Impact of Periodontal Therapy on General Health
Evidence from Insurance Data for Five Systemic Conditions

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Background: Treatment of periodontal (gum) disease may lessen the adverse consequences of some chronic systemic conditions.

Purpose: To estimate the effects of periodontal therapy on medical costs and hospitalizations among individuals with diagnosed type 2 diabetes (T2D); coronary artery disease (CAD); cerebral vascular disease (CVD); rheumatoid arthritis (RA); and pregnancy in a retrospective observational cohort study.

Methods: Insurance claims data from 338,891 individuals with both medical and dental insurance coverage were analyzed in 2011–2013. Inclusion criteria were (1) a diagnosis of at least one of the five specified systemic conditions and (2) evidence of periodontal disease. Subjects were categorized according to whether they had completed treatment for periodontal disease in the baseline year, 2005. Outcomes were (1) total allowed medical costs and (2) number of hospitalizations, per subscriber per year, in 2005–2009. Except in the case of pregnancy, outcomes were aggregated without regard to reported cause. Individuals who were treated and untreated for periodontal disease were compared independently for the two outcomes and five systemic conditions using ANCOVA; age, gender, and T2D status were covariates.

Results: Statistically significant reductions in both outcomes ($p < 0.05$) were found for T2D, CVD, CAD, and pregnancy, for which costs were lower by 40.2%, 40.9%, 10.7%, and 73.7%, respectively; results for hospital admissions were comparable. No treatment effect was observed in the RA cohorts.

Conclusions: These cost-based results provide new, independent, and potentially valuable evidence that simple, noninvasive periodontal therapy may improve health outcomes in pregnancy and other systemic conditions.
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Introduction

There is a growing body of evidence that periodontal (gum) disease is associated with negative systemic health consequences for individuals with certain diseases and conditions. To the extent that this is true, it is reasonable to expect that successful treatment of periodontal disease might prevent or mitigate at least some adverse effects associated with medical conditions such as type 2 diabetes (T2D); rheumatoid arthritis (RA); cerebral vascular disease (CVD); and adverse pregnancy outcomes.

Direct confirmation of such links generally poses formidable difficulties arising from the long time course of chronic disease, the complex and multifactorial nature of the medical outcomes, and the ethical issues surrounding controlled clinical trials. Nevertheless, the potential preventive value of such a simple and low-risk intervention as dental hygiene in the management of patients with serious medical conditions justifies efforts to determine whether, and to what degree, a causal link exists.

Periodontal disease is a chronic inflammatory disease in which a pathogenic bacterial biofilm develops on the tooth root surface in a susceptible patient. If untreated, it can lead to alveolar bone resorption, infection, and tooth loss. It has been suggested that periodontal disease may also have an impact on systemic health via dissemination

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of bacterial species, host response factors, or some combination thereof. The deep pockets that are often present in untreated patients with periodontal disease offer a favorable environment for proliferation of pathogenic plaque bacteria and facilitate entry of bacteria and bacterial products into the bloodstream of otherwise apparently healthy patients via ulcerated and inflamed tissues.

Elevated serum levels of inflammatory mediators such as tumor necrosis factor–alpha, interleukin (IL)-6, IL-1β, prostaglandin E$_2$, and C-reactive protein are a consequence. Systemic effects are believed to arise from some combination of disseminated toxins, bacterial insult, and the actions of both innate and adaptive immunity. The exact connections between oral and systemic disease, however, remain complex and obscure. It is most probable that the causal agents and mechanisms differ among and within oral–systemic disease pairs. Tonetti and Kornman[1] provide a comprehensive review of current knowledge about the oral–systemic link.

Treatment of periodontal disease can be as simple as cleaning the teeth above and below the gum line, termed "scaling and root planing" (SRP), which is sometimes augmented by use of an antimicrobial mouthrinse. In more advanced cases, periodontal surgery may also be required. Such procedures aim to reduce gingival inflammation, thereby reducing bacterial biofilms on the tooth and root surface, ultimately leading to a reduction of both bacterial populations and transmission of bacteria and toxins through the gingival tissue.

In the case of pregnancy, there is credible evidence linking periodontal disease to spontaneous preterm birth (sPTB). Although intervention studies have had mixed results, several studies[2,3] indicate that among women with moderate to severe periodontal disease, simple conventional therapies such as SRP with or without antimicrobial mouth rinse[4] can significantly reduce the incidence of sPTB. Further, it has been found that successful periodontal treatment is strongly correlated with full-term birth.[5]

In contrast to pregnancy, which is inherently time-limited and has quantifiable outcomes such as birth weight and gestational age, the other medical conditions examined here are chronic, developing and persisting over many years, and manifest as complex constellations of symptoms. Nevertheless, associations have been reported between periodontal disease and T2D,[6,7] CVD,[8–10] coronary artery disease (CAD),[8,11] and RA.[12] Double-blind clinical intervention trials have been conducted, typically employing laboratory test values as surrogates for morbidity (e.g., glycosylated hemoglobin levels in diabetic patients[13]).

It is important to clarify whether, in what circumstances, and to what extent periodontal disease impacts general health. Controlled intervention trials would be ideal, but large clinical trials in chronic conditions pose practical difficulties, especially when endpoints of interest are direct health outcomes as opposed to indirect markers and surrogate measures. Consequently, the evidence concerning the systemic effect of periodontal disease on health remains inconclusive.

This retrospective intervention cohort study drew on insurance records to explore possible associations between periodontal therapy and medical costs and hospitalizations. These outcomes are not only important in themselves but also as plausible surrogates for the severity of systemic disease.

The work reported here is a retrospective study designed to test the hypothesis that treatment of periodontal disease reduces medical costs and inpatient hospital admissions during the 5 years after periodontal treatment in individuals with five systemic medical diseases or conditions: T2D, CAD, CVD, RA, and pregnancy.

Methods

Data Sources

Dental insurance claims data were obtained from United Concordia Companies, Inc. (UCCI, Harrisburg PA), and medical claims were obtained from Highmark, Inc. (Pittsburgh PA). These affiliated companies share a common data management system with common patient identifiers. Individually identifiable information was stripped from the data before transmission to the investigators. The study was submitted to the University of Pennsylvania IRB, which issued a letter of exemption.

Inclusion Criteria

From the unified database, subjects were selected who satisfied all of the following conditions:

1. Were enrolled in both a UCCI dental plan and Highmark medical plan in calendar year 2005 (the baseline year, Year 0);
2. Remained simultaneously and continuously enrolled in both plans for at least 1 succeeding year (i.e., 2006);
3. Received at least one covered visit for periodontal treatment or maintenance in the baseline year, as evidenced by the corresponding Current Dental Terminology (CDT)-5 codes (Table 1);
4. Had no recorded evidence of periodontal treatment in 2004, thus ensuring that initial treatment, if any, occurred in 2005; and
5. Experienced at least one completed pregnancy in the period 2005–2009, or, as of 2005, had a diagnosis of one or more specified systemic condition (T2D, CAD, CVD, or RA).

Individuals who at any time in the 2005–2009 interval ceased to be covered under either or both plans were excluded from analysis in subsequent years and not re-entered.

Table 1. Medical and dental insurance codes used in the study

Condition/treatment	Standard	Applicable codes
Dental: periodontal therapy		
Treatment for periodontitis or gingivitis	CDT-5	D4210, D4211, D4240, D4241, D4245, D4260, D4261, D4263, D4264, D4265, D4266, D4267, D4274, D4341, D4342, D4381
Maintenance		D4910
Prophylaxis		D1110
Chronic medical conditions		
Type 2 diabetes	ICD-9	250–25099, 3572–35729, 3620–36209, 36641, 6480
Cerebral vascular disease		433, 434
Coronary artery disease		411, 413, 414, 4292
Rheumatoid arthritis		7140, 7141, 7142, 71481
Pregnancy and delivery		
Supervision of high-risk pregnancy	ICD-9	V23
Treatment incidental to pregnant state		V22.2

CDT-5, Current Dental Terminology, 5th Edition

Classification According to Systemic Condition

Subjects whose insurance records indicated the presence of any of four chronic systemic disease conditions—T2D, CVD, CAD, or RA—were identified on the basis of corresponding ICD-9 codes (Table 1), as were pregnant women receiving prenatal and perinatal care. A subject whose record showed one or more suitably coded encounters in the baseline year (2005) was construed as having the relevant condition throughout the study period, regardless of whether the codes recurred in subsequent years. Treatment for pregnancy was treated not as a chronic disease, but as an event recorded in the year(s) in which it occurred. These medical conditions are not mutually exclusive; therefore, a client with complicated medical conditions would be included in multiple cohorts.

Determination of Treatment Threshold

For any yes/no decision rule, a receiver operating characteristic (ROC) defines the tradeoff between sensitivity and specificity as a function of some threshold parameter.[14] Here, the demarcation between treated and untreated groups was determined by applying ROC analysis to all subjects meeting the inclusion criteria, where the dichotomous outcome was defined as one or more hospitalizations in 2007, and the level of treatment as the number of periodontal visits in 2005.

A threshold of four visits in 2005 optimized discrimination between outcomes based on periodontal treatment intensity, and was subsequently taken as the definition of completed treatment throughout the study. This level happens to coincide with the typical recommended course of therapy for moderate to severe periodontitis.

Measures

Outcome measures. For each treatment group, each medical condition, and each study year (2005–2009), two outcomes (dependent variables) were calculated from the database:

1. *Primary outcome*: the mean total annual covered medical (non-dental) costs per client, inpatient, and outpatient; in the case of pregnancy, only those costs incidental to pregnancy (ICD code V22.2) and for supervision of high-risk pregnancy (V23); for other conditions, all costs irrespective of cause; and
2. *Secondary outcome*: the annual number of hospitalizations per thousand clients, irrespective of cause (not computed for pregnancy).

Independent variable. All qualifying subjects were deemed to have been diagnosed with periodontal disease by a licensed professional, by virtue of the inclusion criteria. They were further categorized into two groups: (1) the treated group, who received follow-up treatment (defined as having at least four visits in calendar year 2005 with the aforementioned CDT-5 codes), and (2) the control group, comprising subjects who elected to remain untreated.

Covariates. Client age, gender, and T2D status were taken as covariates for all analyses except where redundant. Other potentially useful factors, such as laboratory values and observations recorded during medical and dental examinations, were not available from the database. Post hoc analysis, however, provided strong evidence that the treatment and control groups did not differ significantly in the baseline year with respect to medical cost, the primary study outcome.

Temporal factors. Data were aggregated into 1-year intervals according to the calendar year in which the services were provided. Costs are in current U.S. dollars, and there was no correction for partial-year enrollment. For technical reasons, total medical costs were not available for 2006 (Year 1) for subjects with CVD, CAD, and RA.

Statistical Analysis

ANCOVA was used to assess the effect of periodontal treatment after accounting for the three covariates (age, gender, and T2D status). Statistical significance was based on Wilks's lambda, using a $p < 0.05$ threshold. The significance of year by year differences was assessed by collapsing over the covariates, and applying Welch's t-test, again with a threshold of $p < 0.05$. Analysis began in 2011 and ended in 2013. Figure 1 depicts the flow of data selection and analysis.

The decision to present only T2D status as a comorbidity factor was based on preliminary analyses in which ANCOVA was applied in turn, treating each of the other conditions as a covariate (i.e., ten analyses). Only in the case of T2D did the contribution of the second systemic condition approach statistical significance.

Results

Sample characteristics and results are summarized in Tables 2 (pregnancy) and 3 (chronic diseases). From a database of individuals with qualifying medical and dental insurance, 338,891 satisfied the inclusion criterion for periodontal disease. These qualifying subjects were 45% women and 55% men; mean age was 48.7 (10.9) years. They were grouped into cohorts based on systemic condition and periodontal treatment.

The tables show subject count in the baseline year (2005); because some individuals terminated medical or dental coverage at some time during the study period, the size of each cohort generally decreased monotonically
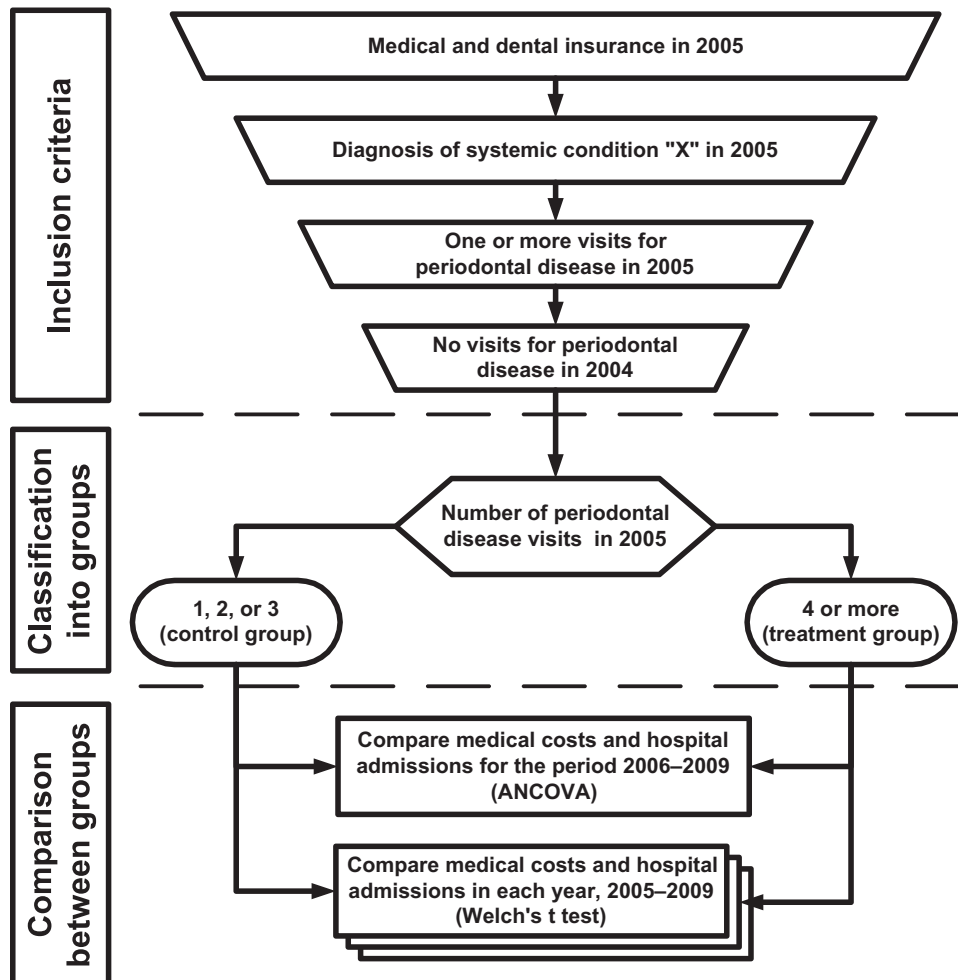

Figure 1. Simplified sequence of data selection and analysis

Note: X denotes one of the following systemic conditions: Type 2 diabetes, coronary artery disease, cerebral vascular disease, or rheumatoid arthritis. Pregnancy need not occur in the baseline year.

Table 2. Pregnancy: comparison of costs for atypical encounters

	Pregnancy and delivery (atypical encounters)			
	First pregnancy 2005–2009		Second pregnancy 2005–2009	
Periodontal treatment				
Total number of qualifying subjects in Year 0 (2005)	8,342		2,536	
ICD-9 codes for inclusion in cohort	V22.2, V23			
Periodontal treatment received	Untreated	Treated	Untreated	Treated
Number in cohort	8,320	22	2,531	5
Percentage periodontally treated	0.3%		0.2%	
OUTCOMES				
Total medical costs				
Total medical costs per subject per pregnancy	$3,299	$866	$3,301	$1,754
Annual reduction with treatment	$2,433	(73.7%)	$1,547	(46.9%)
Significance, Wilks's lambda	**$p < 0.001$**		NS	
Hospital admissions	N/A		N/A	

Note: Differences significant at the $p < 0.05$ level are shown in boldface.
N/A, not applicable; NS, not significant

from the initial counts shown. Only a small portion (approximately 1%) of patients diagnosed with periodontal disease received treatment by the rather stringent, but clinically realistic, criterion employed (i.e., four visits in 2005).

The cost and admissions savings reported in Table 3 are averages taken over the 4-year post-treatment period, 2006–2009. There was no significant difference in the case of RA, but all the remaining associations were significant at the $p < 0.05$ level.

In contrast to the other systemic conditions, where outcomes were aggregated without regard to reported cause, the costs for only two pregnancy-related treatment codes were included in the analysis (V22.2, treatment incidental to pregnancy, and V23, supervision of high-risk pregnancy). These constitute atypical, rather than total, costs of pregnancy. For these components, the cost impact was especially large, with a 74% difference for the first delivery. Because only five subjects had two pregnancies during the period, the observed cost difference for the second instance, though large, was not statistically significant.

Figure 2 shows the mother's costs for atypical pregnancy care only; Figure 3 presents year-by-year results for T2D, CVD, CAD, and RA. In all cases, the untreated group appears in broken, and the treated group in continuous, lines. Solid markers indicate that the then-year difference was significant at the $p < 0.05$ level (Welch's *t* test), whereas hollow markers indicate a lack of statistical significance. Because these year-by-year tests compare only the two intervention groups and collapse

the covariates, they are not simply related to the ANCOVA results.

Patients with diabetes or CVD showed large (around 20%–40%) and significant reductions in both outcomes relative to controls, which appeared to persist up to 3 years after initial periodontal therapy. In the case of CAD patients, the number of hospitalizations showed a similar trend, although cost differences appeared less pronounced and of varying significance over time. The absence of an effect in RA was noted.

Discussion

This study shows lower medical costs and hospitalizations in the time period following periodontal treatment in patients in four of the five conditions examined (T2D, CVD, CAD, and pregnancy), when compared to untreated controls. In each case, the difference is both statistically significant and substantial in magnitude (11%–74% lower in the treated group). The absence of a corresponding effect in RA is intriguing. Unlike the other systemic conditions, RA is clearly known[15] to be at its core an autoimmune inflammatory disease, which may help account for this marked difference in outcomes.

Although the intergroup comparisons are clear, they cannot answer the crucial question of whether differences are caused by periodontal therapy or whether a patient's completion of periodontal therapy arises from a complex of factors that tend to improve health outcomes irrespective of periodontal disease. Some insight can be

Table 3. Chronic medical conditions: comparison of costs and hospitalizations

	Chronic systemic disease							
	Type 2 diabetes		**Cerebral vascular disease**		**Coronary artery disease**		**Rheumatoid arthritis**	
Periodontal treatment								
Total number of qualifying subjects in Year 0 (2005)	91,242		13,007		8,458		81,439	
ICD-9 codes for inclusion in cohort	250–25099, 3572–35729, 3620–36209, 36641, 6480		433, 434		411, 413, 414, 4292		7140, 7141, 7142, 71481	
Periodontal treatment received	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Number in cohort	90,329	913	12,868	139	8,368	90	80,903	536
Percentage periodontally treated	1.0%		1.1%		1.1%		0.7%	
OUTCOMES								
Total medical costs								
Total medical costs per subject per year (mean 2006–2009)	$7,056	$4,216	$13,895	$8,214	$10,222	$9,133	$9,218	$8,637
Annual reduction with treatment	$2,840 (40.2%)		$5,681 (40.9%)		$1,090 (10.7%)		$581 (6.3%)	
Significance, Wilks's lambda	**$p < 0.04$**		**$p < 0.04$**		**$p < 0.04$**		NS	
Hospital admission								
Inpatient admissions per 1,000 subjects per year (mean 2006–2009)	66.6	40.4	444.4	350.0	65.2	46.6	142.7	136.3
Annual reduction with treatment	26.3	(39.4%)	94.4	(21.2%)	18.7	(28.6%)	6.4	(4.5%)
Significance, Wilks's lambda	**$p < 0.05$**		**$p < 0.002$**		**$p < 0.01$**		NS	

Note: Differences significant at the $p < 0.05$ level are shown in boldface.
NS, not significant

gained by examining the detailed time histories of the outcomes, but the present evidence is mixed.

In all cases, costs for the treatment and non-treatment groups are statistically indistinguishable in the baseline year, consistent with the hypothesis that there is no unmodeled common causal factor. The same is true for hospitalizations (the secondary outcome) in all cases except CAD, where the roughly parallel time courses suggest that the observed differences could be due to an unmodeled confounder rather than periodontal treatment itself.

The question of causality, therefore, must remain open pending prospective randomized intervention trials. Although this research provides no insight into the exact nature, much less the cause, of the observed differences, total per capita medical costs and number of hospitalizations are reasonable surrogates for a wide spectrum of health outcomes, including but not limited to those directly associated with the underlying medical condition.

In a "bounding" study such as this with a high degree of data aggregation (as to time, treatment, and diagnoses), absence of a significant correlation would not be
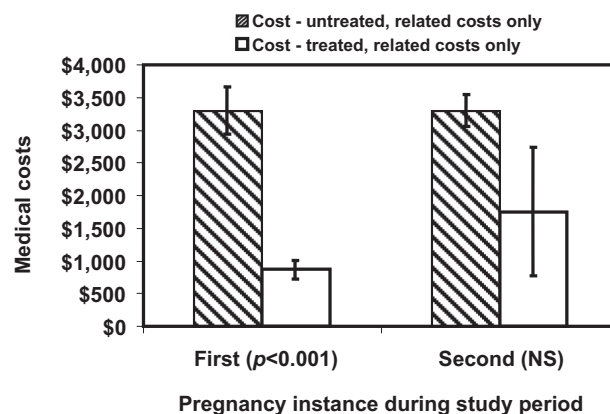

Figure 2. Atypical pregnancy and delivery cost by periodontal treatment group
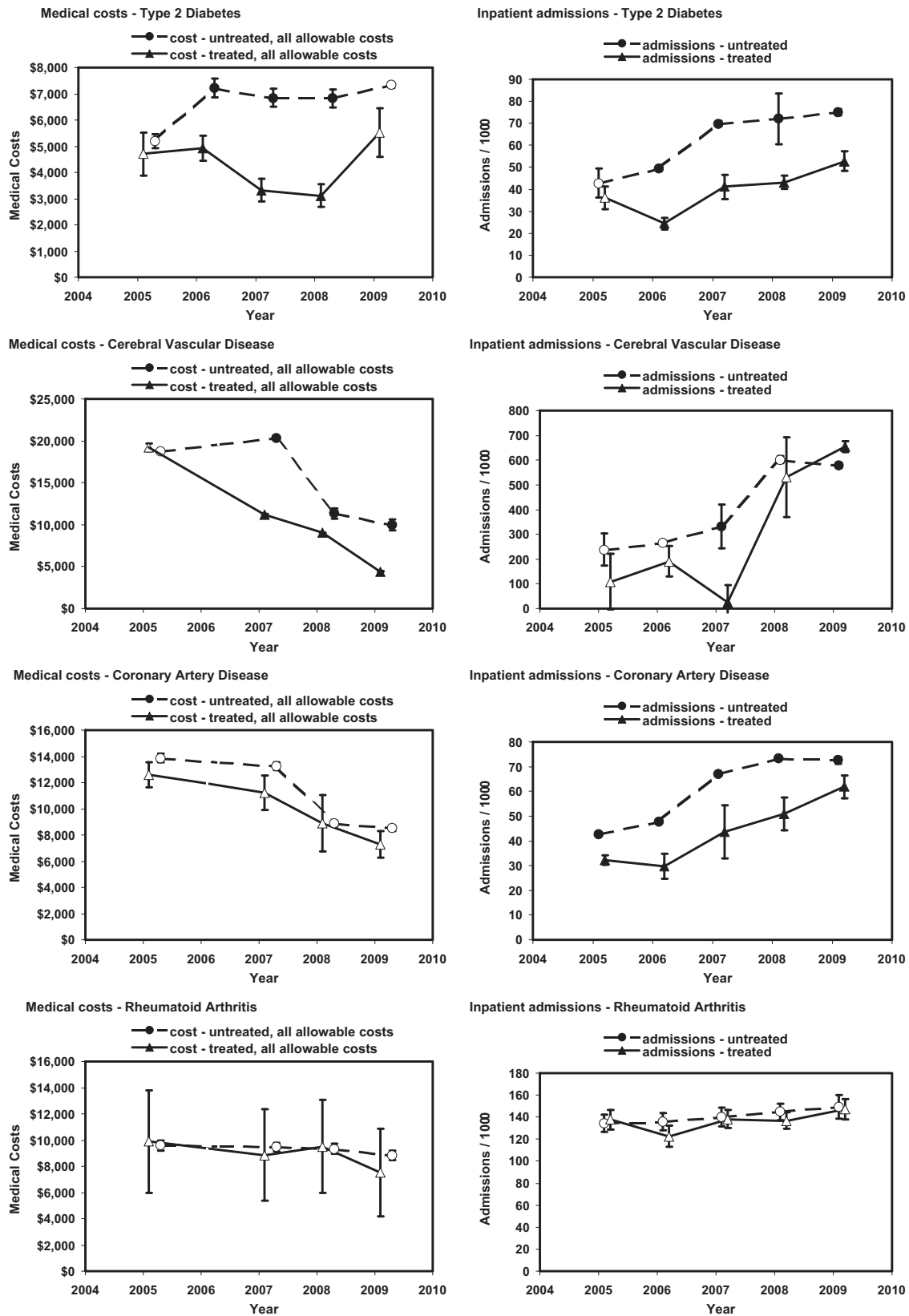NS, not significant

Figure 3. Medical cost and number of hospitalizations by periodontal treatment group
Note: Points offset horizontally for clarity.
Error bars are ± 1 SE.

surprising and would not in itself constitute evidence against an oral–systemic link in specific conditions and medical outcomes. On the other hand, the statistically significant relationships reported here are strongly suggestive of an underlying biomedical link, irrespective of the mechanisms and causal chains that might drive it.

Strengths and Limitations

The strengths and weaknesses of this research are worth noting. On the positive side, the design is a true intervention study, as cohorts were defined solely on the basis of a particular treatment and followed thereafter. On the other hand, it lacks the prospective, controlled, blinded, and balanced properties that yield the strongest clinical evidence achieved by a double-blind RCT. Moreover, the approach is both indirect, to the extent that cost and inpatient admissions are viewed as surrogates for general health, and simplified in that data were aggregated by calendar year. Potentially informative but unavailable data such as laboratory values could not be used as covariates.

The fact that U.S. dental insurance codes report only procedures, not diagnoses, required that periodontal disease status be indirectly inferred in this study. Although this approach is valid, it is necessarily based on a relatively broad-brush view of dental status. Explicit dental diagnostic data would have enabled a more refined and potentially more informative analysis. Given the obvious utility of diagnostic codes in both research and patient care, it is difficult to understand why they have not been adopted in dentistry.

Although beyond the scope of the present study, similar methods could be used to determine how cost and hospitalization vary with the number of periodontal visits defined as "treated." Such dose–response data would provide valuable insight into benefits derivable from less-than-optimal patient adherence.

Health insurance records can be a rich source of research data if careful steps are taken to protect patient confidentiality. From this starting point, analyses may range from straightforward correlations to more elaborate kinds of inference, of which the present work is a modest example. Further explorations of this and other databases are planned, using other strategies including time-series analysis to increase the power and refinement of the results. As additional data elements (e.g., lab values and dental diagnostic codes) become available, they will be exploited. It is hoped that other investigators, with access to other insured populations, will replicate and extend the methods developed here.

Inherent limitations in the source data restricted this study to only rudimentary demographic variables. Many other factors—medical, behavioral, economic, and others—might be postulated in addition to periodontal therapy to explain the observed differences between groups. However, the fact that total medical costs did not differ significantly between groups in the baseline year constitutes strong evidence that the net influence of all unmodeled factors is insufficient to require the inclusion of further covariates in the model.

Implications for Disease Management and Prevention

If evidence continues to accumulate that an oral–systemic health link not only exists but also can be exploited to improve general health, two important consequences can be expected. Clinically, it would be logical for assessment and treatment of periodontal disease to be routinely considered in the management of specific medical conditions. Scientifically, further research, clinical and otherwise, could be better focused on the underlying pathways and causal factors.

The findings to date certainly do not prove that treatment of active periodontal disease has a beneficial effect beyond the mouth. However, they are entirely consistent with such a hypothesis, and reinforce evidence of other kinds and from other sources. Nevertheless, simple periodontal treatment as examined here comes at modest cost and minimal risk. Therefore, although its interventional efficacy remains open to debate, we recommend that it be considered part of the preventive armamentarium for chronic disease management.

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