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A model for oral health gradients in children: using structural equation modeling

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Detecting the underlying socioeconomic and behavioral determinants is essential for reducing oral health disparities in children. ***Objective:*** To test a conceptual model in children to explore the interaction amongst social, environmental, behavioral factors and oral health outcomes. ***Methods:*** This analytic cross-sectional study was performed in 2014-2015 in Shiraz, Iran. The sampling was conducted using a multistage stratified design to represent the whole 6-year-olds in Shiraz County. Participants were 830, 6-year-old first grade primary schoolchildren and their parents. Children were examined to register decayed, missing and filled teeth (dmft) and simplified oral hygiene index (OHI-S). Parents were asked for data on socio-cultural risk factors, oral health behaviors and children's oral health related quality of life (C-OHRQoL). Data on environmental risk factors were collected from several sources. The proposed model, a development of Peterson's, was tested using structural equation modeling (SEM). ***Results:*** The tested model could empirically demonstrate the wide range of social and behavioral factors affecting C-OHRQoL. Socioeconomic status (SES) affected the OHRQoL of children through several pathways. Tooth brushing frequency, use of oral health services and consuming cariogenic foods were the mediators, through which SES affected dmft and subsequently C-OHRQoL. ***Conclusions:*** Using the modified Petersen's model and SEM, the paths in which different distal and proximal factors affect oral health outcomes in children could be clearly identified. It showed that addressing the underlying social, economic and behavioral determinants is essential for reducing oral health disparities among Iranian children.

Key words: *quality of life, oral health, children, socioeconomic status, tooth brushing, structural equation modeling, Iran*

Introduction

It is generally accepted that oral diseases are multifactorial conditions and that oral health inequalities within and between countries cannot be explained just by genetic, biological and lifestyle factors. Social, economic, political and environmental disparities also need to be considered (Patrick *et al.*, 2006; Yeung, 2014).

Similar to other aspects of health, the socio-environmental gradients in oral health are of great importance at individual, community and political levels. (Guarnizo-Herreño *et al.*, 2014; Sabbah *et al.*, 2007). Besides assessing the social gradients in oral health status, the interaction amongst environmental factors, socio-behavioral factors, oral health status and children's oral health related quality of life (C-OHRQoL) should be investigated. However, the vast majority of OHRQoL studies in the primary dentition have focused on isolated social determinants (Abanto *et al.*, 2011; Kramer *et al.*, 2013; Scarpelli *et al.*, 2013). Hence, assessing each of the oral health determinants with traditional techniques and without a conceptual model is illusive.

Several conceptual models have recently been introduced to compensate for the shortcomings of considering a few isolated factors in the existing literature (Fisher-Owens *et al.*, 2007; Lee and Divaris, 2014; Newton and Bower, 2005; Patrick *et al.*, 2006). Conceptual models try to exhibit several oral health determinants at macro and micro levels. Each model has its own strengths and limitations. Newton's conceptual model, for example, tries to demonstrate oral health determinants as concisely as possible (Newton and Bower, 2005). However, the application of the model to a population is problematic. Some models seem comprehensive, but currently they are all at the theoretical phase (Lee and Divaris, 2014; Patrick *et al.*, 2006). Several studies need to be performed to evaluate the effects of distal and proximal factors on oral health outcomes to facilitate the tracing and understanding of the interactions amongst these factors.

Among the above models, Petersen's oral health model is a more comprehensive multidimensional model recently recommended by the World Health Organization for public health administrators as an operational model for data collection (WHO, 2013). The model clearly divides socio-behavioral oral health risk factors into proximal and distal levels and suggests that distal factors such as socio-cultural risk factors, health system and environmental risk factors can affect oral health indirectly and through proximal factors, such as the use of oral health services and risk behaviors (Petersen, 2003).

Testing conceptual models by using structural equation modeling (SEM) method enables researchers to clearly show the direct and indirect impacts. Silveria *et al*. (2014), for example, suggested a hypothetical model and investigated the direct and indirect impacts of socioeconomic status (SES) on oral health behaviors, oral health status and subsequently quality of life in Brazilian adolescents.

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Qiu *et al*. (2014) in China hypothesized an oral health model according to the previous theories on knowledge, attitude and practice. The model could reveal the details of the impact of SES on dental caries through the caregivers' knowledge, attitudes, behaviors and subsequently children's oral health behaviors. As mentioned, previous tested models using SEM in primary dentition did not consider environmental factors, other oral health determinants and life quality in one comprehensive model.

The interaction amongst socioeconomic factors, other environmental oral health determinants, individual aspects, oral health status and quality of life in children has not been fully assessed in the literature (Barbosa and Gaviao, 2008; Gao *et al.*, 2010). While previous studies with traditional techniques could not exhibit indirect impacts, SEM allows the researcher to assess the direct and indirect impacts of oral health determinants on oral health outcomes in a complex model. SEM can present complex relationships visually in a path diagram. Moreover, this technique can incorporate unobserved (latent) variables, like SES, in the hypothesized model. Therefore, it seems essential now for a study to assess the pathways through which different oral health determinants, at different levels, can affect oral health status and quality of life.

The present study tested the modified Petersen model for factors affecting oral health in 6-year-olds of Shiraz County to explore interactions amongst social, environmental, behavioral factors and oral health outcomes. Shiraz County, Southern Iran, is a less developed area of a developing country, which has recently prompted international concerns regarding social inequalities.

Methods

This analytic cross-sectional study was performed in 2014-2015. Ethical permission was obtained from the Postgraduate Faculty of Shiraz University of Medical Sciences (93-126808). Permission to enter the selected schools was obtained from the Educational Head Office of Fars Province. The study objectives were described to parents or caregivers at the beginning of the study. They were asked to fill out consent forms for interviewing and clinical examination of their children.

Data were mainly collected based on variables described in Peterson's risk factor model. The recommended 20 participants (Kline, 2010) for each of the 21 observed variables in the model was used in the sample size calculation then doubled to allow for the stratified sampling used in this study (k=2). Therefore, a sample of about 840 was considered ample.

The participants were 6-year-old first grade primary schoolchildren and their parents in Shiraz County. Sampling was conducted in a multistage stratified design to represent all 6-year-olds across all the County's four education zones. The zones were then divided into rural and urban areas and public and private schools. Rounded up proportionate numbers of boys and girls were then selected by simple randomization, using schools' registers. A total of 830 children were selected from 35 schools. All consented children were included in the study except for those with mental or physical disabilities and those who have not lived with their caregiver for at least six months.

Data on environmental risk factors were collected from a variety of sources. Moreover, parents or caregivers were interviewed using a questionnaire covering SES, oral health behaviors, use of oral health services, diet and C-OHRQoL. Intra-oral examination was conducted to assess the children's dmft and OHI-S status.

Socio-cultural risk factors were considered as a latent variable. The information about parents' educational level and occupation, house ownership, private room for their children, number of cars in the family, well-fare facilities, family structure, social support and household income was obtained from the socioeconomic section of the questionnaire.

In the absence of a standardized socio-environmental index in Iran, the data on environmental risk factors (rate of children with preschool formal education, land prices, the foreigners' population in each school area and number of public and private oral health centers in a district) were obtained from multiple resources. Environmental risk factors were also considered as latent variables.

Each school was scored for the percentage of their children with formal preschool education.

The average price of land in each district was obtained from four estate agencies in that district. The land price in each district was then transformed to scores which ranged from 1 to 30 each scale point representing 2 million Rials (64US$).

In Iran, most non-Iranian children are from immigrant families who have fled their own (more deprived) neighboring country due to war and now residing in the poorest districts. Therefore, the percentage of non-Iranian children in a school was used as an index of deprivation of that district and calculated from names on each school's registers.

The number of public and private oral health centers in a district was used as the index for accessibility of the children of schools in that district.

The reason for a child visiting a dentist (regular check-up, whenever needed, only in pain, or never) was asked and used as the index for use of oral health services.

Regarding risk behaviors, the frequency of brushing teeth with fluoridated toothpaste was categorised as: twice a day or more, once a day, less than once a day and never. Then the average frequency of snacks, fruits, milk, sugary foods, and table sugar intake in each month was obtained from the questionnaire. Based on the Cariogenic Potential Index (CPI), different foods received CPI scores (Mundorff *et al.*, 1990; Bowen *et al.*, 1980). For each food type, the frequency was multiplied by its CPI score. Calculated scores for different kinds of foods were summed as the final diet score for each child. Higher scores indicated a more cariogenic diet.

All clinical examinations for oral health status were conducted by one calibrated examiner in the schools. A headlight, disposable dental mirrors and tongue blades were used to assess the dmft Index (based on WHO, 1997 criteria) and Simplified Oral Hygiene Index (OHI-S) (Miglani *et al.*, 1973). The Miglani version of the OHI-S for primary dentition was adopted with the presence of plaque and calculus assessed for the buccal surface of six index primary teeth (51, 55, 65, 71, 75, 85).

The Farsi version of Early Childhood Oral Health Impact Scale (F-ECOHIS) was used to assess the C-OHRQoL (Jabarifar *et al.*, 2010). The response to each of its 13 questions (nine questions on child impact and four on the impacts of child oral health on family) was scored from 1, never, to 5, very often. All scores were then summed to generate a simple total score, range 13 to 65 with higher scores indicating worse OHRQoL.

The Petersen model was used to create the flow chart of the possible interaction of the assessed risk factors for dmft, OHI-S, and F-ECOHIS Indices. The structural equation modeling (SEM) method was used for analysis. Variables discussed in the present study are observed (represented by square in graphics, except outcomes represented by octagonal) and unobserved (latent) variables (represented by oval in graphics).

The Confirmatory Factor Analysis (CFA) was used in the current study to assess the construct validity of dimensions of questionnaires on socio-cultural risk factors and environmental risk factors.

The goodness-of-fit model was assessed using Root Mean Squared Error of Approximation (RMSEA), Tucker-Lewis Index (TLI) and Comparative Fit Index (CFI). The model fit was considered acceptable when RMSEA<0.1, CFI and TLI>0.90 (Hu and Bentler, 1999). Descriptive and analytical analyses study were performed using SPSS (v.18) and Mplus (v.7). Mplus uses a robust weighted least squares estimator, using a diagonal weight matrix (WLSMV) optimal for analysis of categorical data in SEM when the sample size is 200 or greater (Rhemtulla *et al.*, 2012).

Results

Some 801 (52.6% male) or 96.5% of 830 invited children and their parents participated in this study. The mean dmft was 5.56, SD 3.97. The mean OHI-S score was 0.59, SD 0.40. The mean F-ECOHIS score was 21.95, SD 7.45. Descriptive data on socioeconomic status and oral health behaviors are in Table 1.

Socio-cultural risk factors were treated as a latent variable. Confirmatory factor analysis was used to assess construct validity of socio-cultural risk factors. The fit indices were all in acceptable ranges with CFI=0.94; TLI=0.930 and RMSEA=0.099. According to Kline (2010), factor loading less than 0.3 should be eliminated from the model. Therefore, mothers' occupation, house ownership and social support which did not meet the criteria were removed from the model.

The environment was also considered as a latent variable. Similarly, confirmatory factor analysis was used to investigate construct validity of environmental factors. Environment comprised four indicators: land prices, the foreigners' population in each school area, rate of children with preschool formal education and number of oral health services around each school. The model fit indices were not in acceptable ranges (RMSEA=0.617; 108; CFI=0.615; TLI=0.155) even after eliminating those having preschool education. Therefore the environment was excluded from the hypothesized model. The factor loading of the observed variables for environmental factors was shown in Table 2.

The hypothesized structural equation model was tested for goodness of fit (Figure 1).The model fit indices (RMSEA=0.082; 108; CFI=0.951; TLI=0.934) were acceptable. SES, tooth brushing frequency and reason for use of oral health services had low, non-significant impact on ECOHIS (Table 2).

Non-significant (P>0.05) paths were eliminated from the model. The final model is illustrated in Figure 2. The model fit indices (RMSEA=0.076; 108; CFI=0.956; TLI=0.943) were much better following the removal of these.

Table 1. Distribution of descriptive variables for 801 6-year-olds

Variable	*Category*	*Frequency*
Gender	Male	421 (52.6 %)
	Female	380 (47.4 %)
Father's education	Illiterate	33 (4.1 %)
	Primary	93 (11.6 %)
	High School	242 (30.2 %)
	Diploma	315 (39.3 %)
	Degree or higher	118 (14.7 %)
Mother's education	Illiterate	45 (5.6 %)
	Primary	97 (12.1 %)
	High School	182 (22.7 %)
	Diploma	378 (47.2 %)
	Degree or higher	99 (12.4 %)
Father's occupation	Unemployed	24 (3 %)
	Part time job	246 (30.7 %)
	Full time job	531 (66.3 %)
Mother's occupation	Unemployed	736 (91.9 %)
	Part time job	28 (3.5 %)
	Full time job	37 (4.6 %)
Monthly income in million Rials (US$)	≤5 (161 $)	151 (18.9 %)
	>5 to 10 (321 $)	390 (48.7 %)
	>10 to 20 (321 to 643 $)	199 (24.8 %)
	>20 (643 $)	61 (7.6 %)
House ownership	Own a house	436 (54.4 %)
	Organization's home	14 (1.7 %)
	Rental house	351 (43.8 %)
Private room	Yes	316 (39.5 %)
	No	195 (24.3 %)
	Share with others	290 (36.2 %)
Number of cars	No car	260 (32.5 %)
	One	519 (64.8 %)
	Two or more	22 (2.7 %)
Having household luxury items	LCD TV	469 (58.6 %)
	Freezer	613 (76.5 %)
	Computer	444 (55.4 %)
	Washing machine	352 (43.9 %)
	Dish washer	67 (8.4 %)
	Furniture	410 (51.2 %)
Number of children in the family	One	232 (29 %)
	Two	389 (48.6 %)
	Three	118 (14.7 %)
	Four or more	62 (7.7 %)
Tooth brushing frequency with fluoridated toothpaste	Twice a day or more	59 (7 %)
	Once a day	297 (37 %)
	Less than once a day	403 (50 %)
	Never	42 (5 %)
Pattern of dental attendance	Regular check-up	29 (3.6 %)
	When felt need	245 (30.6 %)
	Only when in pain	268 (33.5 %)
	Never attended	259 (2.3 %)

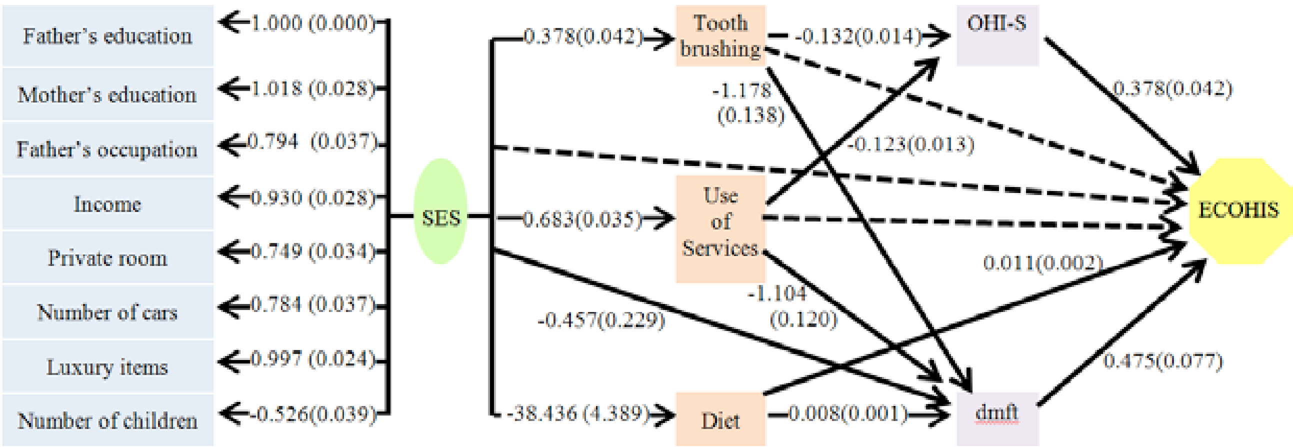

Figure 1. *The hypothesized model for oral health determinants, Estimate (standard error)*

Table 2. Estimated standard error and bivariate correlation in the hypothesized model

Domains	*Items*	*Estimate*	*SE*	*P value*
Socioeconomic status §	Father's education	0.825	0.015	<0.001*
	Mother's education	0.840	0.016	<0.001*
	Father's occupation	0.655	0.030	<0.001*
	Income	0.767	0.020	<0.001*
	Private room	0.619	0.027	<0.001*
	Number of cars	0.648	0.029	<0.001*
	Luxury items	0.823	0.015	<0.001*
	Number of children in the family	0.416	0.028	<0.001*
Environmental risk factors §	Land prices	0.599	0.034	<0.001*
	Foreigners' population in each school area	0.686	0.021	<0.001*
	Children with preschool formal education	0.942	0.026	<0.001*
	Number of oral health services in each school area	0.531	0.039	<0.001*
	Tooth brushing ← Socioeconomic status	0.378	0.042	<0.001*
	Use of services ← Socioeconomic status	0.683	0.035	<0.001*
	Diet ← Socioeconomic status	-38.436	4.398	<0.001*
	dmft ← Socioeconomic status	-0.457	0.229	0.046*
	ECOHIS ← Socioeconomic status	0.837	0.456	0.066
	OHI-S ← Tooth brushing	-0.132	0.014	<0.001*
	OHI-S ← Use of oral services	-0.123	0.013	<0.001*
	dmft ← Tooth brushing	-1.178	0.138	<0.001*
	dmft ← Use of oral services	-1.104	0.120	<0.001*
	dmft ← Diet	0.008	0.001	<0.001*
	ECOHIS ← Tooth brushing	-0.420	0.306	0.170
	ECOHIS ← dmft	0.475	0.077	<0.001*
	ECOHIS ← Use of oral services	-0.154	0.273	0.574
	ECOHIS ← Diet	0.012	0.002	<0.001*
	OHI-S with ECOHIS	0.225	0.092	0.015*

SE Standard Error; § Factor loading of the observed variables for their latent variables (socioeconomic status and environmental risk factors); * P<0.05 is significant

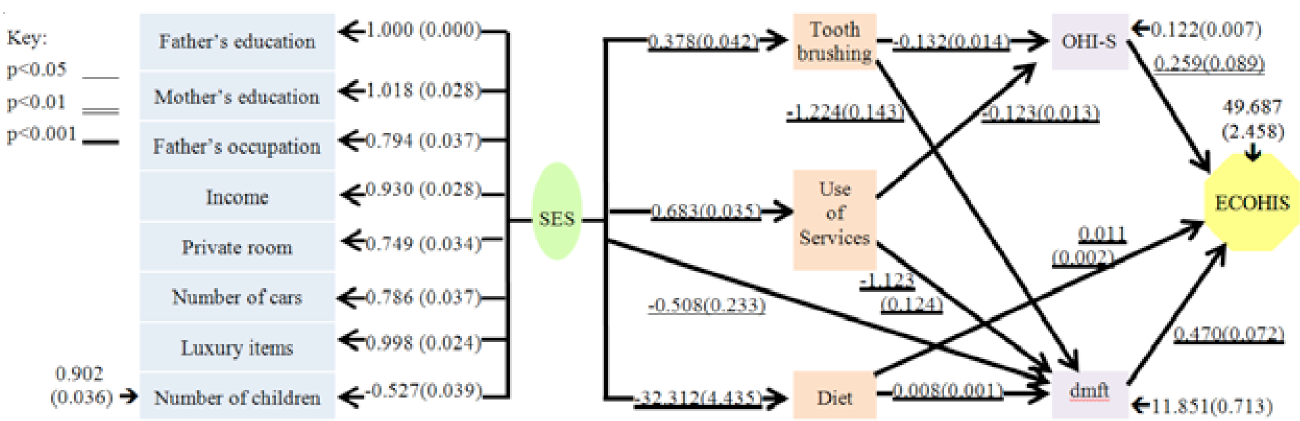

Figure 2. *The final model for oral health determinants, Estimate (standard error)*

In the final model, SES had no direct effect on ECOHIS (P=0.66). However, higher SES corresponded with : increased frequency of tooth brushing (Estimate: 0.378); more regular dental visits (Estimate: 0.683); and consumption of less cariogenic foods (Estimate: -32.312). SES had an inverse effect on dmft (Estimate: -0.508).

Tooth brushing only indirectly affected ECOHIS (through dmft). The dmft score of children who brushed their teeth twice a day or more, once a day, less than once a day and never, increased with 1.224 estimates. The higher dmft scores resulted to worse OHRQoL (higher ECOHIS scores).

A decrease in the tooth brushing frequency was linked to an increase in OHI-S and dmft scores. The OHI-S score of children with twice daily or more tooth brushing was 0.132 lower than those who brushed once a day. Similarly, those who brushed once a day had lower score (0.132) than those who brushed less than once a day. Finally, children who brushed less than once a day had lower score (0.132) than those who never brushed their teeth.

In this model, use of services did not have direct impacts on ECOHIS (P=0.574). Children with regular dental visits had the lowest dmft scores and lowest ECOHIS scores. The dmft scores increased gradually with the estimate of 1.123 as the children visited a dentist regularly, when they felt the need, when in pain and never. Dental attendance had also negative impacts on OHI-S scores. Children with regular dental visits had the lowest OHI-S scores. The OHI-S scores increased gradually with the estimate of 0.123 as the children visited a dentist regularly, when they felt the need, when in pain and never.

Diet had both direct and indirect effects on ECOHIS (through dmft). Children consuming more cariogenic foods had higher dmft scores and worse OHRQoL. As the cariogenic food consumption increased by one unit, the dmft score increased by 0.008. Similarly, as the cariogenic food consumption increased by one unit the ECOHIS score increased by 0.011.

Discussion

This study implies that the suggested model can be used to assess and demonstrate the direct and indirect factors affecting oral health status and OHRQoL. The final model showed that the SES affected the OHRQoL of children through several pathways. Tooth brushing frequency, use of oral health services and consuming cariogenic foods were the mediators through which SES affected dmft and subsequently C-OHRQoL. SES influenced the outcomes through the cariogenic food consumption more than the other paths. Tooth brushing had the greatest impact on dmft while diet had the least. Furthermore, oral health behaviors (tooth brushing and use of dental services) affected oral hygiene status and life quality.

Parents' education, father's occupation, income, private room, number of cars, having luxury items and number of children in the family were all good estimators for socioeconomic status of the examined children. Mothers' occupation was removed from the model, probably because most mothers in this study (91.9 %) were unemployed. House ownership was also removed as these indices were not good indicators of socioeconomic differences possibly because owning a house in some disadvantaged areas was of similar SES to renting in some high socioeconomic areas.

Some limitations of the dmft Index have previously been established (Marcenes and Sheiham, 1993). The findings of this study have also shown that the influence of SES on oral health outcomes was more obvious if each component of dmft was separately investigated. A similar study in Brazil tested a hypothetical model by assessing the number of filled, missing and decayed teeth separately in the model (Silveira *et al.*, 2014). Their results showed significant impact of SES only on the number of teeth needing treatment (dt).

Few other studies have tested hypothetical models, exploring the factors affecting children's oral health status. Their conceptual models were not comprehensive and required further modification. Qiu *et al.* (2014), for example, tested a conceptual model to assess the factors affecting children's caries. In contrast with the current study, dental visits had positive significant correlation with children's caries. Children mostly visited a dentist for their dental problems rather than regular checkups (Qiu *et al.*, 2014). Therefore, asking about dental visits without considering the reason for the visits might be misleading to the researchers. In the current study, the reason for service utilization successfully demonstrated the difference in oral health of children with regular checkups and those who visited a dentist in pain or never.

Previous hypothetical tested models for children did not consider the impact of oral conditions on their quality of life. They merely assessed the impact of social and behavioral factors on children's caries (Gao *et al.*, 2010; Qiu *et al.*, 2014). Hence, in the model presented in the current study, the impact of several social, behavioral and normative condition of oral health was assessed on C-OHRQoL.

In the current study, children were selected from all urban and rural, public and private schools in Shiraz County. Therefore, the results can truly demonstrate the oral health profile of the area's 6-year-olds. Another advantage of this study over most previous studies is the division of the risk factors for oral health status and quality of life in children with primary dentition into distal and proximal factors, and studying them in a comprehensive model. The SEM method used has several advantages over the regression techniques in that it assesses the interrelationships among all variables simultaneously. Further, the selection of a specific age of children minimized any potentially confounding effects of age.

On the other hand, a limitation in this study was lack of accurate systematic information on environmental factors, unlike, for example, in Australia where Index of Relative Socioeconomic Disadvantage data quantify the socioeconomic profile of areas (ABS,1998). The limitation of the study's cross-sectional design could be avoided by conducting a longitudinal study which could demonstrate the causal pathways of factors affecting oral health status. Another limitation was that parents answered the questions about their children's oral health behaviors as the 6-year-olds could not accurately recall events.

Future research might usefully be performed in larger samples, probably on a national scale, so any differences in environmental factors can be clarified. The model used in this study clearly identified the pathways. Therefore, other populations with different socio-cultural structures can rely on this tested model and develop the model with more variables (psychosocial factors, health system and oral health services). The findings have implications for policy makers in Iran. A better understanding of the socio-behavioral determinants of C-OHRQoL can help them to reduce the oral health gradients through underlying socio-behavioral factors.

Policy makers should focus on the barriers to regular dental attendance for socially disadvantaged groups. Moreover, consuming cariogenic foods and poor oral hygiene behaviors suggest developing public education programs in poor and disadvantaged children. School-based oral health promotion programs should be considered to reduce the burden of oral diseases especially in socially disadvantaged school children.

Conclusions

The hypothetical oral health model could empirically demonstrate the wide range of social, economic and behavioral factors contributing impacts on C-OHRQoL. The socioeconomic gradients in C-OHRQoL were partially explained by tooth brushing, cariogenic diet, use of oral health services and oral health status. Based on the empirical evidences from the tested model, addressing the underlying social, economic and behavioral determinants is essential for reducing oral health disparities in children.

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