Unraveling Oral Health Disparities: Investigating the Link Between Dental Professional Density and the Prevalence of Dental Conditions from 1990 to 2019

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Abstract

Background:

Oral health disparities are a significant issue affecting populations all over the world. This study examines the relationship between change in dental professional density, socioeconomic development, and risk factors and change in dental condition prevalence from 1990 to 2019. Such insights can inform interventions to alleviate oral health burdens and improve access to care.

Data:

Using estimates produced by the Global Burden of Disease Study 2019, we analyzed data on caries prevalence for 204 countries and territories. We control for the socio-demographic index and healthcare access and quality index, high sugar and sweetened beverages, and a diet low in calcium.

Methods:

Our study employs multiple linear regression. Dental professional density and its relationship with caries of permanent teeth prevalence was investigated by examining within-country change, using fixed effects on location and considering potential confounders.

Results:

These disparities were revealed globally—increases in dental professional density was correlated with declines in caries prevalence, suggesting a key role of accessible care. Changes in socioeconomic development was negatively associated with caries prevalence. A diet of low calcium indicated significant decreases in caries prevalence.

Discussion:

The study emphasizes the importance of accessible dental care and its potential to address dental burdens. This study highlights the critical roles of dental professional density and socioeconomic development in influencing global dental condition prevalence. Targeted policies to improve oral healthcare access and dietary habits can reduce dental burdens and enhance global oral health equity.

Keywords: oral health, dental professional density, socioeconomic development, caries of permanent teeth, multiple linear regression, Socio-Demographic Index (SDI), dietary habits, healthcare access, public health, global burden of disease.

Background

The Centers for Disease Control and Prevention (CDC) state that oral health disparities exist across different socioeconomic groups, with individuals from low-income and minority populations experiencing higher rates of oral diseases and less access to dental care (CDC, 2021). CDC further explains that this can lead to a higher prevalence of untreated oral diseases, significantly impacting overall health and quality of life. Moreover, CDC highlights the need for research to understand better the factors contributing to these disparities and to identify effective interventions that can improve oral health outcomes for all individuals (CDC, 2021).

The World Health Organization (WHO) states that gum disease and dental decay are the most prevalent noncommunicable illness globally (WHO*,* 2023). CDC and WHO point out that dental disease impacts individuals of all ages and socioeconomic levels but is more common in underdeveloped areas. WHO highlights that untreated oral conditions can cause discomfort, make it challenging to consume food and talk, and lower one's quality of life. Additionally, they may cause severe health issues like illnesses, heart disease, and diabetes. Low-income areas also

frequently have restricted access to dental treatment, increasing the frequency of untreated oral diseases, as mentioned by WHO and CDC. According to the WHO, having access to dental care is a fundamental human right, and expanding access to care is crucial for lowering the incidence of oral illnesses (WHO, 2023).

According to the National Institute of Dental and Craniofacial Research (NIDCR), efforts to enhance oral health necessitate a thorough understanding of the factors influencing dental problem prevalence and the availability of dental specialists (NIDCR, 2021). Dental professionals, such as dentists and dental assistants, play an important role in preventing, diagnosing, and treating dental problems. The population density of dental practitioners is an essential measure of access to oral healthcare services. Furthermore, the social and economic setting in which people live significantly impacts their dental health results. Income, education, and healthcare infrastructure are all socio-demographic characteristics that might influence the prevalence of dental diseases and the accessibility of dental services (NIDCR, 2021).

Understanding the complicated connection between the number of dental professionals, socioeconomic development, and the prevalence of dental problems is crucial for developing successful oral health policies and interventions. This study intends to add to the body of knowledge in oral health by investigating these correlations and informing evidence-based decision-making. We thus aim to answer the following: what is the relationship between the change in the prevalence of dental conditions and the change in the density of dental professionals over time? Addressing this question can enable policymakers, healthcare providers, and public health experts to develop ways to improve oral health, minimize the burden of dental diseases, and improve access to dental care services.

Data

The Global Burden of Disease Study 2019 (GBD 2019) provides a comprehensive dataset for tackling this research question (Global Burden of Disease Collaborative Network, 2020). For the period of 1990 through 2019, the study provided estimates for a broad spectrum of diseases and injuries, including oral disorders, in 204 countries and territories. This study will use this dataset to acquire insights into global patterns of dental problems, examine the

availability of dental practitioners, and investigate the relationships between socioeconomic development and oral health outcomes.

We used estimates made available by the Institute for Health Metrics and Evaluation (IHME) for our outcome (prevalence of caries of permanent teeth) and the controls (Dentist Density per 10,000 employed individuals, Dental Assistant Density per 10,000 employed individuals, Socio-Demographic Index, Healthcare Access and Quality Index, Diet Low in Calcium, and Diet High in Sugar-Sweetened Beverages) in our analysis. First, we focus on variations in the prevalence of caries of permanent teeth for the age group of 25 and above, which are defined as permanent dentition showing an unmistakable cavity, undermined enamel, a detectably softened floor or wall, a tooth with a temporary filling, or a tooth that is filled but also with decay present (Institute for Health Metrics and Evaluation. (2019). Caries of permanent teeth, level 4 cause.).

Data underpinning estimates of dentists and dental assistants derived from self-report of individuals interviewed in surveys and censuses and administrative data from the WHO. International Standard Classification of Occupations (version 88) was used to categorize dentists and dental assistants. Data standardization and adjustment methods were used to ensure comparability and address inconsistencies. The authors used spatiotemporal Gaussian process regression (ST-GPR) models to estimate densities for dentistry personnel in 204 countries from 1990 to 2019 (Haakenstad, 2022).

The Socio-Demographic Index (SDI) is a composite measure of social and economic development comprised of fertility, education among women aged 15-24, and ten-year lag-distributed income per person. This index utilizes a scale that easily merges these indicators, enabling cross-country comparisons and nuanced insights into development trajectories (IHME, 2020).

The Healthcare Access and Quality Index (HAQI) estimates were produced using data from the Global Burden of Diseases, Injuries, and Risk Factors Study 2019 (GBD 2019) (Haakenstad, 2022). We focus on the overall HAQ Index, for ages 0–74. The HAQ Index structure utilized the average mean of scaled mortality-to-incidence ratios

(MIRs) and risk-standardized death rates (SDRs) for 32 causes of death that should not occur in the presence of timely, quality health care (Haakenstad, 2022).

The high sugar and low calcium variables represent crucial dietary components with significant oral health implications, focusing mainly on the age group of 25 and above. IHME defines diet high in sugar sweetened beverages as "any intake (in grams per day) of beverages with ≥50 kcal per 226.8 gram serving, including carbonated beverages, sodas, energy drinks, and fruit drinks, but excluding 100% fruit and vegetable juices." (IHME, 2020). The measure originates from dietary assessments and national food consumption surveys (Murray, 2020). IHME defines diet low in calcium as "average daily consumption (in grams per day) of less than 1.06–1.10 grams of calcium from all sources, including milk, yoghurt, and cheese" (IHME, 2020). This variable is derived from dietary surveys and nutrient databases for the age group of 25 and above (Murray, 2020).

There is no need for funding for the current study; however, in the future, comprehensive research might need funding sources.

Methodology

This analysis aims to explore the relationship between the change in the prevalence of caries of permanent teeth and the change in the density of dental professionals per 10,000 employed individuals over time while controlling for each country's non-time varying factors, SDI, HAQI, and risk factors between 1990 and 2019.

Inclusion and Exclusion:

Two important questions were initially considered: Q 1: Establishing the correlation between dental condition prevalence, dental professionals' numbers (dentists and dental assistants), and the Social Development Index (SDI) in 2019; and Q 2: Uncovering the relationship between changes in dental condition prevalence and shifts in dental professionals' density over the years (while accounting for non-time varying factors and SDI) between 2000 and 2019. However, a comprehensive analysis could not be conducted due to data limitations. Therefore, the study's

scope aimed to address modified research questions, which explore the relationship between dental condition prevalence and the density of dental professionals over time.

The intended use of SDI data, dental profession data, and dental caries prevalence data (for permanent and deciduous teeth and periodontal diseases) had to be modified. The study excluded prevalence data for periodontal diseases and deciduous teeth due to insufficient data on confounding factors. The focus was then narrowed down to the prevalence of caries in permanent teeth. The attempt to explore periodontal diseases and deciduous teeth across all age groups was discontinued due to limited data availability. This analysis was constrained to an age group of 20+ or 25+ years for permanent and deciduous teeth. Consequently, the study primarily concentrated on the prevalence of caries in permanent teeth within the age group of 25+ years.

The analysis process extended to regression modeling, which introduced additional variables, the Health Access and Quality (HAQ) variables, and dietary factors. In the case of dietary variables, an initial set of three variables—diet low in milk, diet low in calcium, and diet high in sugar and sweetened beverages—was considered. As the exploration progressed, it became evident that the age group under study primarily consisted of adults with limited milk intake. This realization led to the exclusion of the “diet low in milk” variable, while the focus on “diet low in calcium” and “diet high in sugar” continued.

Numerous regression models were examined to explore the individual contributions of each variable to caries prevalence, both in the density of dental assistant and dentist individually and in combination with the density of dental assistant and dentist data. After thorough analysis, it was decided to merge dental assistant and dentist data in the regression model. The culmination of this process generated the final model, which is the centerpiece of this study’s findings and is presented in the research paper.

Loading and Cleaning Data:

The data were collected from different sections of the GBD study 2019; therefore, each piece of data was loaded separately and cleaned. The methodology starts by collecting and preparing relevant data. All data were processed to

remove redundant or irrelevant information, restructure data frames, and adjust variables for seamless integration. Moreover, these processed datasets are combined to form a comprehensive and readable dataset for further analysis.

Testing Regression Models:

To address the research question, we employed a multiple linear regression analysis approach, allowing us to explore multiple variables' simultaneous influence on the dependent variable, caries_perm_prev (prevalence of dental conditions). In each model, we include log-transformed variables for dentist_density and dental_assistant_density to capture the effects of dental professionals' density. Additionally, we control for several covariates to isolate the relationship of interest. Multiple regression models were developed to explore the relationship of the outcome with each independent variable. The model also focuses only on within-country variation by including fixed effects on location in each regression. Different combinations of predictor variables were considered to thoroughly examine the association between caries prevalence and various factors, and separate models were generated and summarized. These models help assess the sensitivity of results to different variables and enhance our knowledge of the robustness of the analysis. We presented the summaries of these models in a structured tabular format to analyze the differences.

Regression Models:

The first model explores the influence of log-transformed dentist density, log-transformed dental assistant density, and SDI on caries prevalence while having country fixed effects.

The second model builds upon Model 1 by including the HAQI, allowing for a more comprehensive assessment of caries prevalence determinants.

The third model is that high sugar and low calcium intake are added as covariates, examining the potential impact of dietary habits on caries prevalence.

The fourth model builds upon model 3, keeping the incorporation of country-specific factors, allowing for the exploration of country-level variations, and including the temporal dimension by incorporating the year as an additional categorical variable, providing insights into caries prevalence trends over time.

Final Regression Model:

A vital methodology component is constructing, developing, assessing, and ultimately selecting the final regression model. Extensive experimentation with different model layouts culminated in exploring the impact of various variables and identifying a robust and interpretable model—the definitive model aimed at unraveling the complex interplay of aspects influencing caries prevalence. The model combines log-transformed dentist density, log-transformed dental assistant density, SDI, HAQI, high sugar consumption, low calcium intake, specific year effects, and location-specific effects. Our final model is as follows:

Prevalence of Caries of Permanent Teeth = $\beta 0 + \beta 1 * \log(\text{Dentist Density per 10,000 employed individuals}) + \beta 2 * \log(\text{Dental Assistant Density per 10,000 employed individuals}) + \beta 3 * \text{SDI} + \beta 4 * \text{HAQI} + \beta 5 * \text{Diet High in Sugar-Sweetened Beverages} + \beta 6 * \text{Diet Low in Calcium} + \mu * \text{Years} + \alpha * \text{Locations}$

Where:

$\beta 0$ is the intercept (constant term);

$\beta 1$ is the coefficient for the natural logarithm of dentist density;

$\beta 2$ is the coefficient for the natural logarithm of dental assistant density;

$\beta 3$ is the coefficient for SDI;

$\beta 4$ is the coefficient for the high sugar;

$\beta 5$ is the coefficient for the low calcium;

μ is a vector of the coefficients for years; and

α is a vector of the coefficients for locations.

Uncertainty:

Standard errors were estimated for each coefficient from an ordinary least squares regression. This approach allowed for an evaluation of the reliability and significance of the relationships identified within the regression model. However, it is essential to note that we did not incorporate uncertainty from the underlying estimates from the Global Burden of Disease (GBD) study 2019, such as the density of dental professions, prevalence of caries, and other covariables. The study acknowledges that the estimates carry uncertainties, reflecting the complex and not primary collected data and methodologies used in the GBD study. While this analysis addressed uncertainty in the regression context, it did not explicitly incorporate the uncertainties associated with the GBD estimates themselves.

World Maps:

Visualizing geographic trends is crucial in understanding the global distribution of caries prevalence and related factors. Geographic data is merged with the prepared dataset to generate maps illustrating caries prevalence, dentist density, and dental assistant density across various countries.

SDI Quintile Plots:

Information on sociodemographic factors' influence is obtained by categorizing countries into quintiles based on the sociodemographic index (SDI). This method uses quintile plots to show changes in caries prevalence, dentist density, and dental assistant density over time within each SDI quintile.

GATHER Statement:

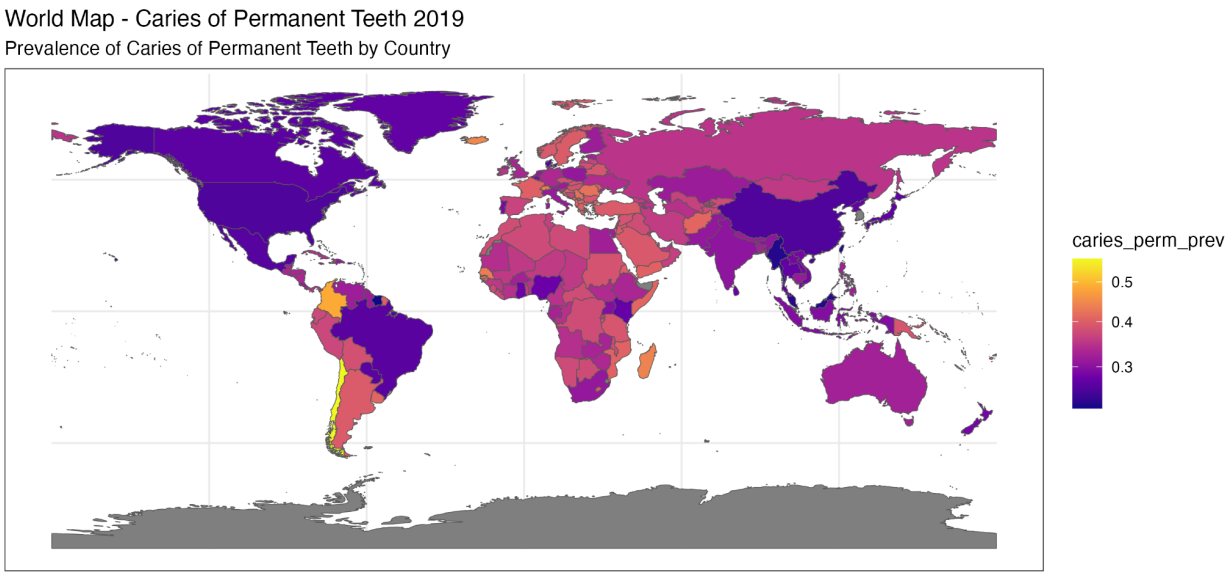
This study complies with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) recommendations. We have documented the steps involved in our analytical procedures and detailed the data sources used in compliance with the GATHER. For additional GATHER reporting, please refer to the appendix

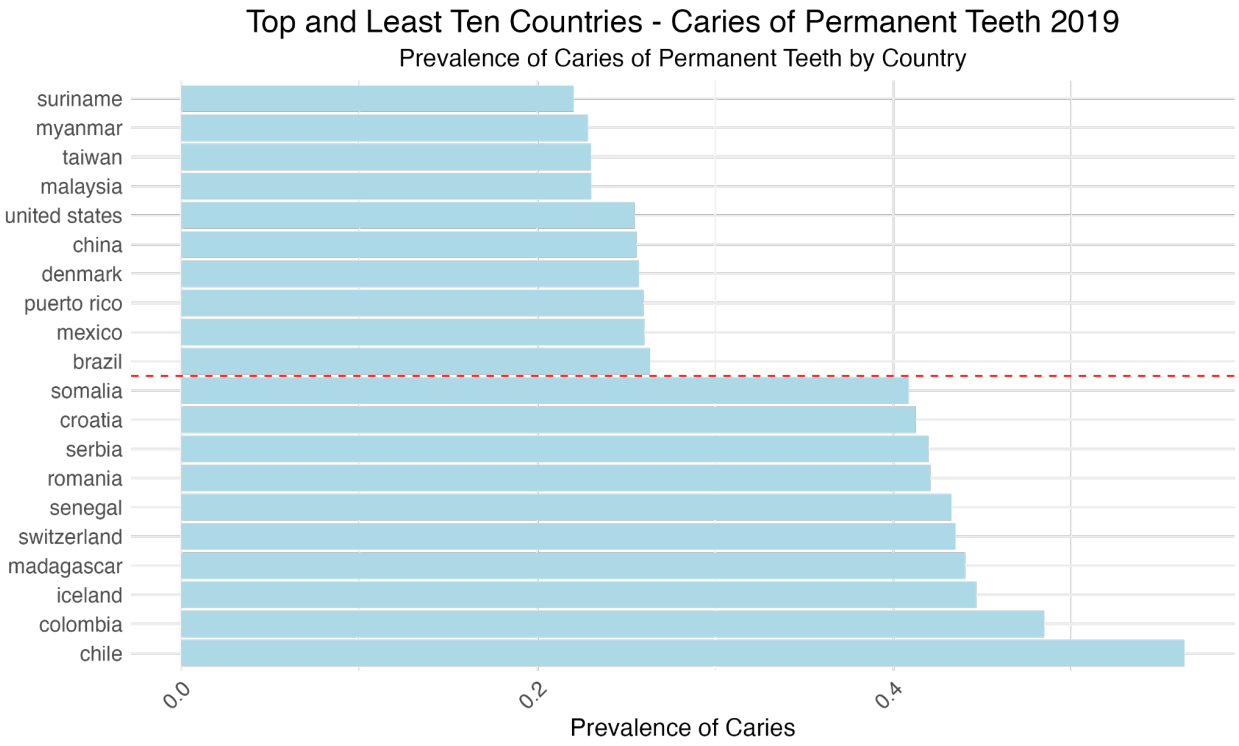
Results

Maps:

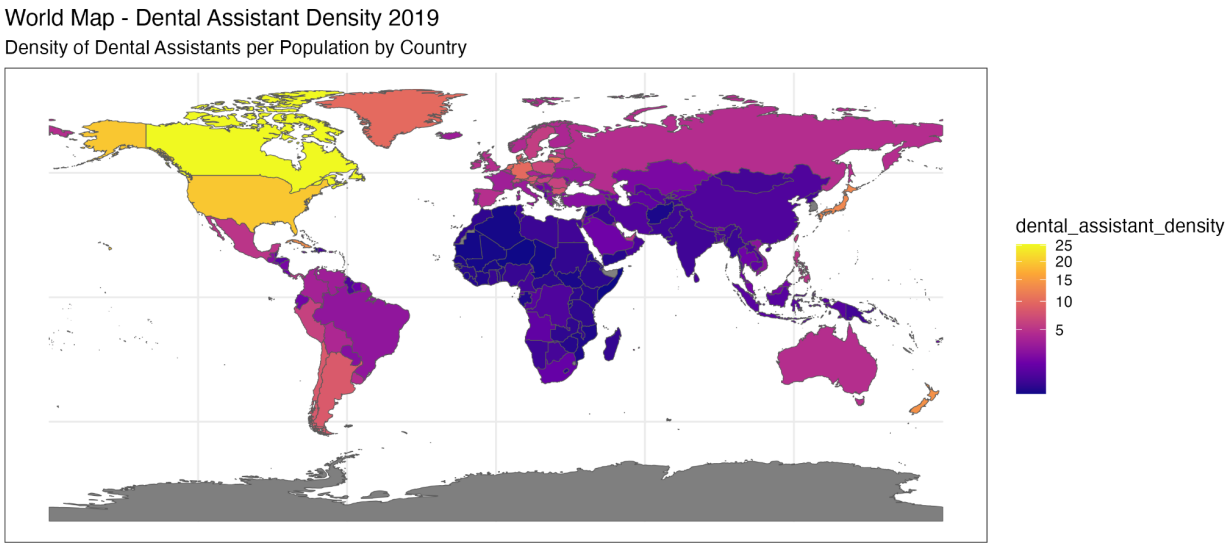
We first present the estimates for the prevalence of caries of permanent teeth, dentist density per 10,000 employed individuals, and dental assistant density per 10,000 employed individuals for all 204 countries and territories. We

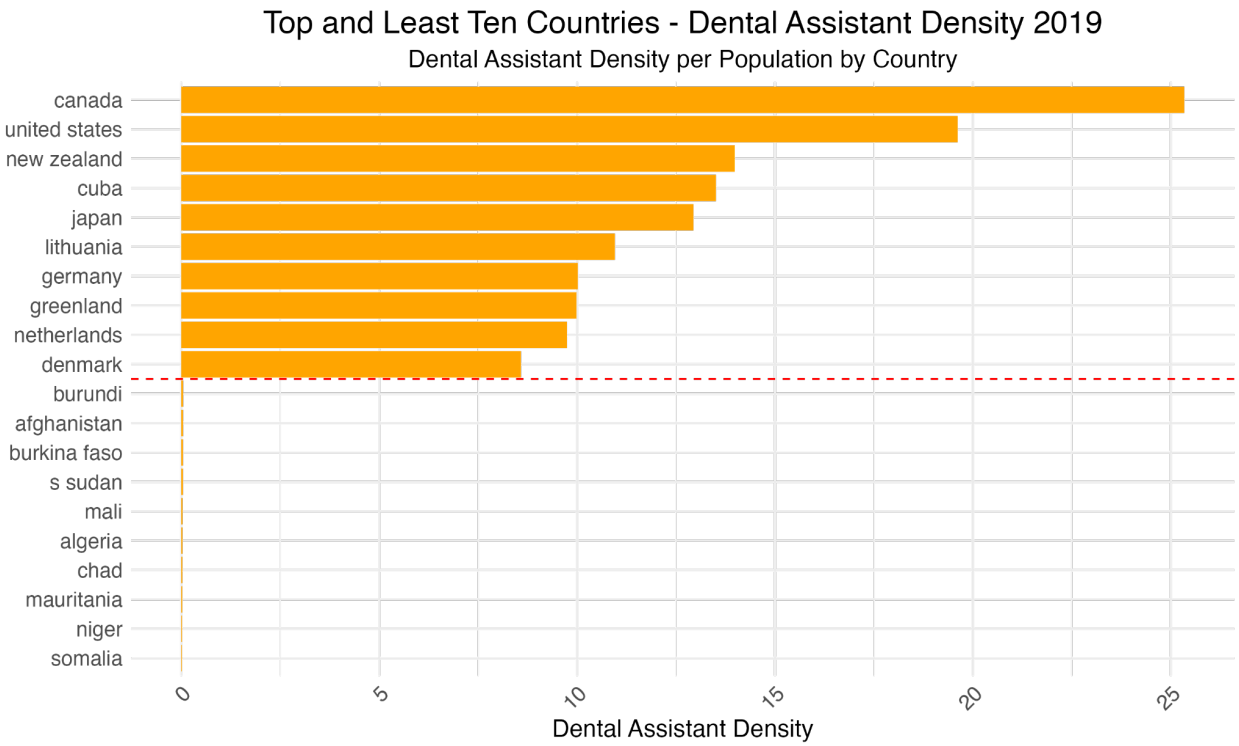
also present the ten countries with the top scores for the indicators as well as the ten countries with the lowest scores.





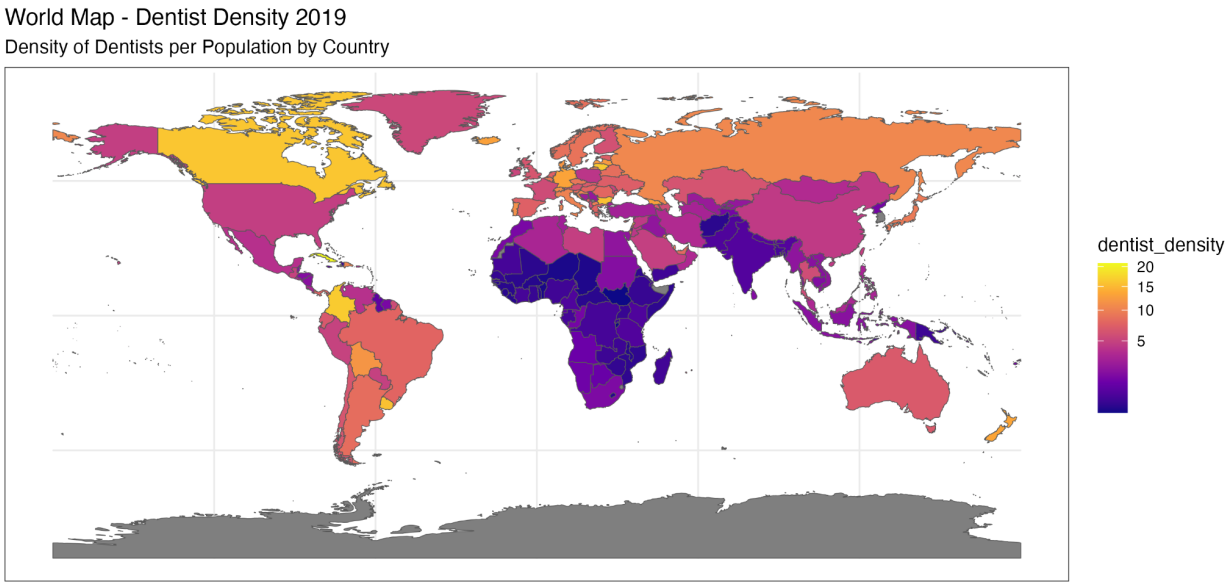
The map of caries prevalence in 2019 identifies countries with both high and low prevalence rates. The United States, Canada, China, and Brazil have lower prevalence. In contrast, many countries in Southern Africa have higher prevalence rates.

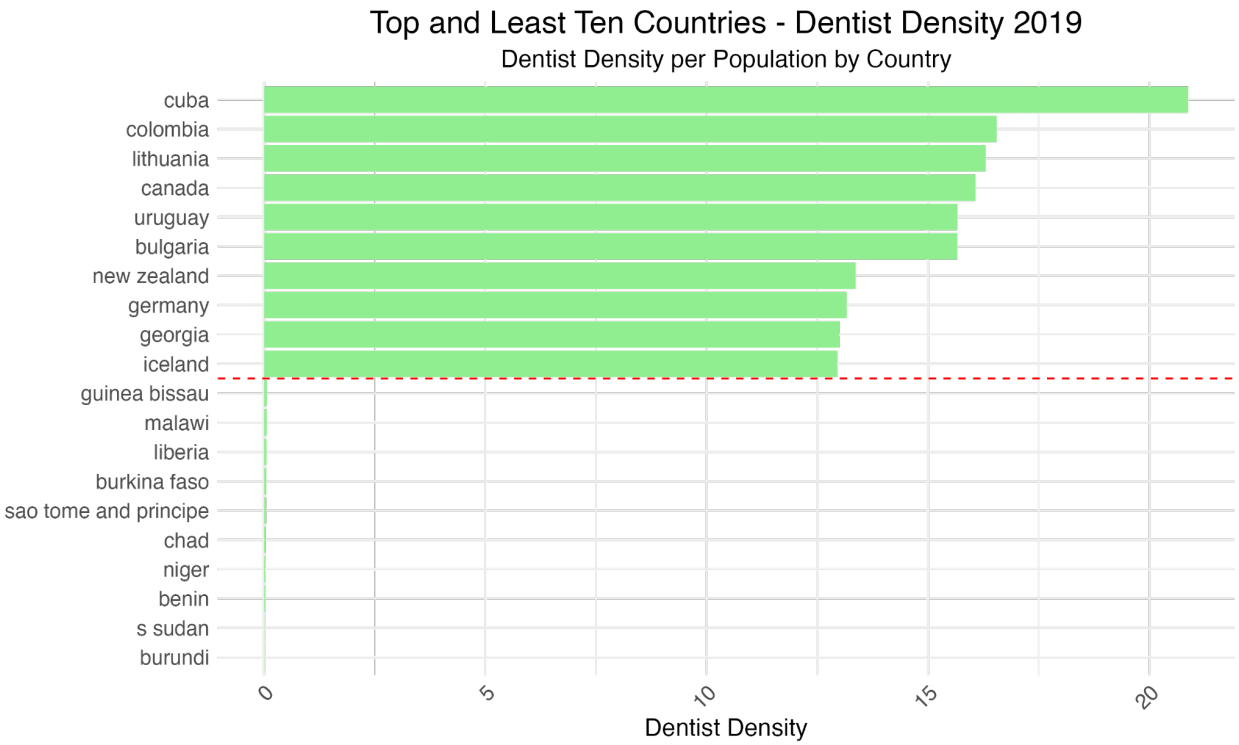




In the map of dentist density in 2019, we observe interesting trends. North America, particularly the United States and Canada, stands out with a higher density of dentists. In contrast, South America and Africa show lower densities

of dentists per population.

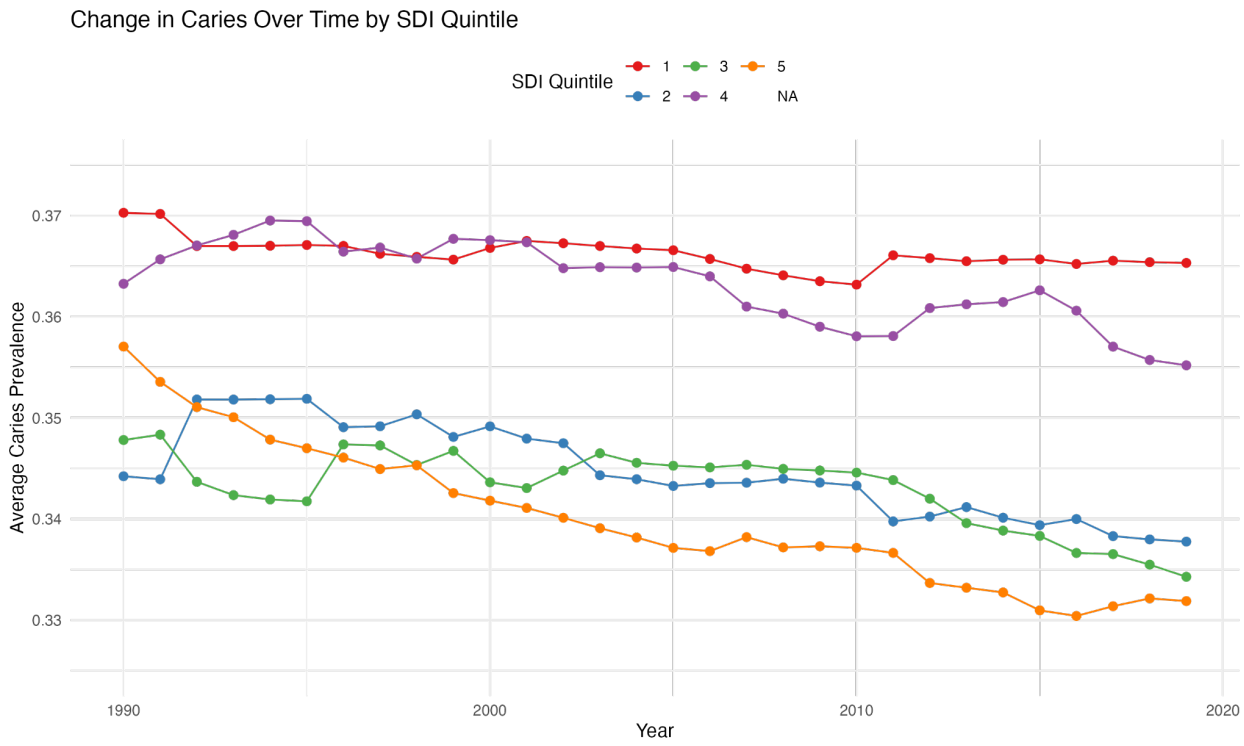




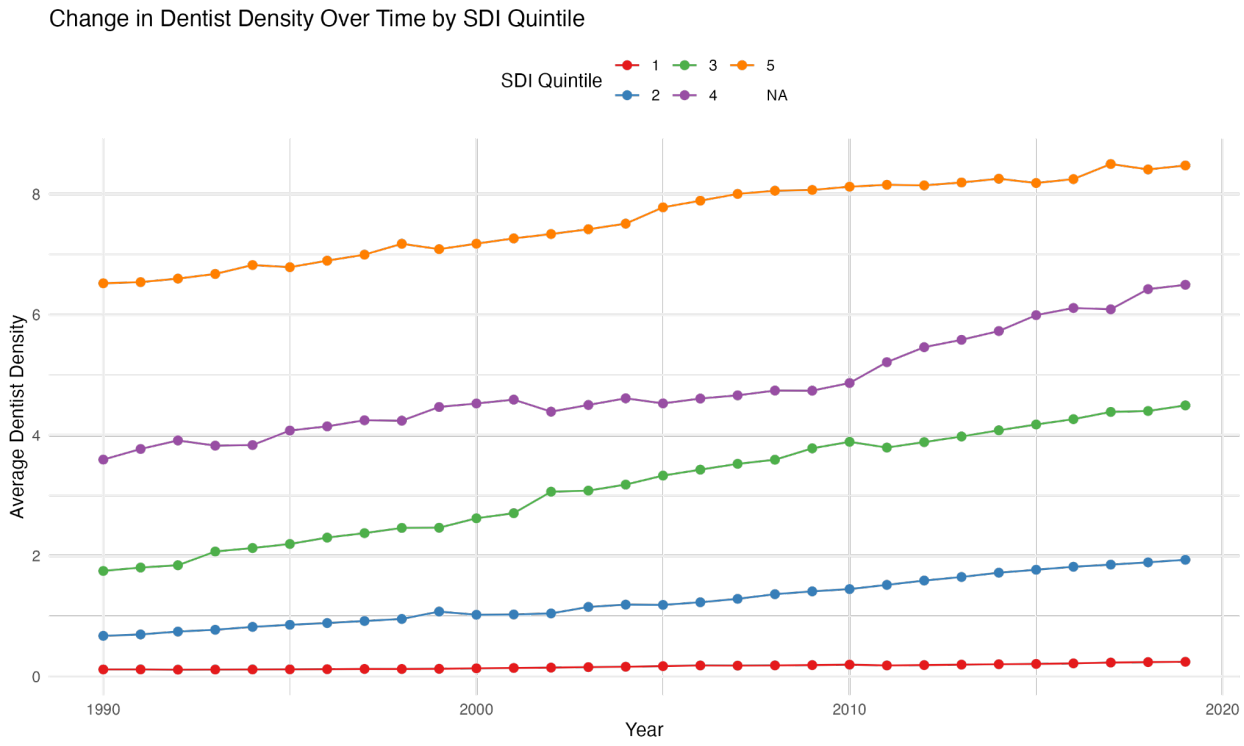
Similar to the previous map, the visualization of dental assistant density in 2019 reveals similar patterns. North American countries show a more notable density of dental assistants, indicating a greater presence of dental assistants. As expected, this density is lower in South American and African countries.

SDI Quintile Plots:

SDI quintiles represent different levels of the Socio-Demographic Index (SDI), a combined measure that reflects a country's population's overall social and economic development. Quintiles divide the data into five groups, each representing a different range of SDI values. SDI Quintile 1's nations have the lowest SDI values, indicating lower income, lower educational attainment, and higher fertility rates. They are low-development countries and may face challenges related to poverty, limited access to healthcare, and lower life expectancy. And SDI Quintile 5's nations have the highest SDI values, indicating the highest income, highest educational attainment, and lowest fertility rates. They are developed countries with advanced economies, extensive access to healthcare and education, and higher life expectancy. The relationship between the variables and the outcome changes across different levels of development and well-being.

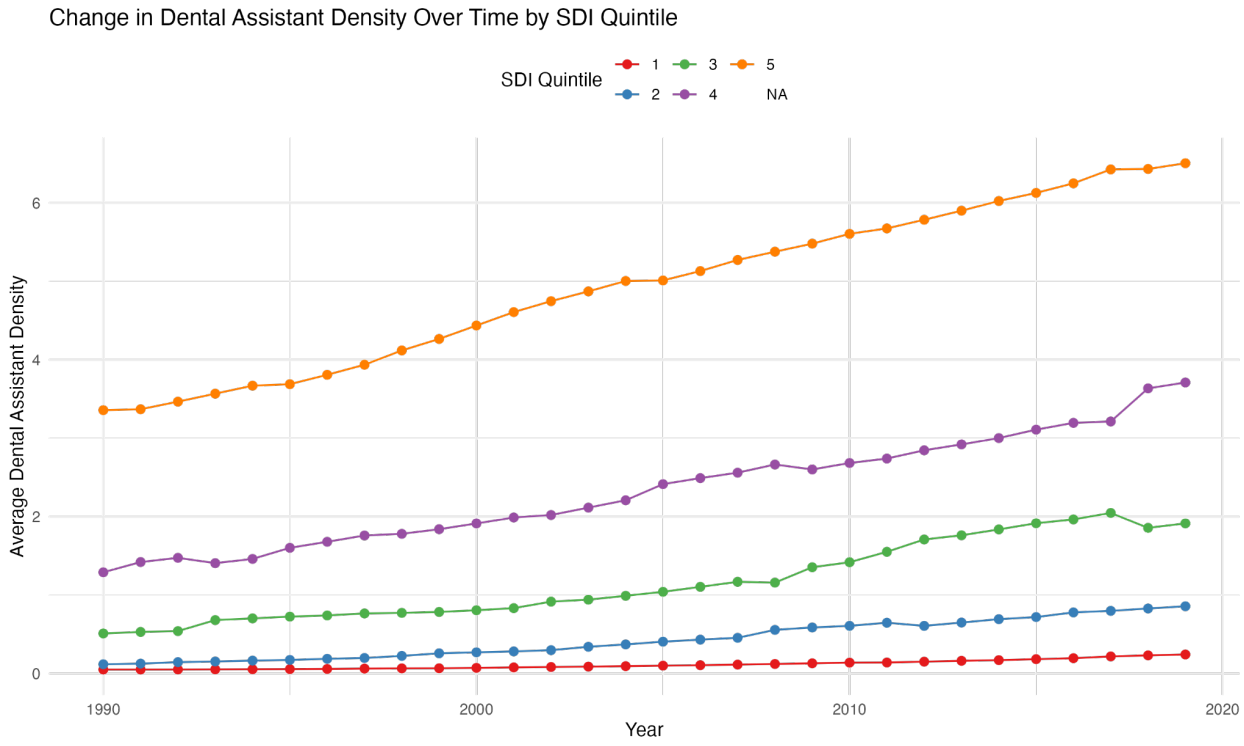


The "Change in Caries Over Time by SDI Quintile" plot shows that each SDI Quintile changes over time. SDI Quintile 1 countries had a higher average caries prevalence in 1990 and, at the end of 2019, still have the highest average prevalence of caries compared to others. SDI Quintile 4 countries have the second-highest average prevalence of caries. The SDI Quintile 5 countries had the third highest in 1990 but the lowest average caries prevalence in 2019. SDI Quintile 3 countries have the second to the lowest average prevalence of caries in 1990 but the second-lowest average prevalence in 2019. Lastly, SDI Quintile 2 countries had the lowest average caries prevalence in 1990 and the third highest in 2019. Overall, all the SDI quintile countries have declines in prevalence over time.



For the "Change in Dentist Density Over Time by SDI Quintile" plot, the order of increase from highest to lowest density is Quintile 5, Quintile 4, Quintile 3, Quintile 2, and Quintile 1. Quintile 5 consistently has the highest dentist

density, indicating increased dentist availability. SDI quintiles countries only have a little progress over time, with dentist density increasing very slowly.



The “Change in Dental Assistant Density Over Time by SDI Quintile” plot is similar to the “Change in Dentist Density Over Time by SDI Quintile” plot, showing that SDI Quintile 5 has the highest dental assistant density and the SDI Quintile 1 have the weak association with dental assistant density. Quintile 5 consistently leads in dental assistant density over time, suggesting a more significant density of dental assistants, whereas SDI Quintile 1 has significantly less progress throughout the years.

Regression Models:

The “Final Model” presented in the table below is the regression model we consider most appropriate for answering our research question. The research question seeks to understand the relationship between changes in the prevalence of dental conditions and changes in the density of dental professionals over time. Addressing this question is crucial

for informing policymakers, healthcare providers, and public health experts to devise strategies for enhancing oral health, reducing the burden of dental diseases, and ensuring improved access to dental care services.

Comparative Analysis of Regression Models: Examining Variable Effects in Different Contexts

	Dependent variable:			
	caries_perm_prev			
	SDI (1)	+ HAQ (2)	+ Risk factors (3)	Final (4)
log(dentist_density)	−0.001099*	−0.001077*	−0.001010*	−0.001130*
	(0.000567)	(0.000565)	(0.000565)	(0.000584)
log(dental_assistant_density)	0.000595	0.000996	0.001150	0.001387
	(0.000877)	(0.000877)	(0.000879)	(0.000910)
SDI	−0.076572***	−0.047189***	−0.052735***	−0.048557***
	(0.007547)	(0.008971)	(0.009073)	(0.010037)
HAQ		−0.000336***	−0.000367***	−0.000364***
		(0.000056)	(0.000057)	(0.000059)
high_sugar			0.132597	0.188640
			(0.214805)	(0.217052)
low_calcium			1.625933***	1.754090***
			(0.430769)	(0.434992)
Constant	0.429598***	0.431011***	0.430427***	0.429031***
	(0.005147)	(0.005137)	(0.005475)	(0.005536)
Observations	6,090	6,090	6,090	6,090
R2	0.966421	0.966626	0.966713	0.966800
Adjusted R2	0.965251	0.965458	0.965536	0.965455
Residual Std. Error	0.009211 (df = 5884)	0.009184 (df = 5883)	0.009174 (df = 5881)	0.009184 (df = 5852)
F Statistic	826.076500*** (df = 205; 5884)	827.155200*** (df = 206; 5883)	821.135700*** (df = 208; 5881)	719.036200*** (df = 237; 5852)
Note:				*p<0.1; **p<0.05; ***p<0.01

Analyzing Final Model Coefficients (Model 4):

Dentist Density per 10,000 employed individuals (log(dentist_density)):

The estimated coefficient from the final(4) model for the log of Dentist Density per 10,000 employed individuals is -0.0011 with a standard error of 0.001. This coefficient is statistically significant with a p-value < 0.1, indicating evidence of an association between the change in Dentist Density per 10,000 employed individuals and the prevalence of Caries of Permanent Teeth. A one-unit increase in the logarithm of Dentist Density per 10,000 employed individuals is associated with a decrease in the prevalence of Caries of Permanent Teeth by -0.0011 units while controlling for other variables in the model.

Dental Assistant Density per 10,000 employed individuals (log(dental_assistant_density)):

The estimated coefficient from the final(4) model for the log of dental assistant density per 10,000 employed individuals is 0.0014 with a standard error of 0.0009. However, this coefficient is not statistically significant,

indicating no strong evidence of a relationship between the change in Dental Assistant Density per 10,000 employed individuals and the prevalence of caries of permanent teeth in the given model.

Socio-Demographic Index Index (SDI):

The estimated coefficient from the final(4) model for SDI is -0.0486 with a standard error of 0.0100. This coefficient is statistically significant with a p-value < 0.01, suggesting evidence of a relationship between the change in SDI and the prevalence of caries of permanent teeth. An increase of one unit in SDI is associated with a decrease in the prevalence of caries of permanent teeth by -0.0694 units while controlling for other variables.

Healthcare Access and Quality Index (HAQ):

The estimate from the final(4) model HAQ is -0.0036 with a standard error of 0.0001. This coefficient is statistically significant with a p-value < 0.01, suggesting evidence of an association between the change in HAQ and the prevalence of caries of permanent teeth. An increase of one unit in HAQ is associated with a decrease in the prevalence of caries of permanent teeth by -0.0036 units while controlling for other variables.

Diet High in Sugar-Sweetened Beverages (high_sugar):

The estimate from the final(4) model diet high in sugar-sweetened beverages coefficient is 0.1886 with a standard error of 0.2171. However, this coefficient is not statistically significant, indicating insufficient evidence to conclude there is a relationship between a diet high in sugar-sweetened beverages and the prevalence of caries of permanent teeth in the given model.

Diet Low in Calcium (low_calcium):

The estimate from the final(4) model diet low in calcium coefficient is 1.7541, with a standard error of 0.4349. This coefficient is statistically significant with a p-value < 0.01, suggesting evidence of a relationship between the change in a diet low in calcium and the prevalence of caries of permanent teeth. An increase of one unit in a diet low in calcium is associated with an increase in the prevalence of caries of permanent teeth by 1.7541 units while controlling for other variables.

In the SDI (1) model, we controlled only for variables related to dental professionals' density and socioeconomic development index (SDI). The model revealed that a decrease in SDI is associated with a statistically significant decrease in the prevalence of caries of permanent teeth. At the same time, an increase in the log of dentist density per 10,000 employed individuals is related to a decrease in the prevalence of caries of permanent teeth, with a higher p-value.

The HAQ (2) model includes the SDI model variables and the Health Access and Quality (HAQ) index. This model also shows that an increase in the log of dentist density per 10,000 employed individuals is related to a decrease in the prevalence of caries of permanent teeth, with a statistically significant p-value. At the same time, the log of dental assistant density per 10,000 employed individuals does not have statistically significant relationships with the prevalence of caries of permanent teeth. However, the coefficient of the HAQ variable is also negative same as SDI, suggesting that higher HAQ and SDI are associated with a lower prevalence of caries of permanent teeth.

The "Risk Factor (3)" expands on t"e HA'(2) model by including additional risk factors. This model shows that one of the risk factors of diet plays a crucial role in increasing the prevalence of caries in permanent teeth, which is a diet of low calcium. On the other hand, the diet of sugar and sweetened beverages is not statically significantly associated with the prevalence of caries in permanent teeth. All the other variables have the same association as other models.

Given these results, we prioritize the "Final(4) Model" as it comprehensively considers various factors while maintaining a logical and coherent interpretation. This model highlights the importance of dentist density per 10,000 employed individuals in influencing changes in the prevalence of caries of permanent teeth after accounting for other relevant factors. Importantly, including year and location factors enhances the model's explanatory power by capturing temporal and geographical variation.

Discussion

Our "Final Model" suggests that the density of dental professionals, represented by dentist density per 10,000 employed individuals and dental assistant density per 10,000 employed individuals, plays a significant role in shaping changes in caries prevalence over time, even when considering other potential influencing factors. However, the change in dental assistant density per population and diet high in sugar-sweetened beverages did not show a statistically significant relationship with the prevalence of caries of permanent teeth in the Final model. This finding underlines the need for policies and interventions that focus on optimizing the density and distribution of dental professionals to improve oral health outcomes and accessibility to dental care services.

Our comprehensive analysis investigated the complexity of changes in caries of permanent teeth prevalence and variations in dental professional densities over time. We explore the relationships among these factors through multiple linear regression while accounting for a range of relevant covariates. Our analysis aims to reveal the impact of dentist and dental assistant densities on caries prevalence amidst the influence of other pertinent variables. By delving into these associations, our findings provide valuable insights that have implications for policy development, healthcare provision, and public health strategies to improve oral health and enhance access to dental care services.

The analysis's findings give an understanding of the variables affecting the occurrence of caries of permanent teeth and, as a result, conducting research, policy, and healthcare interventions. The discovered relationships emphasize the importance of particular factors in determining oral health outcomes. The analysis reveals a significant association between changes in dental professionals' density per population and the prevalence of caries of permanent teeth. This underlines the key role of dental professionals in shaping oral health outcomes and emphasizes the need for strategies that prioritize optimal dentist-to-population ratios. Our study also shows that there is significant association between low calcium and higher prevalence, indicating that there should be a way to encourage calcium intake.

We do not find a significant association between caries and dental assistant density. We hypothesis dental assistants play a key role in oral health that is not directly associated with dental caries. Their diverse responsibilities encompass tasks aimed at promoting overall well-being and comprehensive patient care. For instance, dental assistants actively monitor patients' blood pressure during appointments, contributing to oral health assessment and

identifying potential heart disease risk factors (Prado, M. (2022, March 1). Patient education by dental assistants bridges oral health and overall wellness, enlightening individuals about the systemic implications of oral hygiene (Leadbeatter et al., 2023). In addition to their educational role, dental assistants create a reassuring patient environment, promote regular dental attendance among apprehensive individuals, and engage in impactful community outreach programs to enhance dental care accessibility, which may ensure patients attend dentist appointments and have contact with dentists. Dental assistants collaborate closely with dentists and hygienists, ensuring seamless procedure execution and introducing complexities that may influence statistical significance in research analyses (Prado, M. 2022, March 1). Therefore, dental assistants' diverse and collaborative roles underscore patients' overall well-being, highlighting that they may not be directly associated with the prevalence of dental caries (Leadbeatter et al., 2023).

We also did not find an association between sugar-sweetened beverage consumption and caries prevalence. A number of studies indicate that various factors contribute to the intricate relationship between sugar-sweetened beverages and the prevalence of dental caries. Diet drinks containing sugars have not been significantly linked to dental disease, specifically dental caries (Samman, 2018, October 24). This lack of association could be attributed to multiple factors, including the composition of diet drinks, the frequency and quantity of consumption, the influence of additional variables, and the complexity of beverage consumption patterns (Samman, 2018, October 24). In addition, the Nutrition and Oral Health for Children Self-study curriculum's recent research has unveiled a more intricate perspective on the connection between sugar consumption and caries development (Module 2 2005, May 6). These studies highlight the collective impact of factors such as consumption frequency, oral hygiene practices, and the nature of ingested foods on cariogenicity (Module 2 2005, May 6). This could justify the absence of a statistically significant association between sugar-sweetened beverages and the prevalence of dental caries in our study.

Policymakers can use these findings to prioritize interventions that enhance dental professionals' density, promote socioeconomic development, and address dietary habits. These strategies can significantly impact the prevalence of caries of permanent teeth on a global scale. For instance, the expansion of dental education programs, such as the establishment and support of new dental schools or the expansion of existing ones, represents a critical strategy to

address the evolving dynamics of the dental workforce. The study emphasizes the need to balance supply and demand, especially in undersupplied regions, by enhancing the capacity of dental education institutions to produce a qualified and diverse workforce (Institute of Medicine (US) Committee on the Future of Dental Education). Programs for Foreign-Trained Dentists Integration streamline the process for foreign-trained dentists to obtain licensure and practice credentials in the country, utilizing their skills to address shortages in rural areas. Some factors affect the recruitment and retention of dental practitioners in rural areas (Godwin D, 2016 Jun 1).

To address the disparities in oral health care, particularly for disadvantaged populations, policymakers could consider integrating oral health and primary care, adopting interventions at multiple levels, and creating health care teams. Dental school partnerships could also be proposed to provide hands-on training for students while delivering care to underserved communities (Northridge ME, 2020 Apr 2).

The research study that explains the importance of calcium nutrition among individuals also found that adults rely on food banks for their nutrition rather than spending money themselves. Considered calcium important for health but faced barriers such as cost and limited knowledge about calcium sources. The study should tailor nutrition education programs to address these barriers and promote better dietary practices among food bank users (Hawkins, 2010).

Workplace Wellness Programs will collaborate with employers to introduce workplace wellness programs that offer employees access to calcium-rich snacks and meals and educational resources on balanced nutrition. Like CalPERS Wellness Program, the program primarily focuses on providing resources, activities, and support for healthy behaviors and lifestyles, including fitness classes, nutrition courses, health screenings, and more. While it showcases an approach to employee wellness (Workplace Wellness).

In addition, the insights gained from this study have implications for both developed and developing countries, suggesting that tailored interventions based on specific contexts and needs are necessary for addressing oral health disparities worldwide. Also, the analysis prompts further research into understanding the distinct contributions of dental assistants, exploring interactions between various determinants, and investigating the potential impact of

different healthcare policies on caries prevalence to reduce the burden of caries and advance ideal oral health globally.

In conclusion, this analysis offers an essential new understanding of the complex network of variables affecting the prevalence of permanent tooth caries. This study provides a roadmap for policymakers and healthcare professionals to build comprehensive interventions that cover healthcare workforce planning, socioeconomic development, and nutritional health.

Limitations:

The limitation arises from its dependence on data from the Global Burden of Disease Study 2019 (GBD 2019), limited to estimates provided by the Institute for Health Metrics and Evaluation (IHME). These estimates contain a diverse range of health indicators, including oral disorders and disease, across 204 countries and territories from 1990 to 2019 (Global Burden of Disease Collaborative Network, 2020). The study relies on methods, including Spatiotemporal Gaussian process regression and stochastic frontier meta-regression, to generate densities of dentistry personnel and construct the socio-demographic index (SDI). Moreover, the Healthcare Access and Quality Index (HAQ Index), derived from GBD 2019 data, supplements the analysis by assessing healthcare access and quality. The linear regression model utilizes data from the Global Burden of Disease Study 2019 (GBD 2019) to estimate the relationship between caries' permanent prevalence and various determinants. The model's coefficients represent estimates of estimates, where the SDI, dentist density, dental assistant density, high sugar intake, low calcium intake, year, and location serve as independent variables. However, it is essential to acknowledge certain limitations inherent in this approach. The analysis relies on modeled estimates rather than directly collected data, which introduces potential uncertainties. Additionally, as the measures are aggregated at the country level, there is a possibility of encountering the ecological fallacy, where individual-level relationships may not hold at the aggregate level. Furthermore, the omission of potentially impactful variables could lead to omitted variable bias, presenting a limitation. The results may also be sensitive to the chosen model specification, making them less robust against alternative modeling approaches. Lastly, it's important to note that the results have not been population-weighted, which could impact the overall interpretation and generalization of the findings. Despite these limitations, the model

provides valuable insights into the complex relationship between caries' permanent prevalence and the specified determinants, offering a foundation for further investigation and policy considerations.

Conclusions

In conclusion, this study delves into the complicated relationships between dental professional density, socioeconomic development, dietary habits, and the prevalence of caries of permanent teeth. Our findings emphasize the significance of dental professionals, particularly dentists, in shaping oral health outcomes. The analysis reveals a notable association between changes in dentist density per population, changes in socioeconomic development (SDI), and changes in low calcium intake with the prevalence of caries of permanent teeth. These findings highlight the importance of healthcare workforce planning, emphasizing the need for optimal dentist-to-population ratios. At the same time, the role of dental assistants and the impact of a diet high in sugar-sweetened beverages show no statistically significant relationship. This research contributes valuable insights to inform evidence-based policies and interventions to improve global oral health. The study's comprehensive approach, accounting for various determinants and their interactions, provides a foundation for designing effective strategies. Policymakers, healthcare providers, and public health experts can leverage these findings to prioritize interventions that enhance dental professional density, promote socioeconomic development, and address dietary habits. The study's importance extends to developed and developing countries, emphasizing the need for tailored approaches to address oral health disparities.

References

1. Centers for Disease Control and Prevention (CDC). (2021). Disparities in Oral Health. Division of Oral Health. Retrieved from https://www.cdc.gov

2. *Diet high in sugar-sweetened beverages - level 3 risk*. The Institute for Health Metrics and Evaluation. October 15, 2020 (n.d.-a). https://www.healthdata.org/results/gbd_summaries/2019/diet-high-sugar-sweetened-beverages-level-3-risk

3. Diet low in calcium - level 3 risk. The Institute for Health Metrics and Evaluation. October 15, 2020 (n.d.-b). https://www.healthdata.org/results/gbd_summaries/2019/diet-low-calcium-level-3-risk

4. Godwin D, Hoang H, Crocombe L. Views of Australian dental practitioners towards rural recruitment and retention: a descriptive study. BMC Oral Health. 2016 Jun 1;16(1):63. doi: 10.1186/s12903-016-0221-0. PMID: 27251191; PMCID: PMC4888206.

5. Haakenstad, A. (2022). Measuring Health Care Access and Quality to Support Universal Health Coverage. IHME Dissertation Series. (41).

6. Hawkins, Johnson, et al. "Calcium Nutrition Perceptions among Food Bank Users Calcium Nutrition Perceptions among Food Bank Users: A Canadian Case Study Calcium Nutrition Perceptions among Food Bank Users." International Electronic Journal of Health Education, vol. 13, 2010, pp. 100–110, files.eric.ed.gov/fulltext/EJ912641.pdf. Accessed 15 Aug. 2023.

7. Institute for Health Metrics and Evaluation (IHME). (2019). Caries of Permanent Teeth, Level 4 Cause. Global Burden of Disease Study 2019. Retrieved from https://www.healthdata.org/results/gbd_summaries/2019/caries-of-permanent-teeth-level-4-cause#:~:text=Definition%20Caries%20of%20permanent%20teeth,but%20also%20decayed%20is%20present.

8. Institute for Health Metrics and Evaluation (IHME). (2020). Global Burden of Disease Study 2019 (GBD 2019) Socio-Demographic Index (SDI) 1950-2019. Retrieved from http://ghdx.healthdata.org

9. Institute of Medicine (US) Committee on the Future of Dental Education; Field MJ, editor. Dental Education at the Crossroads: Challenges and Change. Washington (DC): National Academies Press (US); 1995. 9, A Dental Work Force for the Future. Available from: https://www-ncbi-nlm-nih-gov.offcampus.lib.washington.edu/books/NBK232249/

10. Murray, C. J. L. (2020). Global Burden of Disease Study 2019 (GBD 2019) Diet High in Sugar-Sweetened Beverages, Age 25+ 1990-2019. Retrieved from http://ghdx.healthdata.org

11. Murray, C. J. L. (2020). Global Burden of Disease Study 2019 (GBD 2019) Diet Low in Calcium, Age 25+ 1990-2019. Retrieved from http://ghdx.healthdata.org

12. *Module 2: Nutrition-Related Risk Factors for Dental Caries*. Nutrition and Oral Health for Children. (2005, May 6). https://depts.washington.edu/pwdlearn/oralhealth/index.php

13. National Institute of Dental and Craniofacial Research (NIDCR). (2021). Oral Health Disparities. Retrieved from https://www.nidcr.nih.gov

14. Northridge ME, Kumar A, Kaur R. Disparities in Access to Oral Health Care. Annu Rev Public Health. 2020 Apr 2;41:513-535. doi: 10.1146/annurev-publhealth-040119-094318. Epub 2020 Jan 3. PMID: 31900100; PMCID: PMC7125002.

15. Leadbeatter D, Tjaya KC, Li P, Ma HS, Phan AJ, Peck C. Professional knowledge acquisition of dental students employed part-time as dental assistants. Eur J Dent Educ. 2023 Feb;27(1):110-117. doi: 10.1111/eje.12782. Epub 2022 Feb 7. PMID: 35108442; PMCID: PMC10078695.

16. Oral Health. (2023). World Health Organization. Retrieved from https://www.who.int

17. Prado, M. (2022, March 1). *Dentals assistants play important role in patients' overall health*. DANB. https://www.danb.org/news-blog/detail/certified-press/dental-assistants-play-key-role-in-patient-health

18. Samman, M. (2018, October 24). *The effect of diet drinks on oral health among us children and adults: Cluster Analysis*. Boston University Libraries OpenBU. https://open.bu.edu/handle/2144/32943

19. Workplace Wellness - CalPERS Health Benefits Program Helping You Take Care of Your Most Valuable Resource. Calpers: Working Together for Workplace Wellness. Retrieved from https://www.calpers.ca.gov/docs/forms-publications/workplace-wellness.pdf