatic apical periodontitis, the presence of a sinus tract and the incidence of interappointment flare-ups. Flare-ups were cases in which on the second or any subsequent visit the patient returned for treatment with acute symptoms; this may or may not have been a scheduled visit. We compared the distribution of different parameters within these variables using a χ^2 analysis. We also compared the diameter of preoperative lesion in millimeters, as indicated by the provider, in the three groups using analysis of variance, or ANOVA.

If the case had been examined more than once postoperatively, we restricted treatment outcome data to data from the last available follow-up examination. We included only data for cases with two years or more of follow-up examinations in the final analysis, with the exception of cases that failed, which we included regardless of when the failure was determined. The variables that we examined as to their influence on the outcome included age, sex, tooth type, history of DM, the presence of a preoperative periradicular lesion, procedure (primary treatment vs. retreatment), status of the provider (predoctoral vs. postgraduate vs. both—patients whose treatment was started by predoctoral students, then was referred to postgraduate students), presence of a restoration at the time of the last follow-up examination and length of postoperative period in months until the last follow-up visit. Initially, we used a χ^2 analysis to determine the association of each variable individually with treatment outcome, except for the postoperative time in months, which we examined using ANOVA. In the final analysis, we performed a multivariate logistic regression analysis to control for a number of confounding factors.

RESULTS

The patient population included in this study is described in Table 1. Many of the patients' endodontic treatments were not completed. They either did not require endodontic treatment, decided to seek treatment elsewhere after the initial examination or had started endodontic treatment but did not return to have it completed. Also, many patients who had completed endodontic treatment did not return for follow-up examinations. The most common reasons for why follow-up examinations were not performed were that the patient could not be contacted, did not wish to return for a follow-up examination, had moved or had the tooth extracted for an unknown reason. We did not include patients in the last category in the analysis of the follow-up data.

Diagnosis. It is well-documented that patients with DM have increased prevalence and severity of periodontal disease.[17,18] Therefore, we studied a number of periodontal disease parameters of the teeth examined, treated endodontically or both in patients with and without diabetes. We found that patients with a history of IDDM had a higher percentage of periodontal disease measures than did patients with NIDDM who, in turn,

TABLE 2

PERIODONTAL DISEASE PARAMETERS FOR TEETH EXAMINED OR TREATED ENDODONTICALLY, BY PATIENT GROUP.*

PATIENT GROUP	NO. WITHOUT PERIODONTAL DISEASE (%)	NO. WITH GINGIVITIS (%)	NO. WITH GENERALIZED PROBING (%)	NO. WITH FURCATION INVOLVEMENT (%)	NO. WITH ISOLATED PROBING (%)	TOTAL
IDDM†	57 (64)	4 (4)	10 (11)	2 (2)	16 (18)	89
NIDDM‡	178 (67)	10 (4)	30 (11)	4 (2)	43 (16)	265
Without Diabetes	4,858 (75)	115 (2)	480 (7)	81 (1)	931 (14)	6,465

* The differences among the three patient groups were statistically significant $\chi^2_8 = 20.85$, $P = .008$.
† IDDM: Insulin-dependent diabetes mellitus.
‡ NIDDM: Noninsulin-dependent diabetes mellitus.

had a higher percentage of periodontal disease measures than did patients who did not have diabetes (Table 2). These differences were statistically significant ($\chi^2_8 = 20.85$, $P = .008$).

Among patients diagnosed with periradicular pathosis, a higher percentage was patients with IDDM diagnosed with acute apical periodontitis or exacerbating apical periodontitis (the two symptomatic diagnoses of periradicular pathosis) compared with patients with NIDDM or patients without diabetes (Table 3). The differences among the three groups of patients showed a strong trend toward being statistically significant ($\chi^2_2 = 5.7$, $P = .058$). We performed an analysis of the number of cases in which flare-ups were noted during treatment, regardless of the number of flare-ups each case had and the degree of pain that the patient had preoperatively. Table 4 shows that patients with diabetes had almost twice as many flare-ups than did patients who did not have diabetes; however, this difference was not statistically significant (χ^2_1 diabetic vs. nondiabetic = 2.83, $P = .09$).

In cases with pulp necrosis and a periradicular lesion, we found no statistically significant differences among the three patient groups in the presence of a preoperative sinus tract or preoperative swelling (χ^2 test, $P > .1$). Furthermore, we found no differences in the preoperative lesions' diameters in millimeters, as noted by the providers based on preoperative radiographs (ANOVA, $P > .9$).

Treatment outcome. About 33 percent of the total number of cases treated nonsurgically had follow-up data of six months or longer postoperatively. The number of cases, however, with follow-up data of two years or longer, including those

TABLE 3

NUMBER AND PERCENTAGE OF CASES WITH SYMPTOMATIC APICAL PERIODONTITIS, BY PATIENT GROUP.*

PATIENT GROUP	TOTAL NO. OF CASES WITH SYMPTOMATIC APICAL PERIODONTITIS (%)	TOTAL NO. OF CASES WITH PERIRADICULAR PATHOSIS
IDDM†	22 (51)	43
NIDDM‡	35 (31)	114
Without Diabetes	1,244 (38)	3,297

* There was a trend toward a statistically significant difference among the patient groups $\chi^2_2 = 5.7$, $P = .058$.
† IDDM: Insulin-dependent diabetes mellitus.
‡ NIDDM: Noninsulin-dependent diabetes mellitus.

that failed at any time, represented only about 10 percent of the sample. The most probable reasons for failed cases were noted at the follow-up examination. Providers documented that nine failed cases (one in a patient with NIDDM and eight in patients who did not have diabetes) had vertical root fractures, so we eliminated these cases from further analysis. We dichotomized the outcome into "successful" and "unsuccessful"; the latter category included the uncertain group that could not be called successful at the last recall. The successful group represented 361 of 531 of all cases (68 percent).

In cases from all patients who returned for follow-up examination two years or longer postoperatively, the effects of sex, tooth type (anterior vs. premolar vs. molar) or the presence of a preoperative sinus tract did not reveal any significant

TABLE 4

THE INCIDENCE OF FLARE-UPS IN ALL CASES FROM THE THREE PATIENT GROUPS.*

PATIENT GROUP	NO. OF CASES WITH PRESENCE OF FLARE-UPS	% WITH FLARE-UPS	NO. OF CASES WITH ABSENCE OF FLARE-UPS	TOTAL NO. OF CASES WITH DOCUMENTED PRESENCE OR ABSENCE OF FLARE-UPS
IDDM†	1	4.0	24	25
NIDDM‡	5	4.7	102	107
Without Diabetes	64	2.3	2,692	2,756
TOTAL	70	2.4	2,818	2,888

* An analysis of the cases of patients with diabetes (collectively) vs. patients without diabetes revealed that the differences were not statistically significant at the $P = .05$ level $\chi^2_1 = 2.83$, $P = .09$.
† IDDM: Insulin-dependent diabetes mellitus.
‡ NIDDM: Noninsulin-dependent diabetes mellitus.

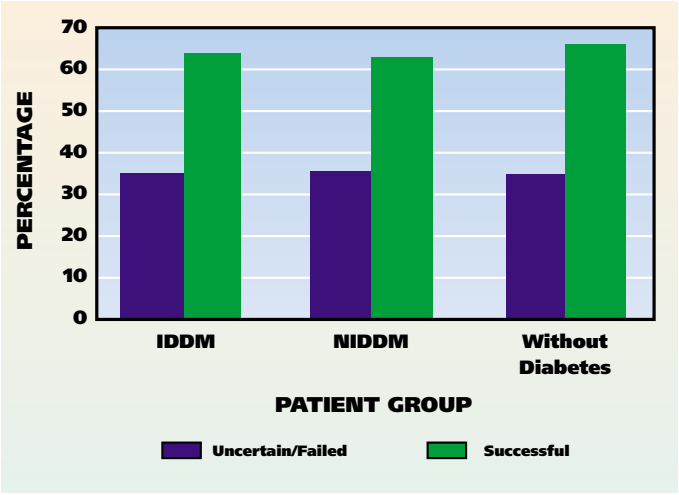

Figure 1. Treatment outcome among cases of patients with insulin-dependent diabetes mellitus, or IDDM, or noninsulin-dependent diabetes mellitus, or NIDDM, and patients without diabetes. The differences were not statistically significant ($\chi^2_2 = 0.65$, $P > .7$).

differences in treatment outcome (χ^2 test, $P > .2$). As expected, cases with a preoperative periradicular lesion had much less chance of being successful than did cases with no lesions ($\chi^2_1 = 47.318$, $P < .0001$). To examine the effect of age on the outcome, we divided all cases into three groups: younger than 40 years (n = 118), 40 to 60 years (n = 234) and older than 60 (n = 178) years old. The success rates in the three groups were: 61 percent, 66 percent and 76 percent, respectively. These differences were statistically significant ($\chi^2_2 = 8.2$, $P = .017$).

The treatment outcome was not different among the patient groups with IDDM or NIDDM and without diabetes (Figure 1) ($\chi^2_2 = 0.65$, $P > .7$). When we considered only cases with preoperative periradicular lesions, however, the results were very different. There was only one failing case in a patient with IDDM in this group; therefore, we combined both groups of patients with diabetes. An analysis of the treatment outcome in these cases revealed that there were significantly fewer successful cases in patients with diabetes and with preoperative periradicular lesions ($\chi^2_1 = 7.2$, $P = .0073$) (Figure 2). We found that the presence of periodontal disease of the tooth that received the endodontic treatment was not significantly related to the outcome (χ^2 test, $P > .2$), although there was a trend toward a decrease in success in cases with a preoperative periradicular lesion if the tooth also had periodontal disease ($\chi^2_1 = 3.08$, $P = .08$).

We analyzed a number of other highly probable confounding factors in the overall follow-up cohort. We found that the success rate was reduced in retreatments compared with primary treatments ($\chi^2_1 = 4.6$, $P = .03$) (Figure 3) and in cases without a permanent restoration at the time of follow-up compared with those with a restoration ($\chi^2_1 = 64$, $P < .0001$). Cases started by predoctoral students that were referred to postgraduate students (we presume due to errors or difficulty during treatment) had a lower percentage of success compared with cases treated only by postgraduate students, which, in turn, had a lower percentage of success than cases treated by predoctoral students ($\chi^2_2 = 27.1$, $P < .0001$). In cases with a preoperative periradicular lesion, the presence of a preoperative sinus tract did not affect the treatment outcome (χ^2 test, $P > .2$). The length of time from final obturation to the last follow-up examination was an important variable since it was significantly less for failed cases than for successful or uncertain cases (ANOVA, $P < .0001$). This finding may be due to the fact that we included in our analysis failures at any time postoperatively and because longer periods are needed to demonstrate complete healing of the lesion.[19]

Because of the confounding factors that

affected the treatment outcome, we structured a hierarchical logistic regression that examined which variables might predict the probability of a successful outcome at two years postoperatively. In this model, we examined only cases with preoperative lesions (n = 178), since they were the patients most at risk of not healing and were the category of patients in which treatment outcome in patients with and without diabetes differed. The overall six-variable model was highly significant ($\chi^2_7 = 34.31$, $P < .001$). Individual Wald tests showed that treatment outcome was not significant for sex, age (raw data in years) or procedure (endodontic treatment vs. retreatment). There was a trend toward significance, however, for provider (predoctoral, postdoctoral or both, Wald test = 2.76, $P = .097$) such that students had a higher likelihood for success (adjusted odds ratio = 2.08). There was a significant effect for restoration (Wald test = 10.34, $P = .001$) in that cases restored at the time of last follow-up showed a higher likelihood for success than did cases without a permanent restoration (adjusted odds ratio = 6.62). There was a significant effect for diabetes status (Wald test = 6.87, $P = .009$) in that the patients without diabetes had a higher likelihood for success than did the patients with diabetes (adjusted odds ratio = 8.13). Finally, none of the other factors moderated the effects of diabetes.

DISCUSSION

The advantage of using an electronic patient record in this study was that we were able to track several patient- and treatment-related factors over an extended period and to easily analyze the outcome data once a sufficient sample was available to show particular trends. We developed the program using a generic relational database program, and it was flexible enough to allow adding specific fields to monitor a variety of important clinical parameters that are not, to the best of our knowledge, collectively offered in commercially available programs. The program was sufficiently secure and robust to conform to generally accepted patient record guidelines.

Despite the annual calibration of the users of this system and the presence of policies and software features that ensure accurate data entry, the information presented should be considered retrospective. This is due to the fact that multiple providers participated in data entry and that subjective assessments were made on the interpretation of clinical data and radiographs and the determination of treatment outcome. Nevertheless, the clinical data entered in this system were valid in that patient care decisions were based on them. Because of the relatively large sample presented, we observed significant findings that warrant further objective prospective investigations.

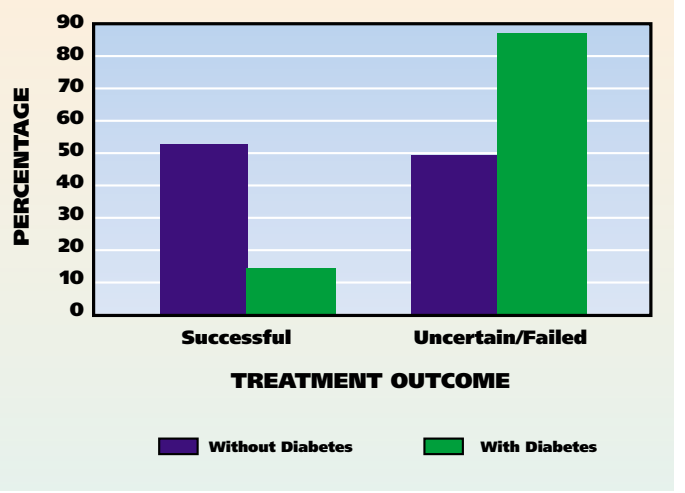

Figure 2. Treatment outcome among the cases of patients with and without diabetes and with preoperative periradicular lesions. The difference was statistically significant ($\chi^2_1 = 7.2$, $P = .0073$).

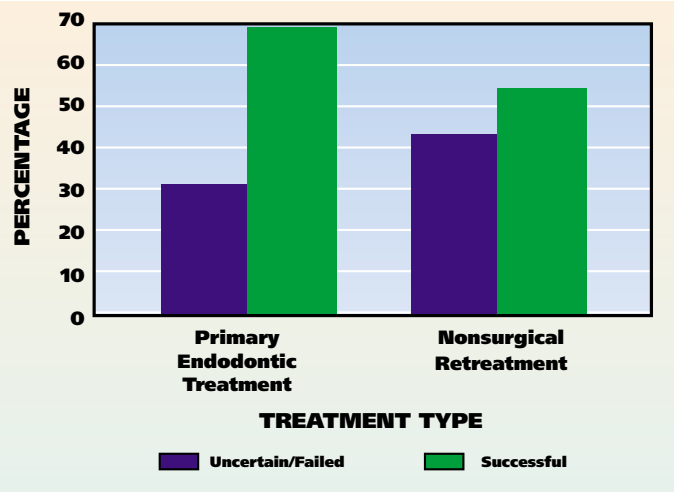

Figure 3. Success rate in retreatments compared with primary treatments in all patient groups. The difference was statistically significant ($\chi^2_1 = 4.6$, $P = .03$).

In this study, we determined that 68 percent of all cases were successful at two years or longer after treatment. This treatment outcome should not be compared with traditional prognosis studies,[3,20] as a relatively small percentage of treated cases were evaluated during the follow-up period. The smaller percentage of follow-ups may reduce the overall success rate observed, as

patients with failing and uncertain cases are likely to return for follow-up, particularly if they are symptomatic. It is not, however, known that any of the independent variables examined may influence the follow-up rate, therefore, the analyses performed of the effects of these variables on the outcome are justified. Additionally, the postoperative follow-up period used in this study was relatively short. Preoperative lesions may take longer than two years to heal completely.[19]

Among the most important findings of this study is the fact that the success of endodontic treatment two years or longer postoperatively in cases with preoperative lesions was reduced more in patients with diabetes compared with patients without diabetes. This was true even when we controlled for a number of other significant risk factors. This finding, which to our knowledge has not been reported previously, may be related to a number of factors. Patients with diabetes have documented alterations in immune functions such as depressed leukocyte adherence, chemotaxis and phagocytosis, as well as increased adherence of microorganisms to diabetic cells.[21,22] Furthermore, patents with diabetes (particularly those with moderate-to-severe periodontitis) have been shown to have significantly increased gingival crevicular levels and monocytic secretion of the important inflammatory mediators prostaglandin E_2, interleukin-1β, and tumor necrosis factor-α, compared with control patients without diabetes.[23]

The success of endodontic treatment two years or longer postoperatively in cases with preoperative lesions was reduced more in patients with diabetes compared with patients without diabetes.

Fouad and colleagues[14] have shown previously in a mouse model that type 1 diabetes has increased morbidity and even mortality in response to endodontic infections compared with control mice without diabetes. Patients with diabetes also may have qualitatively or quantitatively different endodontic microbial flora from patients without diabetes, which makes them susceptible to more severe periradicular disease. Fouad and colleagues[24] recently compared the presence of 10 putative pathogenic bacteria in root canals with the necrotic pulp of patients with and without diabetes using polymerase chain reaction–based identification techniques. In that study, some potential trends of associations were determined between the presence of DM and certain virulent root canal bacteria. A more pathogenic microbial profile in the necrotic pulps of patients with diabetes compared with patients without diabetes may explain the trends toward increases in incidences of painful apical periodontitis and flare-ups that were noted in the current study.

We found no differences in outcome between patients with and without diabetes in the overall cohort of cases, including those with no periradicular lesions. This directly implicates the root canal infectious process in accounting for the differences between both patient groups. Thus, further studies in this area using sensitive microbiological techniques and objective pain measures are warranted.

Cases treated by postgraduate students as primary or secondary providers had lower percentages of success compared with cases treated by predoctoral students. Predoctoral students treated comprehensive care patients, whereas postgraduate students saw many referrals from outside practitioners for limited endodontic care. This tended to decrease the follow-up rate among postgraduate students' patients and potentially skewed their follow-up pool toward failing cases. Postgraduate students also treated more difficult cases, including retreatments, which had lower levels of success than primary treatments in this and another study.[3] In a recent treatment outcome study based on insurance data, the study's authors noted that the incidence of tooth extraction (used as an outcome for endodontic success) was comparable in cases treated by general dentists and endodontists.[25] The technical complexity of endodontic cases and its effect on the treatment outcome are difficult to evaluate. The American Association of Endodontists[26] has developed a risk assessment form to assess difficulty of endodontic cases; however, the validation of this form has not been reported.

CONCLUSIONS

The findings of this study are consistent with evidence of the association of diabetes and periodontal disease.[17,18] Furthermore, the findings associate diabetes with a decrease in the success of endodontic treatment in cases with preopera-

tive periradicular lesions (that is, cases with endodontic infections). Patients with diabetes also may have increased flare-ups during treatment, and those receiving insulin may have increased preoperative periradicular pain. The treatment outcome was better in older age groups. It also was highly affected by the presence of a permanent coronal restoration at the time of follow-up, which is consistent with other studies in this area.[27-29] ■

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