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Links between oral health-related quality of life in US adults and type 2 diabetes: structural equation modeling analysis

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Objectives: To analyze the effects of type 2 diabetes mellitus (T2DM), need for dental care, personal health practices and use of services on oral health-related quality of life (OHRQoL) in US adults. ***Basic research design***: The sample included 2,945 participants (aged ≥ 20) selected from the National Health and Nutrition Examination Survey (NHANES) 2003-2004 stratified probability sample that represented 124,525,899 individuals in the weighted sample. Two-stage structural equation modelling (SEM) assessed interrelationships between T2DM regressions on factors associated with OHRQoL in a simplified three-factor Andersen Behavioral Model (ABM). ***Results***: SEM supported the hypotheses that T2DM directly predicted need (perceived need, evaluated need, general health condition) with a significant path coefficient of 0.49 (β=0.49, $p<0.05$). Need had direct (77%) and indirect (23%) effects on OHRQoL (β_{direct}=0.30, $\beta_{indirect}$=0.09, $p< 0.001$). Need predicted personal health practices including use of services (reason for dental visit, frequency of dental visits, smoking status) (β=0.46, $p<0.001$). Need, in turn, predicted OHRQoL (β=0.19, $p<0.001$). In the model, 23.8%, 59.7%, and 18.1% of the variance was explained by need, personal health practices including use of services, and OHRQoL, respectively. ***Conclusions***: The results confirmed T2DM predicted need, which in sequence had direct and indirect effects on OHRQoL.

Keywords*: Quality of Life, Oral Health, United States, Type 2 diabetes, Structural Equation Modeling*

Introduction

The increasing prevalence of type 2 diabetes mellitus (T2DM) and attendant comorbidities (e.g., vascular complications, respiratory infections, periodontal diseases, tooth decay, tooth loss) provide several public health motivations for prevention of acute and chronic oral complications (Verhulst *et al*., 2019). One expected outcome of these prevention efforts is improved quality of life for people with T2DM. Poorly controlled T2DM is associated with periodontal disease, a major cause of adult edentulism, and attendant problems with mastication, speech, and deglutition (Azogui-Lévy *et al*., 2018; Tavares *et al*., 2014). Tooth loss and poorly fitting dentures negatively affect eating habits, restrict food choice, and contribute to nutritional imbalance, and lower quality of life (Azogui-Lévy *et al*., 2018). T2DM is associated with oral disease has negative effects on daily living and quality of life (Azogui-Lévy *et al*., 2018).

In addition to the clinical impact of dental diseases, personal perception of one's well-being influences an individual's valuation of physical, psychological, and social functioning (Azogui-Lévy *et al*., 2018). Oral health-related quality of life (OHRQoL) is a multidimensional self-report instrument that assesses oral health effects on day-to-day functions (Locker, 1988; Slade and Spencer, 1994). OHRQoL in adults can be measured using the Oral Health Impact Profile (OHIP) (Maida *et al*., 2013; Sanders *et al*., 2009; Seirawan *et al*., 2011). The National Health and Nutrition Examination Survey 2003-2004 (NHANES) included a seven-item version of OHIP (OHIP-NHANES), with established psychometric adequacy (Maida *et al*., 2013; Sanders *et al*., 2009; Seirawan *et al*., 2011). The OHIP-NHANES was previously used to analyze the association of perceived dental needs and predictors with OHRQoL in US adults (Maida *et al*., 2013; Seirawan *et al*., 2011). Adjusting for demographic factors, those studies found that OHRQoL was strongly associated with evaluated and perceived treatment need, general medical health, personal health practices, and use of dental services (Maida *et al*., 2013; Seirawan *et al*., 2011).

Unlike traditional regression models that evaluate the effects of predictors on OHRQoL while holding the effects of covariates constant, structural equation modelling (SEM) tests all relevant direct and indirect pathways of factors that simultaneously predict OHRQoL (Seirawan *et al*., 2011). Several studies (Baker, 2009; Baker *et al*., 2008) have used SEM to test pathways of contextual factors associated with OHRQoL using general population samples. Baker (2009) used SEM to analyze the effects of contextual factors within the Andersen Behavioral Model of Health Care Utilization (ABM) that predict adult OHRQoL. That study provided evidence for UK policymakers that might allow them to see the effects of their policies and other factors simultaneously affecting OHRQoL, compared to traditional regression models. However, no published studies have used SEM to analyze all factors simultaneously as a system of multiple direct and indirect pathways of ABM factors that predict OHRQoL in the US population with a systemic disease such as T2DM.

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This study used a simplified three-factor ABM as a theoretical framework to test pathways between T2DM and contextual factors associated with OHRQoL (Figure 1). We hypothesized that T2DM would predict need, which in turn, would have direct and indirect effects on OHRQoL. Need would also predict personal health practices and use of services, then personal health practices and use of services would predict OHRQoL. The overarching goal of this investigation was to analyze OHRQoL and oral health, ultimately deriving an applied model to improve access to dental care services for this T2DM vulnerable population. The principal aim of this study was to apply SEM to a simplified ABM to analyze the causal effects of T2DM and other factors on OHRQoL in adults from a nationally representative survey in the US.

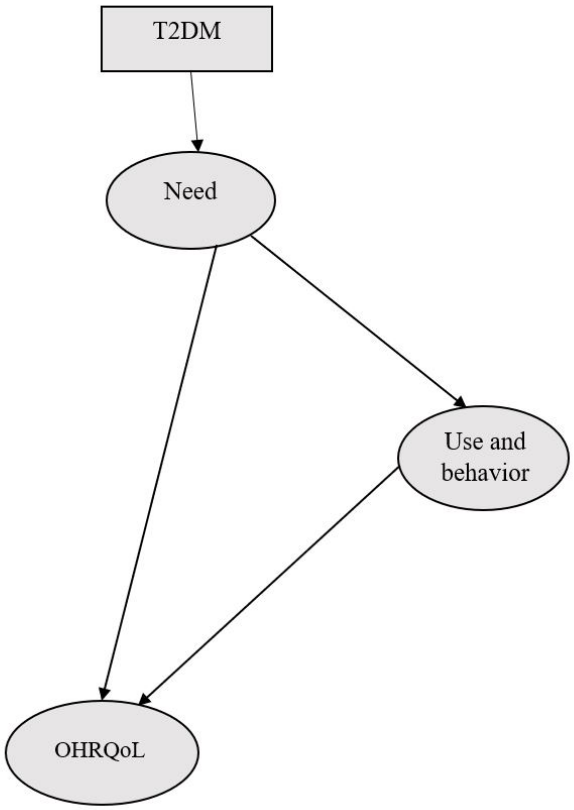


Figure 1. The hypothesized three-factor Anderson Behavioral Model.

Methods

All non-pregnant participants aged 20 years or older in the 2003-2004 NHANES who provided complete data for the OHIP-NHANES (i.e., participated in a household interview, attended an examination center for dental screening) were included in the analysis (Maida *et al*., 2013), resulting in 2,798 unique individuals. The NHANES survey used multi-stage probability cluster sampling design (Huang and Park, 2015), and provided the weights for use in future analysis. The weighted sample represented 124,525,899 individuals in the US population.

The ABM conceptual framework guided the analysis of the association of oral health conditions and OHRQoL building on prior studies (Azogui-Lévy *et al*., 2018; Baker, 2009; Maida *et al*., 2013; Sadeghi *et al*., 2014; Sandberg and Wikblad, 2003; Sanders *et al*., 2009; Tavares *et al*., 2014; Verhulst *et al*., 2019). We adapted a simplified ABM to analyze contextual factor pathways (Baker, 2009) to evaluate the effects of T2DM on need, personal health practices and use of services, and OHRQoL. The model was fully adjusted for demographics such as education level and income range (Baker, 2009). Predisposing factors (participant demographics that are associated with higher rate of poor OHRQoL) and enabling factors (resources that enable participants to use dental care services) were simplified by modelling these effects as covariates (e.g., education, income), instead of latent variables. A solution was not computationally possible when predisposing factors (e.g., gender, race) were included in the model. Need factors included perceived and evaluated medical and dental treatment needs (Azogui-Lévy *et al*., 2018; Baker, 2009; Sandberg and Wikblad, 2003; Verhulst *et al*., 2019). T2DM was used as an independent variable instead of an indicator of the need latent variable to avoid multi-collinearity. This modification of the model improved measurement of oral health care need.

Measured indicators were selected based on the ABM and prior studies (Azogui-Lévy *et al*., 2018; Maida *et al*., 2013; Sadeghi *et al*., 2014; Sandberg and Wikblad, 2003; Sanders *et al*., 2009; Tavares *et al*., 2014; Verhulst *et al*., 2019). The model included three latent variables (need, personal health practices and use of care, and OHRQoL), one independent variable of interest (T2DM), and two covariates (education and income). Latent and measured variables used in the analysis are described in Table 1.

The need latent variable included three measured ordinal variables: evaluated need, perceived treatment need, and general health condition. Evaluated need was assessed by clinical recommendation of restorative, periodontal, and denture care. Evaluated need was coded ordinally as no need, need one of the three treatment types, need two of the three or need all three types. Perceived need was assessed by responses to the questions "Do you need…teeth filled/gum treatment or teeth cleaned/dentures made?" and coded as no need, need one of the three, need two or need all three treatment types. General medical health condition was assessed by responses to the following question: "Would you say your health in general is…" and coded as excellent, very good, good, fair or poor.

Personal health practices and use of dental services included three measured ordinal variables: reason for dental visit, frequency of dental visits, and smoking status. Reason for dental visit was reported using the following question: "What was the main reason you last visited the dentist?" with responses coded as Went in on own for check-up, examination, or cleaning"; "Was called in by the dentist for check-up, examination, or cleaning"; "Something was wrong, bothering or hurting"; "Went for treatment of a condition that dentist discovered at earlier checkup or examination" or "Other reasons". Frequency of dental visits was assessed in response to: "When did you last visit a dentist?" Responses were coded as six months or less, more than six months but not more than one year ago, more than one year but not more than two years ago, more than two years ago but not more than three years ago, more than three years but not more than five years ago, more than five years ago or never have been to a dentist. Smoking status was evaluated in response

Table 1. Characteristics of study variables in the weighted sample

	Total	*T2DM*			*p*
		No	*Yes*		
			Controlled	*Uncontrolled*	
	N = 124,525,899	*N = 113,920,136*	*N = 8,296,968*	*N = 2,308,795*	
Income	%	%	%	%	< 0.001
> 400% FPL (ref.)	38.9	40.3	22.7	28.0	
200-400 FPL	32.6	32.6	34.6	23.5	
< 200% FPL	28.5	27.1	42.7	48.5	
Education					< 0.001
Bachelor's or above (ref.)	28.6	29.3	22.9	10.8	
Associate degree	32.3	32.6	31.1	22.0	
High school diploma	26.3	26.5	22.5	27.1	
9-11th grade	7.9	7.3	10.3	29.5	
Less than 9th grade	4.9	4.2	13.2	10.6	
Need					
Perceived need					< 0.001
No need (ref.)	38.6	38.7	35.3	43.1	
1 treatment	36.5	36.8	37.8	19.7	
2 treatments	19.9	20.1	19.0	8.7	
3 treatments	5.0	4.4	7.8	28.4	
Evaluated need					< 0.001
No need (ref.)	68.2	68.5	67.0	59.7	
1 treatment	25.8	25.7	25.7	30.9	
2 treatments	5.9	5.7	7.3	9.4	
3 treatments	0.1	0.1	0	0	
General health conditions					< 0.001
Excellent (ref.)	13.5	14.5	2.1	5.5	
Very good	37.4	39.1	21.1	11.4	
Good	33.9	33.3	40.9	38.9	
Fair or Poor	15.2	13.1	35.9	44.2	
Use					
Reason					< 0.001
Self-come check-up (ref.)	46.5	48.2	29.6	19.1	
Called to check-up	10.8	10.9	9.3	10.8	
Bother or hurting	28.2	27.3	37.9	39.6	
Treatment	8.3	7.9	9.8	21.4	
Other	6.2	5.7	13.3	9.2	
Frequency					< 0.001
≤ 6 months (ref.)	49.2	50.5	35.9	31.1	
≤ 1 year	16.6	16.8	16.0	12.1	
≤ 2 years	10.8	11.1	7.8	9.0	
≤ 3 years	5.8	5.7	6.1	9.1	
≤ 5 years	5.8	5.7	8.0	2.7	
> 5 years or never	11.8	10.3	26.1	36.0	
Smoking					< 0.001
Never smoke (ref.)	50.2	50.4	50.5	41.1	
Former smoker	28.2	27.3	37.7	36.1	
Current smoker	21.6	22.3	11.8	22.4	
OHRQoL					
OHIP - Physical	7.11 (± 3.27)	7.06 (± 3.19)	7.44 (± 3.76)	8.23 (± 4.52)	< 0.001
OHIP - Psychological	1.39 (± 0.95)	1.37 (± 0.90)	1.56 (± 1.15)	2.04 (± 1.70)	< 0.001
OHIP - Social	1.11 (± 0.47)	1.11 (± 0.46)	1.13 (± 0.51)	1.11 (± 0.47)	< 0.001

ref. = reference category

to number of cigarettes participants smoked in their lives. Responses were coded as "never smoked", smoked less than 100 cigarettes in their lives, "former smoker" if they had smoked at least 100 cigarettes in their lives but had quit smoking. Participants were coded "current smoker" if they have smoked at least 100 cigarettes in their lives and currently smoked cigarettes (Tomar and Asma, 2000).

OHRQoL was measured using OHIP-NHANES with three sub-scales of OHIP-physical, OHIP-psychological, and OHIP-social. OHIP-NHANES assesses participants' frequency of oral health-related problems on seven dimensions during the previous twelve months (Maida *et al*., 2013; Sandberg and Wikblad, 2003; Sanders *et al*., 2009). Participants were asked to rate for the last twelve months each item on a five-point ordinal scale and coded as: never, hardly ever, occasionally, fairly often, and very often. Three subscales were created to represent the three domains, physical (five items), social (1 item), and psychological (1 item) (Sanders *et al*., 2009).

The main independent variable of interest was T2DM status as assessed in response to the NHANES survey question: "other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes?" Responses were coded as "do not have T2DM", "participant had T2DM with controlled HbA1c" if the response was "yes" and HbA1c <8 or "have T2DM with uncontrolled HbA1c" if the response was "yes" and HbA1c ≥8 (Verhulst *et al*., 2019).

Participant education level was classified into five levels and coded as bachelor's degree or above, associate degree or some college, high school diploma, 9-11th grade or less than 9th grade. Income was categorized as: > 400% Federal Poverty Level (FPL), 200% - 400% FPL or <200% FPL. All variables were coded so that higher numbers indicated a larger risk of the variable.

Traditional two-stage SEM was used (Baker, 2009; Baker *et al*., 2008; Meyers *et al*., 2016). Confirmatory factor analysis (CFA) tested whether the indicators selected for the hypothesized measurement models had an acceptable factor structure (Baker, 2009). SEM is an appropriate statistical technique to assess and modify the theoretical framework because it allows simultaneous testing of complex interrelationships between variables specified within an *a priori* model (Baker, 2009; Meyers *et al*., 2016). CFA measures the relationship between observed (indicator) items (i.e., evaluated need, perceived treatment need, general health condition) and the unobserved underlying (latent) constructs (e.g., need factors). After specifying the measurement model, the hypothesized SEM was tested to explore the *a priori* direct and indirect relationships between T2DM and latent variables (i.e., need, personal health practices and use of services, OHRQoL).

The initial step of the analysis was to test whether the data were consistent with the hypothesized three-factor model, a simplified ABM version. The three latent variables were oral health care need, personal health practices and use of services, and OHRQoL. Indicators were not allowed to load on more than one factor (construct) (Meyers *et al*., 2016). In addition, error terms were orthogonal (Meyers *et al*., 2016).

The overall model fit was assessed using the chi-square test statistic (χ^2) and five fit indices: root-mean-square error of approximation (RSMEA) with 90%CI, standardized root mean square residual (SRMR), the Goodness of Fit Index (GFI), the Normed Fit Index (NFI), the Incremental Fit Index (IFI), the Tucker-Lewis index (TLI), and the comparative fit index (CFI) (Baker, 2009; Baker *et al*., 2008; Meyers *et al*., 2016). The chi-square statistic divided by degree of freedom (χ^2/d.f.) ratio was used as the measure of overall goodness-of-fit because the chi-square statistic can be inflated by sample size. The goodness of fit model was indicated by a χ^2/d.f. ratio≤5.00, RMSEA values ≤0.06, GFI, NFI, IFI, CFI, and TFI values ≥0.90, and a SRMR value ≤0.08.

After an adequate measurement model was specified, a structural model was tested to estimate the direction and magnitude of the direct and indirect lagged paths between T2DM and the three latent variables. In previous studies (Azogui-Lévy *et al*., 2018; Verhulst *et al*., 2019) that measured the association between T2DM with oral and medical conditions, T2DM was hypothesized to predict need, and OHRQoL mediated by need. Demographic variables (i.e., education, income) were included to control for possible effects of education and income.

SAS version 9.4 statistical software (SAS Institute, Inc., Cary, NC, USA) was used for data management and descriptive statistics. Version 1.1.3.1 of the Complex Survey Structural Equation Modeling packages (*lavaan.survey*) in R software was used for CFA and SEM. Many indicators were non-normal or categorical, which prevented use of the standard maximum likelihood estimation method. The alternative was to use a diagonally weighted least squares (DWLS) derived by Muthen and Kaplan (1992). Standardized path coefficient estimates were calculated using the *lavaan.survey* R package because the model contained measured variables with different units (Muthen and Kaplan, 1992).

Results

In the weighted sample (N=124,525,899), 51.9% of the participants were female and 48.1% male. Mean age was 48.63 years (SD=16.84, range=20-85). Nearly 8.5% had T2DM, and 22.4% of T2DM participants had poor glycemic control (i.e., HbA1c ≥8) (Table 1).

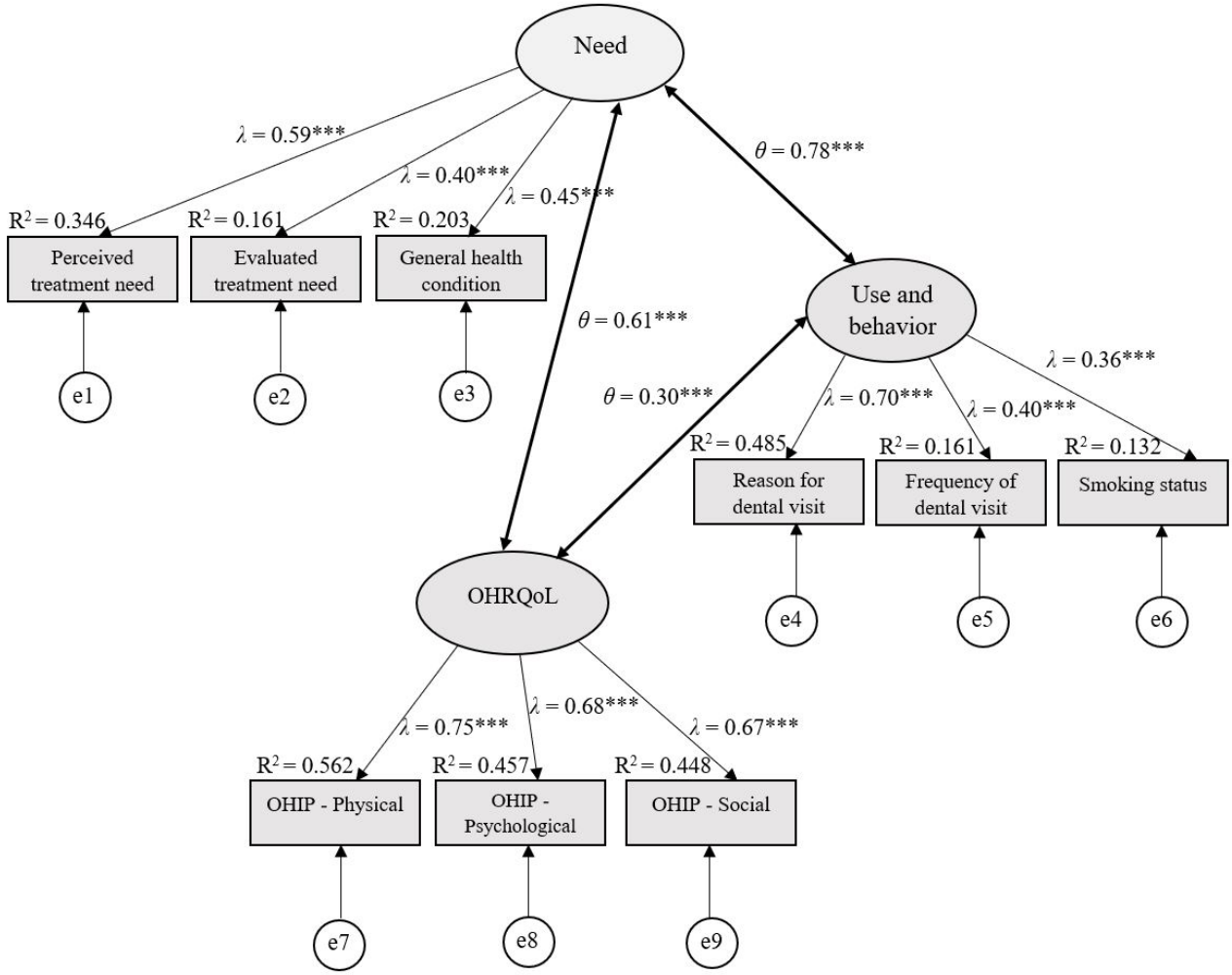
The simplified three-factor ABM (measurement model – Model 1) was a good fit to the data meeting seven of the *a priori* criteria (Table 2 and Figure 2). Standardized correlation and factor loading ($\boldsymbol{\lambda}$) estimates for this model are shown in Figure 2. Factors (latent variables) are in ellipses, indicators (measured variables) are in rectangles, and residual errors terms (variances) in circles. All hypothesized correlation estimates between three latent variables were significant (p<0.001) and the three factors had correlations ranging from $\boldsymbol{\theta}$=0.30 and $\boldsymbol{\theta}$=0.78, indicating acceptable discriminant validity (i.e. <0.85) (Meyers *et al*., 2016; Muthen and Kaplan, 1992)(Figure 2 and Table 3).

Factor loadings ($\boldsymbol{\lambda}$) were associated in the expected direction. Higher perceived and evaluated dental treatment need, and worse general (medical) health conditions were associated with greater need (Table 3). Perceived need had a greater factor loading than evaluated need. Oral problems as a reason for dental visit, infrequent dental visits in the last twelve months, and current smoking were strongly associated with "personal health practices and

Table 2. Fit indices for the measurement (CFA) and SEM models.

Model	*Absolute indices*					*Relative indices*				*Criteria*
	χ^2/d.f.	*p*	*RMSEA (95 CI)*	*SRMR*	*GFI*	*NFI*	*IFI*	*CFI*	*TLI*	*fitted*
1	5.582	0.000	**0.040 (0.034 – 0.047)**	**0.060**	**0.999**	**0.949**	**0.958**	**0.958**	**0.936**	7
2	**1.743**	0.001	**0.017 (0.011 – 0.022)**	0.099	**1.000**	**0.932**	**0.969**	**0.968**	**0.959**	7

Figures in bold are those in line with the model-fitting criteria.
Model 1 = measurement model;
Model 2 = structural model; d.f. = degrees of freedom; RSMEA = root-mean-square error of approximation; SRMR = standardized root mean square residual; GFI = Goodness of Fit Index; NFI = Normed Fit Index NFI, IFI = Incremental Fit Index (IFI); CFI = comparative fit index; TLI = Tucker-Lewis Index.



*p < 0.05; **p < 0.01; ***p < 0.001

λ = Factor loadings
θ = Correlation coefficients
δ = Path coefficients
β = Direct effect coefficients
α = Indirect effect coefficients
ω = Total effect coefficients
R^2 = Variance
e = Error term

Figure 2. Standardized estimates for the confirmatory factor analysis.

Table 3. Factor loadings and correlation coefficients in CFA.

Factor loadings of measured indicators	*Need*	*λ* *Use and behavior*	*OHRQoL*	*p*
Perceived treatment need	0.59			< 0.001
Evaluated treatment need	0.40			< 0.001
General health conditions	0.45			< 0.001
Reason for dental visits		0.70		< 0.001
Frequency of dental visit		0.40		< 0.001
Smoking status		0.36		< 0.001
OHIP – Physical			0.75	< 0.001
OHIP – Psychological			0.68	< 0.001
OHIP – Social			0.67	< 0.001
Correlations between latent variables		*θ*		*p*
Need ↔ Use and behavior		0.78		< 0.001
Need ↔ OHRQoL		0.30		< 0.001
OHRQoL ↔ Use and behavior		0.61		< 0.001

λ = Factor loadings
θ = Correlation coefficients

use of services". The best indicator of personal health practices and use of services was the reason for dental visit (λ=0.70) followed by frequency of visits (λ=0.40).

In the model testing the direct and indirect paths between T2DM and latent variables in (Figure 3), the hypothesized paths were all significant, including the direct paths from T2DM to need (denoted as T2DM→need). Worse personal health practices and use of services predicted lower OHRQoL. Worse personal health practices and use of services was predicted by education and income.

Whilst need indirectly predicted OHRQoL, comparison of the direct path and total effects indicated that 77($\frac{0.30}{0.39}$) of the impact of need on OHRQoL was direct.

This model fitted the data well (Table 2, Model 2). Explained variance was 23.8%, 59.7%, and 18.1% for need, personal health practices and use of services, and OHRQoL, respectively (Figure 3).

Discussion

These findings support the hypotheses that T2DM predicted need, need had direct and indirect effects on OHRQoL, and that need predicted personal health practices and use of services. In turn, personal health practices and use of services predicted OHRQoL. Specifically, we analyzed several social and behavioral factors important to improve the understanding of oral health in the adult T2DM population in the US in 2003-2004. T2DM had influences on need for oral care. The coefficient of the path from T2DM to need was 0.49, indicating T2DM would strongly predict need of dental care treatment.

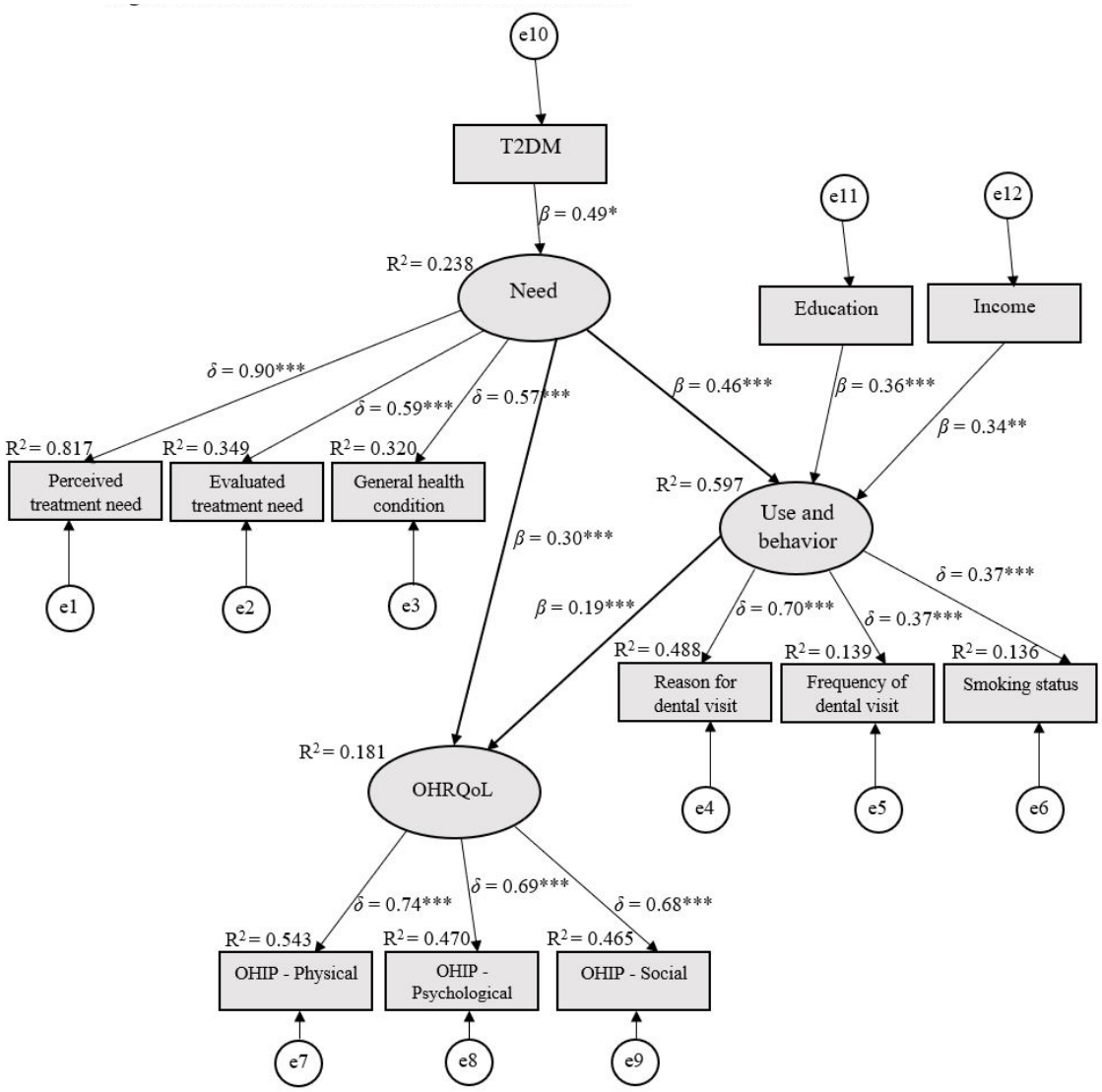
This study is one of a few reports to explore key determinants of dental service use, OHRQoL, and their interrelationships in adult T2DM populations. This study provides findings important to test complex relationships between key contextual factors when oral health is evaluated through direct and indirect paths. Dental treatment need strongly predicted OHRQoL both directly and with indirect effects mediated by personal health practices and use of services (Figure 3). Importantly, the need factor was constructed by combining evaluated and perceived need with general health conditions.

Surprisingly, perceived treatment need's factor loading (λ=0.59) was much larger than evaluated need (λ=0.40, Table 3). This indicates that patients may evaluate the impact of oral treatment need differently from their dentists based on various aspects of their lives. General health conditions also had an important effect on need.

The factor loadings of psychological and social functioning were relatively small compared to physical function. Psychological and social functioning were measured by a single OHIP item for each function, "embarrassed because of mouth conditions" and "had difficulty with job because of mouth conditions," but were significant. CFA results support the importance of these dimensions in OHRQoL.

We used a three-factor ABM, instead of the five in the full ABM used by Baker (2009). Predisposing and enabling factors were not included in the simplified model. However, the pathways of predisposing factors to four other factors of the full ABM were not significant in Baker's SEM study (Baker, 2009). In the present study, education and income were used as covariates instead of measured indicators of latent variables (e.g., predisposing, enabling). Education and income predicted personal health practices and use of services. Higher education and income were associated with favorable attitudes toward oral health (Baker, 2009).

Social structural factors (e.g., attitudes, beliefs, and knowledge about the oral health and dental services) may increase the explanatory power of ABM models (Baker, 2009). According to the Theory of Planned Behavior (Ajzen, 2011), an individual's intention to perform a behavior (e.g., going to see a dentist) is a result of beliefs (e.g., attitudes, values, and knowledge about oral health and dental services) (Baker, 2009). These social structural factors may influence enabling resources, need, and a pattern of preventive oral care services and may explain why "the reason for dental visit" was a better predictor than frequency of dental visits and smoking in the measurement of personal health practices and the use of services. Participants with favorable attitudes toward dental care were more likely to have better



*p < 0.05; **p < 0.01; ***p < 0.001

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R^2 = Variance
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Figure 3. Standardized estimates for the structural model.

evaluated oral health outcomes (Baker, 2009). Conversely, individuals with negative attitudes toward dental care and lower income had the poorest oral health, cost-related treatment delays, and smoked cigarettes. In the present study, smoking, problem-oriented dental visits, and frequency of dental visits were linked to OHRQoL. This finding contradicts a previous SEM study using United Kingdom (UK) data that found that less frequent brushing, not visiting the dentist annually, and only visiting a dentist when there is pain were linked to better OHRQoL (Baker, 2009). The difference may partially be the result of the way latent constructs were operationalized. Nonetheless, the present findings align intuitively with a large body of evidence that recent dental clinic attendance, a preventative pattern of dental care, and good oral habits have a positive effect on evaluated and perceived oral health outcomes (Baker, 2009; Tavares *et al*., 2014). More importantly, previous studies have found strong links between T2DM and oral health and OHRQoL (Tavares *et al*., 2014; Azogui-Lévy *et al*., 2018; Shrivastava *et al*., 2018). The new finding of the present study is that the T2DM direct predicts need, and in turn need affects personal health practices and use of services and OHRQoL.

Using the advantages of SEM over traditional regression, the causal pathways of contextual factors associated with OHRQoL were assessed simultaneously here to provide clinical and policy implications for clinicians, policymakers, and health policy researchers. Adults with T2DM are more likely to develop other systemic diseases such as cardiovascular disease, neuropathy, nephropathy, retinopathy (Verhulst *et al*., 2019). In the other hands, individuals with oral conditions (e.g., periodontal diseases, dental caries, tooth loss) are associated with increased risk of chronic diseases including T2DM, renal failure, coronary artery disease, hypertension (Tavares *et al*., 2014; Verhulst *et al*., 2019). Our finding that T2DM appears to play an important role in the need for dental treatment, that in sequence affects personal health practices and OHRQoL suggest that dental preventive programs may adopt different interventions to reduce modifiable risk factors and improve protective factors of OHRQoL. Perceived need for treatment had the greatest effect on need, and the reason for dental visits had the greatest influence on personal health practices. General health and oral health are strongly connected (Tavares *et al*., 2014). T2DM is a common risk factor for both general health and oral health (Verhulst *et al*., 2019). Glycemic control is associated with lower risk of T2DM's systemic and oral complications (Tavares *et al*., 2014; Verhulst *et al*., 2019). Health policies might simultaneously improve individual perception of oral care need, provide benefits of regular dental check-ups for T2DM individuals with low income (< 200% FPL), and encourage dentists to recommend T2DM patients to check HbA1c before a dental visit. Health education programs to improve oral health attitudes and T2DM individuals could be the focus of these dental preventive programs. The findings help physicians, dentists and health policymakers better understand casual pathways between T2DM and perceived oral health outcomes (OHRQoL) to have appropriate treatments and policy for this vulnerable population.

The present study used SEM because it is a valid statistical technique for theory-driven analysis, but the causal relationships between items and constructs must be conceptually clear (Baker, 2009). For example, income and education were modelled as predisposing or enabling factors in previous studies (Babitsch *et al*., 2012; Baker, 2009). Income and education may both predispose and enable access, but it is not possible analytically for an item to have multiple latent construct roles (Babitsch *et al*., 2012; Baker, 2009). Clarifying these issues will help devise and incorporate valid indicators to capture the underlying concepts adequately (Baker, 2009). Our findings relating to oral care utilization may only be applicable within the structure of dental policy in the USA. Further studies should use samples from other countries with different dental public health policies to cross-validate the present findings.

In conclusion, analysis of the interrelationships between T2DM, dental treatment need, personal health practices and use of services with OHRQoL in found that T2DM had an impact on need, which in turn, had direct and indirect effects OHRQoL. Refinement and replication of the model developed in this investigation to analyze the effects of T2DM on OHRQoL is needed. This will help improve dental public health policy for this T2DM vulnerable population by better understanding the causal pathways of T2DM and oral health.

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