

Original Article

Diabetes or Hypertension as Risk Indicators for Missing Teeth Experience: An Exploratory Study in a Sample of Mexican Adults

VJ Delgado-Pérez^{1,2}, R De La Rosa-Santillana², ML Márquez-Corona², L Ávila-Burgos³, H Islas-Granillo², M Minaya-Sánchez⁴, CE Medina-Solís^{1,2}, G Maupomé^{5,6,7}

¹Advanced Studies and Research Center in Dentistry "Dr. Keisaburo Miyata" of Faculty of Dentistry at Autonomous University State of Mexico, Toluca, ²Academic Area of Dentistry of Health Sciences Institute at Autonomous University of Hidalgo State, Pachuca, ³Health Systems Research Centre at National Institute of Public Health, Cuernavaca, ⁴Faculty of Dentistry of Autonomous University of Campeche, Campeche, Mexico, ⁵Indiana University/Purdue University at Indianapolis School of Dentistry, ⁷Indiana University/Purdue University at Indianapolis Richard M. Fairbanks School of Public Health, Indianapolis, ⁶Indiana University Network Science Institute, Bloomington, IN, USA

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INTRODUCTION

Oral diseases such as caries and chronic periodontitis are considerable public health problems worldwide because they affect a large proportion of the population; the ultimate outcome of those two epidemiologically important diseases is often the loss of affected teeth. Missing teeth reflect the history of dental diseases in an individual as well as dental treatment courses throughout his/her life. Moreover, tooth loss is further moderated by attitudes of patients and dentists, the dentist-patient relationship, the availability and accessibility of dental services, and dental care prevailing philosophies.^[1]

ABSTRACT

Background: To determine an exploratory estimation of the strength of type 2 diabetes mellitus (T2DM) and hypertension diagnoses as risk indicators for missing teeth in a sample of Mexican adults. **Materials and Methods:** A comparative cross-sectional study of sixty adult patients in a health center in Mexico included as dependent variable, the number of missing teeth (and having a functional dentition) and as independent variables, diagnoses for diabetes or hypertension, age, sex, maximum level of schooling, and tobacco use. Of the 60 participants, 20 were diagnosed with T2DM, 13 with hypertension, and 27 were otherwise diagnosed as healthy in their most recent medical checkup. A negative binomial regression (NBR) model was generated. **Results:** Mean age was 50.7 ± 16.2 and 50.0% were women. Mean number of missing teeth was 4.98 ± 4.17 . In the multivariate NBR model, we observed that individuals with T2DM had higher risk of more missing teeth (incidence rate ratios [IRRs] = 3.13; 95% confidence interval [CI] = 2.09–4.69), followed by those with hypertension (IRRs = 2.63; 95% CI = 1.77–3.90). In addition, participants with current tobacco use were significantly more likely to have suffered tooth loss ($P < 0.05$) than those who were never smokers or former smokers, just like older participants ($P < 0.05$). **Conclusions:** T2DM and hypertension are independently associated with higher experience of missing teeth in an open adult population in Mexico. Future studies with a more sophisticated epidemiological design and encompassing a more detailed landscape of chronic diseases, type and length of use of long-term medications, and patterns of dental care use are needed to better delineate these associations.

KEYWORDS: Adult, hypertension, Mexico, tooth loss, type 2 diabetes

Severe tooth loss (having fewer than nine remaining teeth) has been placed as the 36th most common condition in the "Global Burden of Disease 2010 Study," with an overall prevalence of at least 2%.^[2] While missing teeth is considered a useful measure of the state of dental health of a community, it is also deemed a

Address for correspondence: Dr. CE Medina-Solís, Avenida del Álamo # 204, Fraccionamiento Paseo de los Solares, Colonia Santiago Tlapacoya, CP 42110, Pachuca de Soto, Hidalgo, México.
E-mail: cemedinas@yahoo.com

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negative indicator by the International Association for Dental Research, the International Dental Federation, and the World Health Organization when setting goals for oral health status, namely, to reducing tooth extractions for caries and periodontal reasons through actions addressing tobacco use, poor oral hygiene, high stress, and as a sequel of systemic diseases.^[3]

Various risk indicators have been associated with missing teeth in the international scene. For example, socioeconomic status, consumption of fluoride in water, use of health services, smoking, use of dental floss, age, and female sex influenced missing teeth in Brazil,^[4] while in Sri Lanka,^[5] participants who were older, female, those with lower education, who used toothpaste without fluoride or brushed their teeth less often, and who used dental services were at higher risk of losing permanent teeth. Similar gradients for socioeconomic disadvantage and poor health behaviors in the context of missing teeth pertain not only to countries with moderate levels of industrialization such as Mexico^[6] but were also found in settings with high standards of living and comprehensive health-care services such as Finland.^[7] While in some cases, a more direct connection between causes such as having had radiotherapy or tobacco use can be associated with greater frequency of missing teeth,^[6] the role of other factors seemingly at play has been more obscure. Case in point is systemic diseases although generally acknowledged to coincide with poorer oral health the mechanisms for such influence is not well characterized.^[8]

In the present research, we propose to explore the association between missing teeth and two major chronic diseases: type 2 diabetes mellitus (T2DM) and hypertension. T2DM is one of the most prevalent chronic diseases worldwide, even without taking into account that in its initial stages is rather insidious; more advanced forms cause serious health complications. According to the National Health Survey 2012 in Mexico (ENSANUT 2012), 9.2% (95% confidence interval [CI] 8.8%–9.5%) of the total adult population reported having a medical diagnosis of T2DM, equivalent to 6.4 million people.^[9] T2DM is one of the systemic diseases associated with periodontal problems, implying that tooth loss becomes more likely because of the deterioration of tissues supporting teeth. In several countries, it has been reported that patients with T2DM have more missing teeth.^[10-12] In the case of high blood pressure (hypertension), it is one of the major risk factors for developing cardiovascular disease, stroke, and kidney failure: these are major causes of mortality in Mexico. According to ENSANUT 2012, the prevalence of hypertension in Mexico is 31.5% (95% CI 29.8–33.1).^[13]

Although the relationship of hypertension with tooth loss is less well documented,^[8] in hypertension animal models, it is involved in the development of periodontitis and bone destruction.^[14-16] Because the latter has been implicated in dental extractions in Mexican adults^[17] and as likely risk indicators for tooth loss in other studies,^[18-20] we propose to add to the limited wealth of data examining the possible relationship between tooth loss and systemic diseases. The aim of the present study was to determine an exploratory estimation of the strength of T2DM and hypertension diagnoses as risk indicators for missing teeth in a sample of adult patients attending a health center in Mexico.

MATERIALS AND METHODS

Study design

A comparative cross-sectional study was conducted in consecutive patients (balanced for sex) seeking periodic medical care at an urban primary health center in Hidalgo, Mexico. Inclusion criteria were patients: (a) of either sex who had received a diagnosis of T2DM or hypertension at that clinic in the past 10 years, (b) 18 years of age and older, and (c) who agreed to participate in the study and had enough level of literacy in Spanish to understand written and spoken descriptions of the research and the implications of participating in the study, including the confidentiality of records. Exclusion criteria were patients: (a) with any cognitive or neurological conditions that prevented participating in the study, (b) diagnosed with both T2DM and hypertension at the same time, or (c) diagnosed with any other major chronic conditions. A convenience sample of 60 consecutive patients were recruited as participants and allocated to either of three groups: 20 had T2DM, 13 hypertension, and 27 were otherwise free of chronic/systemic diseases (specifically, being registered patients in that clinic without ever being diagnosed with T2DM or hypertension or any other major chronic conditions listed in the Mexican social security roster). The clinic offered medical care under a third-party payment plan medical care plan; dental services were not part of the services.

The dental health-care system in Mexico is a mixed system up services supplied by public institutions, third party payment systems, and private carriers. Most services are delivered under a fee-for-item, out-of-pocket scheme. The public health sector is responsible for a small set of services that are almost restricted to the urban settings.^[21]

Clinical data collection

Clinical examinations were performed by one trained and standardized dentist under artificial light, with a

flat dental mirror and the World Health Organization periodontal probe. Training was undertaken in another group of participants in a separate pilot study, using identical scales and instruments; kappa values for the various health indicators were >0.85 . Third molars were not taken into account. Root tips were considered as missing teeth.

Variables and data transformation

The dependent variable was the mean number of missing teeth, which was operationally defined as the number of missing teeth in the sample as determined by a clinical examination. Independent variables included were age and schooling (quantitative variables). Other variables were sex (0 = male), medical diagnosis of T2DM (0 = no), medical diagnosis of hypertension (0 = no), tobacco use (0 = no/never [participant had not smoked at all or smoked fewer than 100 cigarettes in his/her lifetime], 1 = former smokers [participants who had smoked more than 100 cigarettes in his/her lifetime but did not currently smoke] and 2 = current smoker). The diagnoses of T2DM and hypertension were first obtained using self-report from the patient, who was asked if he/she had previously been diagnosed by a doctor. Such diagnoses were corroborated against the medical records, with prior approval of patient.

Statistical analysis

Statistical analysis started with describing variables: for continuous variables as measures of central tendency and dispersion and for categorical variables, frequencies, and percentages. Bivariate analyses included nonparametric tests of Mann–Whitney and Chi-square. Finally, we modeled the average experience of missing teeth using negative binomial regression (NBR). NBR was chosen after graphically verifying the distribution of observations; Poisson regression model was discarded because data did not have such distribution. NBR was chosen because (a) missing teeth is a discrete variable (count) with integer values. With missing teeth, not being a continuous variable, linear regression model was inappropriate. (b) There was data overdispersion (variance is greater than average) in the dataset. Variance was 17.40, average of 4.98. In addition, (c) NBR offers the advantage of modeling the outcome “number of missing teeth” as a continuous variable rather than a dichotomous outcome used in binary logistic regression. In this way, the association of exposure variables with the degree of severity of missing teeth could be evaluated, not merely the presence or absence of the outcome. Incidence rate ratios (IRR) with 95% CIs were calculated. In the final model, those variables that in the bivariate analysis showed a value of $P < 0.25$ were

included in the study.^[22] The statistical package used was STATA 13.0® (StataCorp, Texas 77845, USA).

Ethical protection of human subjects and approval statement

The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013. The protocol was approved and met the guidelines for protection of human participants in research, adhering to the ethical regulations of the Autonomous University of Hidalgo State. All participants signed a form of informed consent. Participants did not receive monetary compensation for their role in the study. The study has been independently reviewed and approved by an Ethics Committee/Institutional Review Board of the Autonomous University of Hidalgo State (Cinv/o/034/2016).

RESULTS

Basic results

Descriptive results are in Table 1. Overall mean age was 50.7 ± 16.2 years. Women made up 50.0% of participants ($n = 30$). Mean years of schooling was 7.1 ± 2.7 . As for smoking, 60.0% had not smoked 100 cigarettes in their lives or have never smoked while 30.0% were current smokers. Of the total sample, 33.3% had been diagnosed with T2DM and 21.7% with hypertension. Mean number of missing teeth was 4.98 ± 4.17 (range 0-19). The percentage of participants with functional dentition (21 or more teeth) was 71.7%.

Table 1: Distribution of independent variables included in the study

Variable	Mean±SD	Minimum–maximum
Age (years)	50.7±16.2	18-80
Schooling (years)	7.1±2.7	0-12
Variable	Frequency (%)	
Sex		
Women	30 (50.0)	
Men	30 (50.0)	
Tobacco use		
Never	36 (60.0)	
Former	6 (10.0)	
Current	18 (30.0)	
Diabetes		
No	40 (66.7)	
Yes	20 (33.3)	
Hypertension		
No	47 (78.3)	
Yes	13 (21.7)	
Neither diabetes nor hypertension		
No	27 (45.0)	
Yes	33 (55.0)	

SD=Standard deviation

Table 2 shows a comparison of independent variables between the non-T2DM, non-hypertension (“healthy”) participants, and those with medically diagnosed T2DM or with hypertension. Patients with T2DM were older ($P < 0.05$). A higher prevalence of hypertension was observed among current and former smokers, and a higher prevalence of T2DM was found in smokers ($P < 0.05$).

Bivariate analyses

The bivariate analyses are in Table 3. A positive correlation ($r = 0.4100$, $P < 0.01$) was observed

Table 2: Distribution of independent variables included in the study comparing the “healthy” participants with those diagnosed with diabetes or hypertension

Variable	Healthy	Diabetes	Hypertension	P
Age (years)	43.0±16.9	61.3±8.6	50.2±15.3	0.0007*
Schooling (years)	7.5±3.1	6.7±1.6	6.9±3.3	0.2374*
Sex				
Women	13 (43.3)	13 (43.3)	4 (13.4)	0.153†
Men	14 (46.7)	7 (23.3)	9 (30.0)	
Tobacco use				
Never	16 (44.4)	14 (38.9)	6 (16.7)	0.049‡
Former	2 (33.3)	4 (66.7)	0	
Current	9 (50.0)	2 (11.1)	7 (38.9)	

*Kruskal–Wallis; †Chi-square; ‡Fisher’s exact test

Table 3: Bivariate analysis between the experience of missing teeth and the independent variables included in the study

Variable	Correlation (r)	P
Age	0.4100*	0.0011
Schooling	-0.2732*	0.0347
Variable	Mean±SD	Value of P
Sex		
Women	4.60±3.39	Z=-0.239†
Men	5.37±4.86	P=0.8114
Tobacco Use		
Never	4.17±3.29	$\chi^2=2.131‡$
Former	5.17±1.94	P=0.3379
Current	6.55±5.74	
Diabetes		
No	3.80±3.80	Z=-3.663†
Yes	7.35±3.93	P=0.0002
Hypertension		
No	4.36±3.84	Z=-2.254†
Yes	7.23±4.69	P=0.0242
Neither diabetes nor hypertension¶		
None	2.15±1.68	$\chi^2=28.085‡$
Diabetes	7.35±3.93	P=0.0001
Hypertension	7.23±4.69	

*Correlation of Spearman; †Mann–Whitney; ‡Kruskal–Wallis; Multiple comparisons: “Healthy” versus diabetes ($P=0.000001$), “healthy” versus hypertension ($P=0.000056$). SD=Standard deviation

between missing teeth and age. A negative correlation ($r = -0.2732$, $P < 0.05$) was observed between schooling and missing teeth. More missing teeth were observed in participants diagnosed with T2DM (7.35 ± 3.93 vs. 3.80 ± 3.80 ; $P < 0.001$) and with hypertension (7.23 ± 4.69 vs. 4.36 ± 3.84 ; $P < 0.05$) than “healthy” individuals. We found no differences for gender and smoking. In Table 4, the bivariate analysis with NBR reached similar results.

Multivariate analyses

Table 5 shows the IRRs and 95% CIs of the multivariate NBR model for missing teeth. The IRRs represent the ratio for the outcome (i.e., missing teeth) for the variable of interest (i.e., people with T2DM or hypertension). Three variables were statistically associated ($P < 0.05$) with the experience of missing teeth. Individuals with T2DM had the highest risk of having experienced

Table 4: Bivariate analysis of negative binomial regression between the experience of missing teeth and the independent variables included in the study

Variable	Coefficient	IRR (95% CI)	Value of P
Age	0.0204	1.02 (1.01-1.03)	0.003
Schooling	-0.0370	Without effect	0.426
Sex			
Women	1*		
Men	0.1541	Without effect	0.468
Tobacco use			
Never	1*		
Former	0.2151	Without effect	0.541
Current	0.4531	1.57 (1.01-2.45)	0.046
Neither diabetes nor hypertension			
None	1*		
Diabetes	1.2300	3.42 (2.32-5.04)	<0.001
Hypertension	1.2137	3.37 (2.19-5.16)	<0.001

IRR=Incidence rate ratios; CI=Confidence interval; *Reference category

Table 5: Multivariate analysis of negative binomial regression between the experience of missing teeth and independent variables included in the study

Variable	Co-efficient	IRR (95% CI)	Value of P
Age	0.0133	1.013 (1.001-1.02)	0.026
Tobacco use			
Never/former	1*		
Current	0.6687	1.95 (1.39-2.74)	<0.001
Neither diabetes nor hypertension			
None	1*		
Diabetes	1.1416	3.13 (2.09-4.69)	<0.001
Hypertension	0.9668	2.63 (1.77-3.90)	<0.001

IRR=Incidence rate ratios; CI=Confidence interval; * Reference category

missing teeth (IRRs = 3.13; 95% CI = 2.09–4.69), as well as those with hypertension (IRRs = 2.63; 95% CI = 1.77–3.90). In addition, participants who were current smokers had more missing teeth (IRRs = 1.95; 95% CI = 1.39–2.74) than never smokers or former smokers. Age was also slightly associated with more missing teeth (IRRs = 1.02; 95% CI = 1.01–1.03) ($P < 0.05$).

DISCUSSION

This study was conducted to explore the strength of association between having been diagnosed with T2DM or hypertension and missing teeth in a population of Mexican adults living independently. After controlling for various factors, participants with either of these systemic diseases had higher average number of missing teeth.

Teeth are lost due to trauma or disease, in the first place; associated treatment reasons (iatrogenic) and dental planning considerations sometimes contribute to decisions for dental extractions.^[21] Extractions by a dental health-care provider are often the most common mechanism for tooth loss while spontaneous loss may occur due to advanced periodontal or various conditions and to trauma.^[5] Chronic periodontal diseases are often considered one of the main reasons why teeth are lost worldwide in adults; they have been reported to be more prevalent among people who have diabetes than among those without diabetes.^[23] More often than not, distinctions between type 1 and type 2 diabetes have been glossed over in the literature. Similarly, diabetics had significantly higher extent of periodontal disease (percentage of affected teeth) than non-diabetics; the cumulative odds ratio of developing bone loss over time was 2.2 in controlled diabetics compared to nondiabetics.^[24] To contrast findings from the present research with relevant literature, we compared studies from Croatia,^[10] Kuwait,^[19] United States,^[11] and India^[12] and found they have shown that patients with diabetes had more missing teeth. While microvascular (due to damage to small blood vessels) and macrovascular (due to damage to large blood vessels) complications of diabetes such as retinopathy, neuropathy, nephropathy, and cardiovascular disease are well recognized, periodontitis is also a consistent complication. Patients with diabetes show evidence of increased pro-inflammatory cytokines within the gingival crevicular fluid and gingival tissues, compared to patients without diabetes.^[25] It was proposed that diabetes may heighten the inflammatory response to periodontal pathogens, thereby supporting a cycle of tissue destruction and impaired wound healing.^[26]

Several studies have focused on the relationship between complete/partial tooth loss as a risk

factor for cardiovascular conditions,^[23,27] including hypertension.^[28,29] There are, however, few epidemiological studies looking at hypertension as a risk indicator for missing teeth. For example, Lee *et al.*^[8] observed in Korea that some indicators of overall health, including blood pressure, were associated with greater tooth loss (variable outcome). In Mexico, Islas *et al.*^[20] noted a tenuous association between missing teeth and hypertension in the elderly, among other factors studied. Al-Shammari *et al.*^[19] found in Kuwait that one of the factors associated with missing teeth due to periodontal reasons was hypertension. In hypertensive participants, periodontitis may enhance the risk and degree of organ damage. The systemic inflammatory process due to endothelial dysfunction, which is the initial step in the development of hypertension and atherosclerosis, may also be the cause of alterations in the periodontium. Besides the systemic inflammation, hypertension also affects the calcium metabolism by activating parathyroid hormone, in turn, causing osteoclast differentiation and increased mobilization of calcium from bone. This phenomenon decreases bone mineral density and prejudices bone repair in both humans and spontaneously hypertensive rats.^[16] A potentially damaging, bidirectional relationship between periodontitis and increased blood pressure includes the systemic generalization of the oral inflammation, just as in the case of diabetes; various dimensions implicated are the host immune response, the direct microbial effect on the vascular system, and alterations in endothelial function. Because hypertension and periodontal conditions share some common risk factors, such complicating scenario must be taken into account when assessing a possible association.^[30]

Case in point is tobacco use. Periodontitis is likely to be an important intermediate factor in the association observed in this study between tobacco use and missing teeth. Tobacco use is the most important behavioral risk factor for periodontal disease, which, in turn, is often considered the main cause for tooth loss among the middle aged and elderly.^[7] Moreover, tobacco use has been associated with fewer remaining teeth and higher prevalence of edentulousness,^[4,6,7] just as we found. Our findings are also aligned with prior reports,^[31] in that tobacco use was not only associated with missing teeth but also that smoking cessation was consistently associated with a reduction in the risk to lose teeth. Although the exact mechanisms for tobacco use undermining periodontal structures are not yet well characterized, it is generally acknowledged that these interactions are multidimensional. These include speculations that the interface between tobacco exposure and signs/symptoms of inflammation is nicotine modified.^[32] This rationale is supported by the fact

that nicotine inhibits attachment and growth of human periodontal ligament fibroblasts *in vitro*.^[33] Nicotine also causes a significant decrease in the protein content and damages the cell membrane of fibroblasts and in their overall growth.^[24]

In the present study, we found that age was a risk indicator for missing teeth as it has often been reported.^[4,5] It is worth posing that the best way to characterize this relationship is to keep in mind that missing teeth depict the cumulative result of chronic oral diseases and exposure to iatrogenic decisions over time.

Missing teeth have a negative impact on various functional aspects;^[34] bodies of knowledge with various strengths of evidence suggest effects on occlusion with tooth migration, extrusion of opposing teeth, TMJ disorders, and even associations with mortality.^[27,35,36] Other indirect associations indicate that certain levels of missing teeth are associated with lower consumption of dietary fiber, fruits and vegetables, and a higher intake of cholesterol and saturated fatty foods.^[37] Such diet is inappropriate for patients with diabetes. Increasing evidence suggests a relationship between oral health and other chronic diseases.^[37]

The present study offers an initial exploration into the potential relationships of T2DM or hypertension with missing teeth in community-dwelling adults. This is the first epidemiological study in a Mexican population that suggests hypertension is associated with tooth loss; studies in other population groups are sparse at best. While supportive of the need for future research to better delineate the relationships found, the study has important limitations. Among those, the study (1) has a cross-sectional epidemiological design, which precludes establishing causal relationships. We do not know the exact moment of tooth loss, which raises the possibility that some of the outcomes may have preceded exposure. And (2) it does not apply directly to the entire Mexican population. In conclusion, we found that the experience of missing teeth was relatively high. The presence of T2DM or hypertension independently had negative effects on the experience of missing teeth; without discarding the possible bidirectionality between these variables, studies with a more sophisticated epidemiological design are needed to confirm these associations. A more finely grained operationalization of variables is essential to allow detailed landscapes for key components of the phenomena at hand if we are to accurately delineate these associations, namely, gauging the role and severity of other chronic diseases that may moderate the overall etiopathological pathways; the anticholinergic nature and length of use of long-term medications prescribed for all chronic diseases and

their potential impacts on periodontal structures and on salivary gland hypofunction conditions; and both distant and recent patterns of dental care services leading to tooth loss.

CONCLUSIONS

T2DM and hypertension are independently associated with higher experience of missing teeth in an open adult population in Mexico. Future studies with a more sophisticated epidemiological design and encompassing a more detailed landscape of chronic diseases, type and length of use of long-term medications, and patterns of dental.

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Conflicts of interest

There are no conflicts of interest.

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