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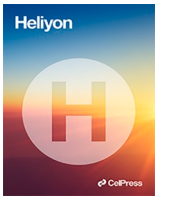

Research article

Impact of lack of transportation on access to dental care

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ABSTRACT

Objectives: Access to healthcare may be influenced by the availability of transportation. Nevertheless, the impact of transportation challenges on access to dental care has not been thoroughly examined. This study investigates the influence of transportation availability on dental care visits, dental cleanings, and exams.

Methods: This is a retrospective observational study. The 2021 Medical Expenditure Panel Survey (MEPS), a national survey in the United States, was used for this study. Adults (≥18 years old) from the 2021 survey were included. The 2021 Full Year Consolidated File and the Dental Visits file were linked to identify the main independent variable and the outcomes.
Weighted zero-inflated negative binomial regression and weighted logistic regression were employed to analyze the outcomes of dental care visits, and dental cleanings, and exams.

Results: The study included a total of 204,704,044 adults, with an average age of 49 (SD: 18) years, and a 51 % female representation. Approximately 5.5 % (n=11,285,968) of the population reported facing transportation challenges. Subjects encountering transportation challenges exhibited a 26 % decrease in dental care visits compared to those without such challenges (Incidence Rate Ratio (IRR)=0.74, $p < 0.01$, 95 % CI: 0.64–0.87). Individuals lacking transportation had 39 % lower odds of receiving a dental cleaning (odds ratio (OR)=0.61, $p < 0.01$, 95 % CI: 0.48–0.77) and 29 % lower odds of undergoing a checkup or exam (OR=0.71, $p < 0.01$, 95 % CI: 0.56–0.90).

Conclusions: The study's findings underscore the significant impact of transportation challenges on access to dental care. Limited access to dental care due to transportation issues could exacerbate disparities in oral health outcomes. Implementing targeted interventions to address transportation challenges could contribute to improved oral health outcomes.

1. Introduction

While there have been significant improvements in the nation's oral health since the 1960s due to advancements in dental care, oral hygiene practices, and public health initiatives such as water fluoridation, disparities persist [1], with certain racial/ethnic and

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socioeconomic groups experiencing worse oral health outcomes. One crucial driver of health that could impact oral health is access to transportation [2,3], a factor that significantly influences an individual's ability to obtain necessary medical care. Annually, 3.6 million people in the United States face barriers to healthcare access stemming from transportation issues, which encompass challenges such as a lack of vehicle access, inadequate public transportation infrastructure, lengthy distances, and extended travel times to reach essential healthcare services [4]. These obstacles impact both rural and urban communities [3], reflecting a broader issue of transportation inequities rooted in decades of policy decisions and infrastructure investments. Furthermore, exclusionary land-use policies have exacerbated these challenges for minority populations [5]. These policies have led to segregated minority communities with fewer healthcare resources, including a lower density of dental providers and inadequate public transportation infrastructure. An estimated 59 million Americans live in dental health professional shortage areas (HPSAs), where access to dental care is severely limited [6]. Lack of transportation options could further restrict individuals' ability to schedule and attend regular dental appointments, making transportation a critical driver of health that directly affects access to dental care.

While previous studies have described the relationship between transportation and healthcare access [3,4,7], a gap exists regarding the connection between transportation barriers and access to dental care. Existing research on barriers to oral health care has identified the following factors: affordability of dental services, cost of transportation or caregiver assistance, limited availability of dental care providers, communication challenges during dental care, low oral health literacy, and a lack of cultural awareness among the dental workforce [8–10]. Notably, barriers to dental care due to a lack of transportation has not been well described. Prior studies examining dental care access and transportation challenges have been limited by small sample sizes [11].

This study addressed these limitations by employing a national survey to examine the influence of transportation on access to dental care. The primary objective was to assess whether transportation deficiencies were linked to variations in the frequency of dental care visits, teeth cleaning, and general exams/checkups, utilizing data collected from a comprehensive national survey conducted in 2021.

2. Methods

2.1. Data

This is a retrospective cross-sectional study. The Medical Expenditure Panel Survey (MEPS), a national survey in the United States conducted by Agency for Healthcare Research and Quality (AHRQ), was used for this study. The MEPS collects information from individuals, families, and medical providers, covering demographics, healthcare use/expenditures, health insurance coverage, socioeconomic status, chronic conditions, and healthcare quality [12]. This survey targets representative non-institutionalized civilians annually, with the most recent available data from 2021.The 2021 Full Year Consolidated File includes demographics, health conditions, healthcare use and spending, and newly introduced measures of social determinant of health (SDOH) [13]. These SDOH measures include food insecurity, discrimination, neighborhood safety, and lack of transportation to medical care or work. The Dental Visits file provides details on dental visits by year/month, general exams, sealant applications, and gum surgeries.

The majority of the MEPS survey was based on self-reporting, which can introduce potential biases, including recall, selection, and response bias. Participants may not accurately remember details, leading to missed or incorrect information that could influence this study's outcomes. Additionally, individuals who answered some questions may differ from those who did not respond. Subjects may also overreport or underreport their behaviors, health symptoms, or access to transportation. These biases can impact study results and limit the generalizability of the findings.

More detail is available from prior publications [14,15]. Since this study used publicly available MEPS data, ethical approval was not required.

2.2. Subjects

Adults aged 18 years and older from the 2021 survey were included in the study. Subjects with missing information in the outcome variable and covariates were excluded.

2.3. Outcomes

Three outcomes were defined based on the survey's three questions. The total number of dental care visits was obtained from the Full Year Consolidated File. Dental clinic visits for teeth cleaning (Yes/No) and dental clinic visits for a general exam/checkup (Yes/No) were derived from the Dental Visits file.

2.4. Covariates

The primary independent variable in the study was lack of transportation (Yes/No), identified from the Full Year Consolidated File using the question: "Has lack of transportation kept the person from medical appointments, meetings, work, or getting things needed for daily living?" Covariates potentially associated with the outcomes were controlled in the regressions, including: age category (18–30, 31–40, 41–50, 51–64, 65–74, and $\geq$75 years old in 2021), sex (male vs. female), race/ethnicity (non-Hispanic White, Hispanic, non-Hispanic Black, non-Hispanic Asian, and non-Hispanic other race or multiple races), family income as % of the poverty line (poor, near poor, low income, middle income, and high income), census region (northeast, Midwest, south, and west), dental insurance

coverage in 2021 (Yes/No), high school graduate (Yes/No), marital status (married, widowed/divorced/separated, and never married), physical limitation (Yes/No), comorbid conditions (hypertension (Yes/No), diabetes (Yes/No), asthma (Yes/No), any cancer diagnosis (Yes/No), high cholesterol (Yes/No), arthritis (Yes/No)), and access to public transportation (good vs. not good).

In the race/ethnicity category, the Hispanic designation includes individuals who identify as having roots in Latin America or Spanish origin. The non-Hispanic categories (White/Black/Asian/Other) refer to subjects who identify as White, Black, Asian, or Other but do not identify as Hispanic. Family income as a percentage of the poverty line is calculated by dividing total family income by the poverty threshold for their family size in 2021. The 'poor' category includes families with incomes below 100 % of the federal poverty level, while the 'near poor' category includes families with incomes between 100 % and 124 % of the federal poverty level. The 'low

Table 1
Characteristics of the population with and without lack of transportation (n=204,704,044).

	Lack of transportation			
Variable	No	Yes	Total	p-value
N	193,418,076 (94.5 %)	11,285,968 (5.5 %)	204,704,044 (100.0 %)	
Age (continuous: mean(sd))	49.551 (17.993)	46.746 (18.074)	49.396 (18.008)	<0.01
Age category				<0.01
18-30	35,430,006 (18.3 %)	2,893,392 (25.6 %)	38,323,398 (18.7 %)	
31-40	34,146,184 (17.7 %)	1,952,810 (17.3 %)	36,098,994 (17.6 %)	
41-50	30,996,433 (16.0 %)	1,761,882 (15.6 %)	32,758,315 (16.0 %)	
51-64	46,413,456 (24.0 %)	2,401,643 (21.3 %)	48,815,099 (23.8 %)	
65-74	27,984,816 (14.5 %)	1,413,864 (12.5 %)	29,398,680 (14.4 %)	
≥75	18,447,182 (9.5 %)	862,376 (7.6 %)	19,309,558 (9.4 %)	
Female	101,743,118 (52.6 %)	6,325,626 (56.0 %)	108,068,744 (52.8 %)	0.08
Race/Ethnicity				<0.01
Hispanic	30,441,036 (15.7 %)	2,219,694 (19.7 %)	32,660,729 (16.0 %)	
Non-Hispanic White	124,946,214 (64.6 %)	5,378,671 (47.7 %)	130,324,885 (63.7 %)	
Non-Hispanic Black	21,159,255 (10.9 %)	1,943,626 (17.2 %)	23,102,881 (11.3 %)	
Non-Hispanic Asian	11,531,496 (6.0 %)	775,175 (6.9 %)	12,306,670 (6.0 %)	
Non-Hispanic other race	5,340,076 (2.8 %)	968,802 (8.6 %)	6,308,878 (3.1 %)	
Family income as % of poverty line				<0.01
Poor	17,372,031 (9.0 %)	3,234,174 (28.7 %)	20,606,206 (10.1 %)	
Near poor	6,535,159 (3.4 %)	910,633 (8.1 %)	7,445,792 (3.6 %)	
Low income	21,485,829 (11.1 %)	2,043,256 (18.1 %)	23,529,085 (11.5 %)	
Middle income	54,205,795 (28.0 %)	2,987,203 (26.5 %)	57,192,998 (27.9 %)	
High income	93,819,262 (48.5 %)	2,110,702 (18.7 %)	95,929,964 (46.9 %)	
Census region				0.012
Northeast	33,239,297 (17.2 %)	1,586,621 (14.1 %)	34,825,919 (17.0 %)	
Midwest	42,368,811 (21.9 %)	2,066,450 (18.3 %)	44,435,260 (21.7 %)	
South	72,041,463 (37.2 %)	5,199,389 (46.1 %)	77,240,853 (37.7 %)	
West	45,768,505 (23.7 %)	2,433,508 (21.6 %)	48,202,012 (23.5 %)	
Dental insurance				<0.01
No	95,439,020 (49.3 %)	8,141,218 (72.1 %)	103,580,237 (50.6 %)	
Yes	97,979,057 (50.7 %)	3,144,750 (27.9 %)	101,123,807 (49.4 %)	
High school graduate				<0.01
No	23,286,120 (12.0 %)	2,594,489 (23.0 %)	25,880,608 (12.6 %)	
Yes	170,131,957 (88.0 %)	8,691,479 (77.0 %)	178,823,436 (87.4 %)	
Marital status				<0.01
Married	105,368,641 (54.5 %)	4,000,359 (35.4 %)	109,368,999 (53.4 %)	
Widowed/Divorced /Separated	37,642,225 (19.5 %)	2,975,080 (26.4 %)	40,617,304 (19.8 %)	
Never married	50,407,211 (26.1 %)	4,310,530 (38.2 %)	54,717,741 (26.7 %)	
Physical limitation	26,073,697 (13.5 %)	3,608,243 (32.0 %)	29,681,940 (14.5 %)	<0.01
Hypertension	65,341,531 (33.8 %)	4,475,463 (39.7 %)	69,816,994 (34.1 %)	<0.01
Diabetes	21,915,151 (11.3 %)	1,867,217 (16.5 %)	23,782,368 (11.6 %)	<0.01
Asthma	27,516,904 (14.2 %)	2,548,155 (22.6 %)	30,065,059 (14.7 %)	<0.01
Any cancer diagnosis	23,337,852 (12.1 %)	974,042 (8.6 %)	24,311,894 (11.9 %)	<0.01
High cholesterol diagnosis	63,174,364 (32.7 %)	3,767,691 (33.4 %)	66,942,055 (32.7 %)	0.69
Arthritis diagnosis	50,396,053 (26.1 %)	4,042,944 (35.8 %)	54,438,997 (26.6 %)	<0.01
Access to public transportation				<0.01
Poor/Fair	71,171,357 (36.8 %)	5,424,353 (48.1 %)	76,595,709 (37.4 %)	
Excellent/Very good/Good	122,246,720 (63.2 %)	5,861,615 (51.9 %)	128,108,335 (62.6 %)	
Outcome				
Number of dental care visits (continuous: mean(sd))	1.054 (1.671)	0.556 (1.250)	1.027 (1.655)	<0.01
Visit for teeth clean				<0.01
No	130,601,343 (67.5 %)	9,762,372 (86.5 %)	140,363,715 (68.6 %)	
Yes	62,816,734 (32.5 %)	1,523,595 (13.5 %)	64,340,329 (31.4 %)	
Visit for general checkup/exam				<0.01
No	134,697,515 (69.6 %)	9,588,948 (85.0 %)	144,286,463 (70.5 %)	
Yes	58,720,561 (30.4 %)	1,697,020 (15.0 %)	60,417,581 (29.5 %)	

income,' 'middle income,' and 'high income' categories refer to families with incomes between 125 % and 199 %, between 200 % and 399 %, and at or above 400 % of the federal poverty level, respectively. The Northeast census region includes states in the northeastern U.S., such as New York and Pennsylvania, while the Midwest includes states in the central U.S., such as Ohio and Michigan. The South region comprises states in the southern U.S., such as Texas and Florida, and the West region includes states in the western U.S., such as California and Washington [16].

Although numerous confounders were considered in the study, unmeasured confounders could still impact the results. For example, anxiety or phobias related to dental care—potentially stemming from past experiences of pain or discomfort during visits—could influence the frequency of dental appointments. However, this information is not available in the data, precluding its inclusion in the regression analyses.

2.5. Statistical approaches

Weighted summary statistics, including mean, standard deviation (SD), and percentages, were used to summarize the characteristics of the subjects in the two groups: subjects with and without transportation challenges. T-tests and Chi-square tests were used to compare the characteristics between these groups. For the first outcome, which involved the number of dental care visits (a count variable with about 60 % of subjects having no dental care visits), weighted zero-inflate negative binomial regression (ZINB) was utilized. ZINB was selected due to the count nature of the outcome variable, with the consideration that zeros might represent a mixture of two underlying data-generating processes. ZINB was chosen over other count regression models, such as Poisson regression and Negative Binomial regression, due to the presence of overdispersion (variance > mean) and a significant number of zeros in the outcome variable. ZINB effectively addresses both of these issues. Results were presented as incidence rate ratios (IRR) from the weighted ZINB regression. For the binary outcomes such as dental clinic visits for teeth cleaning (Yes/No) and dental clinic visits for a

Table 2
Factors associated with number of dental care visits (n=204,704,044).

Variable	incidence rate ratios (IRR)	p-value	95 % Confidence Interval	
Lack of transportation	0.74	<0.01	0.64	0.87
Age category				
18-30	reference			
31-40	1.14	0.05	1.00	1.30
41-50	1.21	<0.01	1.07	1.38
51-64	1.46	<0.01	1.29	1.66
65-74	2.01	<0.01	1.75	2.31
≥75	1.90	<0.01	1.65	2.20
Female	1.33	<0.01	1.25	1.41
Race/Ethnicity				
Non-Hispanic White	reference			
Hispanic	0.58	<0.01	0.51	0.66
Non-Hispanic Black	0.72	<0.01	0.63	0.81
Non-Hispanic Asian	0.75	<0.01	0.65	0.86
Non-Hispanic other race	0.85	0.08	0.71	1.02
Family income as % of poverty line				
Poor	0.53	<0.01	0.46	0.60
Near poor	0.52	<0.01	0.40	0.69
Low income	0.65	<0.01	0.58	0.73
Middle income	0.77	<0.01	0.72	0.82
High income	reference			
Census region				
Northeast	reference			
Midwest	0.97	0.51	0.87	1.07
South	0.83	<0.01	0.75	0.93
West	1.11	0.07	0.99	1.25
Dental insurance	1.30	<0.01	1.20	1.40
High school graduate	1.44	<0.01	1.25	1.64
Marital status				
Married	reference			
Widowed/Divorced/Separated	0.92	0.03	0.86	0.99
Never married	1.10	0.06	1.00	1.21
Physical limitation	0.99	0.78	0.91	1.08
Hypertension	0.90	<0.01	0.84	0.96
Diabetes	0.93	0.14	0.85	1.02
Asthma	1.07	0.09	0.99	1.16
Any cancer diagnosis	1.20	<0.01	1.11	1.30
High cholesterol diagnosis	1.19	<0.01	1.11	1.29
Arthritis diagnosis	1.08	0.03	1.01	1.16
Access to public transportation				
Poor/Fair	reference			
Excellent/Very good/Good	0.94	0.03	0.88	0.99

general exam or checkup (Yes/No), weighted logistic regression was used. The results from these logistic regressions were reported as odds ratios (OR). To accurately calculate standard errors of covariates that reflect the complex sample design of the survey and ensure the accuracy of the p-values, the Taylor-series linearization method was used [16]. P-values less than 0.05 were considered statistically significant. The analysis was conducted using Stata software version 18.0.

3. Results

The 2021 MEPS data included a total of 258,042,685 adults (survey-weighted number). Among them, 48,236,437 adults were excluded due to non-responses to the transportation question during the survey. Additionally, 5,102,204 adults were excluded for non-responses in key covariates such as income, education, and chronic medical conditions. After these exclusions, the study included a total of 204,704,044 adults.

Table 1 presents the characteristics of subjects with and without transportation challenges. Subjects with transportation challenges were younger on average than those without, although this difference was not statistically significant (46.7 vs. 49.6 years old; p=0.08). A significantly higher percentage of subjects with transportation challenges fell into the poor income category compared to those without transportation challenges (29 % vs. 9 %; $p < 0.01$). Similarly, a higher proportion of subjects with transportation challenges reported having a physical limitation compared to those without transportation challenges (32 % vs. 13.5 %; $p < 0.01$). Subjects with access to transportation had a higher average number of dental care visits compared to those without transportation challenges (1.05 vs. 0.57; $p < 0.01$). Additionally, a greater percentage of subjects with access to transportation visited dental clinics for teeth cleaning (32.5 % vs. 13.5 %; $p < 0.01$) and general checkups/exams (30.4 % vs. 15.0 %; $p < 0.01$) compared to those without transportation access.

Table 2 presents factors associated with the total number of dental clinic visits in 2021. Subjects lacking transportation experienced

Table 3
Factors associated with a dental visit for teeth cleaning (n=204,704,044).

Variable	Odds ratio	p-value	95 % confidence interval	
Lack of transportation	0.61	<0.01	0.48	0.77
Age category				
18-30	reference			
31-40	0.98	0.78	0.82	1.17
41-50	1.21	0.03	1.02	1.44
51-64	1.26	0.01	1.06	1.51
65-74	1.93	<0.01	1.58	2.35
≥75	2.00	<0.01	1.59	2.53
Female	1.49	<0.01	1.38	1.62
Race/Ethnicity				
Non-Hispanic White	reference			
Hispanic	0.46	<0.01	0.39	0.55
Non-Hispanic Black	0.52	<0.01	0.42	0.64
Non-Hispanic Asian	0.62	<0.01	0.51	0.76
Non-Hispanic other race	0.48	<0.01	0.37	0.64
Family income as % of poverty line				
Poor	0.39	<0.01	0.32	0.48
Near poor	0.33	<0.01	0.25	0.44
Low income	0.44	<0.01	0.37	0.52
Middle income	0.61	<0.01	0.54	0.69
High income	reference			
Census region				
Northeast	reference			
Midwest	1.07	0.45	0.89	1.30
South	0.87	0.09	0.73	1.02
West	1.02	0.79	0.85	1.23
Dental insurance	1.53	<0.01	1.37	1.72
High school graduate	2.01	<0.01	1.65	2.45
Marital status				
Married	reference			
Widowed/Divorced/Separated	0.68	<0.01	0.61	0.76
Never married	0.94	0.28	0.83	1.05
Physical limitation	0.73	<0.01	0.63	0.84
Hypertension	0.86	0.01	0.77	0.97
Diabetes	0.77	<0.01	0.67	0.88
Asthma	1.00	0.95	0.87	1.16
Any cancer diagnosis	1.26	<0.01	1.11	1.42
High cholesterol diagnosis	1.23	<0.01	1.11	1.35
Arthritis diagnosis	0.93	0.29	0.82	1.06
Access to public transportation				
Poor/Fair	reference			
Excellent/Very good/Good	0.93	0.12	0.85	1.02

a 26 % decrease in the visit rate compared to those without transportation challenges (IRR=0.74, $p < 0.01$). As subjects aged, their expected number of dental visits significantly increased. For example, the 41-50 year-old group had 1.21 times more visits (IRR=1.21, $p < 0.01$), and the 51-64 year-old group had 1.46 times more visits (IRR=1.46, $p < 0.01$). Females had 1.33 times more expected dental clinic visits than males (IRR=1.33, $p < 0.01$). Having dental insurance was associated with 1.30 times higher expected dental clinic visits (IRR=1.30, $p < 0.01$). Interestingly, individuals with good access to public transportation had a 6 % lower expected count of dental clinic visits compared to those without good access (IRR=0.94, p=0.03).

Table 3 presents potential factors associated with a dental visit for teeth cleaning using logistic regression. Subjects lacking transportation had 39 % lower odds compared to those without transportation challenges (OR=0.61, $p < 0.01$). Females had 49 % higher odds than males for a dental clinic visit for teeth cleaning (OR=1.49, $p < 0.01$). Compared to the high-income group, all other income groups had lower odds of visiting a dental clinic for teeth cleaning. For instance, the poor income group had an odds ratio of 0.39 ($p < 0.01$), and the low-income group had an odds ratio of 0.44 ($p < 0.01$). Individuals with physical limitations had 27 % lower odds compared to those without any physical limitations (OR=0.73, $p < 0.01$).

Table 4 shows potential factors associated with a dental clinic visit for a checkup or exam in 2021. Subjects lacking transportation had 29 % lower odds of visiting a dental clinic for a checkup or exam compared to those without transportation challenges (OR=0.71, $p < 0.01$). Females had 39 % higher odds of visiting a dental clinic for a checkup or exam compared to males (OR=1.39, $p < 0.01$). Compared to non-Hispanic Whites, other racial/ethnic groups had lower odds of visiting a dental clinic for a checkup or exam. For example, Hispanics had 56 % lower odds (OR=0.44, $p < 0.01$), and non-Hispanic Blacks had 44 % lower odds (OR=0.56, $p < 0.01$). Those with dental insurance had 56 % higher odds (OR=1.56, $p < 0.01$), and high school graduates had 77 % higher odds of visiting a dental clinic for a checkup or exam (OR=1.77, $p < 0.01$).

Table 4
Factors associated with a dental visit for a checkup or exam (n=204,704,044).

Variable	Odds ratio	p-value	95 % confidence interval	
Lack of transportation	0.71	<0.01	0.56	0.90
Age category				
18-30	reference			
31-40	0.96	0.68	0.80	1.16
41-50	1.16	0.13	0.96	1.40
51-64	1.23	0.02	1.03	1.47
65-74	1.74	<0.01	1.43	2.12
≥75	1.72	<0.01	1.36	2.18
Female	1.39	<0.01	1.28	1.50
Race/Ethnicity				
Non-Hispanic White	reference			
Hispanic	0.44	<0.01	0.37	0.52
Non-Hispanic Black	0.56	<0.01	0.46	0.69
Non-Hispanic Asian	0.57	<0.01	0.46	0.71
Non-Hispanic other race	0.62	<0.01	0.45	0.85
Family income as % of poverty line				
Poor	0.45	<0.01	0.37	0.55
Near poor	0.35	<0.01	0.26	0.48
Low income	0.57	<0.01	0.48	0.67
Middle income	0.66	<0.01	0.59	0.75
High income	reference			
Census region				
Northeast	reference			
Midwest	1.19	0.05	1.00	1.41
South	0.88	0.12	0.74	1.03
West	1.07	0.43	0.90	1.26
Dental insurance	1.56	<0.01	1.39	1.76
High school graduate	1.77	<0.01	1.46	2.15
Marital status				
Married	reference			
Widowed/Divorced/Separated	0.71	<0.01	0.63	0.80
Never married	0.92	0.15	0.82	1.03
Physical limitation	0.83	0.01	0.72	0.96
Hypertension	0.83	<0.01	0.75	0.93
Diabetes	0.84	0.01	0.73	0.96
Asthma	1.04	0.57	0.91	1.18
Any cancer diagnosis	1.25	<0.01	1.10	1.43
High cholesterol diagnosis	1.24	<0.01	1.12	1.37
Arthritis diagnosis	0.94	0.34	0.82	1.07
Access to public transportation				
Poor/Fair	reference			
Excellent/Very good/Good	0.88	<0.01	0.80	0.96

4. Discussion

In a comprehensive, nationally representative survey of American adults aged 18 and older conducted in 2021, our findings highlighted a significant disparity in dental care access between individuals with and without transportation access. Those lacking transportation had a lower average number of dental visits compared to those with transportation access (0.57 visits vs. 1.05 visits; $p < 0.01$). Furthermore, adults without transportation exhibited a 39 % decrease in the likelihood of having a dental cleaning visit and a 29 % decrease in the likelihood of visiting a dental clinic for a checkup or examination, in contrast to their counterparts with transportation access. Our results indicate that factors such as being female, having dental insurance, and older age were associated with a higher expected number of dental clinic visits, which aligns with previous findings [11,17–22]. McKernan et al. reported similar findings regarding differences in dental utilization between males and females. They found that males were significantly less likely than females to have had a dental visit (OR=0.68, $p < 0.01$) [10]. Furthermore, minority racial/ethnic groups exhibited a lower likelihood of undergoing dental cleanings or checkups compared to non-Hispanic White adults. There was also a positive association between education level and the odds of having dental visits, dental cleanings, and dental exams.

This study significantly contributes to our understanding of the pivotal role transportation plays as a determinant of health in accessing dental care. The findings presented here align with earlier research, which consistently underscores transportation as a significant barrier to healthcare access [3]. A 2005 study estimated that approximately 3.6 million individuals in the United States annually miss or delay nonemergency medical treatment, despite having healthcare coverage, due to inadequate transportation to care facilities [4]. While the hindrances posed by transportation in healthcare access have been extensively examined, a noteworthy literature gap exists concerning the impact of transportation barriers on dental care for adults in the US. Existing studies that delve into barriers to dental care access predominantly identify factors such as age [23], gender [20,23], education [17], and income [24–26]. Moreover, the findings within the adult population are not uniform across various studies [27]. The unique contribution of this study lies in its assessment of the association between lack of transportation and access to dental care among US adults, utilizing a nationally representative study sample. This enhances the generalizability of our findings, making a valuable addition to the existing body of knowledge. Oral health has been identified as a leading health indicator [28], and factors leading to disparities in oral healthcare deserve separate attention from overall healthcare. In the US, the perception of dental care as elective rather than essential can further differentiate the accessibility of oral healthcare compared to other healthcare services. While oral health is integral to overall well-being, dental coverage is frequently viewed as an additional component of health insurance, rather than being recognized as an essential and integrated part of it. Although strides have been made in integrating oral health into primary healthcare for children, the same level of integration has not been achieved for adult dental care. In the US, the oral health workforce has historically been concentrated in private practice settings where dentists lead teams comprised of dental hygienists, assistants, lab technicians and office personnel. Most of these practices continue to operate independently of most primary health practices and health systems. Specifically for subpopulations that face barriers like lack of transportation, integrating oral health care with primary care might improve access. Additionally, the introduction of mobile dental clinics could significantly enhance access to dental care for those with limited transportation. The success of Minnesota's Children's Dental Services mobile program demonstrates that large-scale mobile dental services can significantly improve access to both preventive and restorative care [29]. While the program primarily targets children, the model can be adapted to serve adults in underserved areas where transportation limitations are a major barrier. However, several obstacles hinder the widespread adoption of mobile dental clinics. High initial costs for setting up a mobile unit, which can exceed $300,000, along with ongoing maintenance and staffing needs, pose financial challenges [30]. State regulations also vary significantly, with some states requiring expensive permits or imposing restrictions that limit where mobile clinics can operate. For example, some states mandate private rooms for pediatric patients or access to toilets, which restricts the venues where mobile care can be provided. Additionally, mobile clinics face challenges with follow-up care, as the mobile team may not be available at the same location for ongoing care or management of complications. Policymakers can support mobile dental programs by providing financial incentives or grants to offset the high costs of mobile units, streamlining state regulations to facilitate for the operation of mobile clinics, and encouraging partnerships between mobile clinics and local healthcare providers to ensure continuity of care. These efforts could help maximize the reach and effectiveness of mobile clinics, particularly in rural and underserved areas. For individuals facing challenges not only with transportation but also with physical limitations, teledentistry platforms could facilitate remote dental consultations, offering advice and assessments without the need for a physical visit. Before 2020, teledentistry was recognized as a tool to reach underserved individuals in Dental Health Professional Shortage Areas (DHPSAs), particularly in rural communities, to reduce oral health inequities [31]. It improved timely access, reduced costs through triage, and offered flexibility for patients unable to attend in-person appointments [32]. Teledentistry also alleviated workforce shortages [33]. However, barriers such as skepticism, technology literacy, broadband access, and reimbursement issues remain [32,34,35]. During COVID-19, interest in teledentistry surged as it effectively provided dental care when in-person services were limited. While it has proven valuable for consultations, follow-ups, and triage, more research is needed on provider usage [36]. A 2020 survey by CareQuest found that 86 % of patients were satisfied with their teledentistry experience [37], highlighting its potential to enhance access and support continuity of care. Policymakers should prioritize expanding teledentistry to mitigate transportation barriers, particularly in DHPSAs and underserved areas. Addressing key challenges such as broadband access and reimbursement policies for providers will be essential to improving access to dental care. The lack of transportation can intensify health disparities, particularly affecting demographics such as females, individuals with lower incomes, older adults, those with less education, and members of minority groups in the United States [4]. While there have been suggestions that the availability of public transport could alleviate some of these disparities in healthcare access [7,38–40], our study contradicts this assumption. Kiuchi et al. reported that Japanese older adults who used public transportation had higher levels of dental care utilization ($\beta = 0.109$, $p < 0.01$ for men; $\beta = 0.094$, $p < 0.01$ for women) compared to those who did not use public

transportation [30]. Contrary to expectations, our study finds that individuals with good access to public transportation exhibited fewer dental care visits (IRR=0.94, p=0.03) and lower odds of visiting dental clinics for examinations or check-ups (OR=0.88, $p < 0.01$). This observation suggests that the relationship between public transportation accessibility and dental care access may be more complex. For instance, public transit may remain unaffordable for lower-income communities or may not connect efficiently to dental providers. Additionally, even when available, public transport can present barriers if it is infrequent, unreliable, or perceived as unsafe. These issues can limit its effectiveness in improving access to dental care. Policymakers should explore various factors that may affect how people perceive the accessibility of public transport, such as frequency of transportation, cleanliness, and safety.

While using national survey data, there are several limitations to consider. First, there was no follow-up data on oral health outcomes after dental care visits or general checkups. Thus, the study was unable to assess the impact of dental care visits or dental checkups for individuals with and without transportation access. Second, the results pertain exclusively to adults. Therefore, the findings from this study may not be generalizable to adolescents or pediatric dental care access. Third, some of the data relied on self-reported information. Thus, there could be recall bias and impact the accuracy of some responses. Fourth, this study utilized data from a single year (2021), which limits its applicability to long-term trends or changes resulting from factors such as the COVID-19 pandemic. Lastly, some states have expanded Medicaid access to include dental care, and in some of these states, transportation services are provided to help individuals get to the dentist. However, this public use file does not include state identification, and the study was unable to control for these factors.

This study underscores the significant impact of transportation challenges on access to dental care, an aspect that has been relatively underexplored in previous research. The results presented in the study suggest that transportation plays a crucial role as a determinant of healthcare access, extending beyond general healthcare services. These findings highlight a potential link between transportation barriers and dental services, suggesting potential disparities in oral health outcomes. Given that access to dental care is a critical component of overall healthcare, addressing transportation-related barriers is essential for promoting equitable health outcomes across diverse populations. Public transportation may not always be a viable solution, as access to it can pose another challenge. Many areas in the U.S., particularly rural regions, may lack well-developed infrastructure for public transportation. Additionally, individuals with physical limitations may face restricted access to public transportation. Therefore, developing targeted interventions to address transportation challenges is crucial for fostering improved oral health outcomes for vulnerable populations.

CRediT authorship contribution statement

Jaewhan Kim: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Indrakshi Roy:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **E. Angeles Martinez-Mier:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Anubhuti Shukla:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Peter Weir:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

Consent statement

Informed consent to participate in the study was not required because it utilized a publicly available dataset. The data are anonymized and completely de-identified by the Agency for Healthcare Research and Quality (AHRQ).

Ethical statement

Review and/or approval by an ethics committee was not required for this study because it utilized a publicly available dataset. The data are anonymized and completely de-identified by the Agency for Healthcare Research and Quality (AHRQ).

Data availability

The data underlying the results presented in the study are available from the Medical Expenditure Panel Survey website: https://meps.ahrq.gov/mepsweb/data_stats/download_data_files.jsp.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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