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Navigating Disparities in Dental Health—A Transit-Based Investigation of Access to Dental Care in Virginia

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ABSTRACT

Objective: To identify vulnerable areas and populations with limited access to dental care in Virginia, the study aimed (1) to calculate travel time and accessibility scores to dental care in Virginia using a transit-based accessibility model for all dental clinics and dental clinics participating in the Medicaid dental program and (2) to estimate factors associated with accessibility to dental clinics participating in the Medicaid dental program in Virginia.

Methods: The study used building footprints as origins of transit trips to dental care services (or destinations). The study then computed transit-based origin–destination travel time matrices based on the detailed trip information, including in-vehicle and out-of-vehicle travel time. Accessibility scores were calculated by counting the number of dental clinics that can be reached within 60 min. Regression analysis was used to measure factors associated with accessibility scores to dental clinics participating in Medicaid.

Results: Residents in smaller regions spent longer travel time to dental clinics by public transit compared with those who resided in larger regions. Medicaid participants also faced longer travel time compared with the general population. Residents spent more than three-fourths of the time waiting for public transit and walking to clinics regardless of where they live and what type of insurance they have. Associations between sociodemographic factors and accessibility scores to dental clinics participating in the Medicaid dental program varied across regions.

Conclusions: Disparities in dental care accessibility exist depending on the size of regions and Medicaid participation in Virginia. The disparities in transit-based access to dental clinics and a disproportionate amount of time spent waiting for public transit and walking to dental clinics could be improved through tailored interventions taking into account the sociodemographic and geographic characteristics of each region.

1 | Introduction

Access to dental care is a national public health crisis in the United States (USA). In 2023, around 21% of Americans are currently living in the dental Health Professional Shortage Areas,

measured using the number of dentists relative to the population with consideration of high needs [1]. Based on the 2022 Medical Expenditure Panel Survey data, only 43% of the USA population had a dental visit in the past 12 months [2]. Access to dental care is also a health disparity issue that manifests a significant gap

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in geographic location and socioeconomic status. In addition to the high cost of dental care, people living in rural areas, having lower income and education, with Medicaid/Children's Health Insurance Plan (CHIP), or being uninsured increases the likelihood of unmet dental needs [1, 3–5].

The disparities in dental care access also vary across different states in the USA. In 2019, the highest density of dentists was 104 dentists per 100 000 population in the District of Columbia, and the lowest was 40.97 in Alabama [5]. While the density of dentists in Virginia (63.19) was above the national average (61.06), it has a huge disparity across different areas [6]. For example, residents in the Northern and Eastern areas of Virginia are more likely to receive dental care than the residents in the Western and Southern districts [7]. The dentist-to-population ratio is generally greater in highly urbanised regions (e.g. Richmond metropolitan area and Northern Virginia) than in rural areas (e.g. Southwest and Southside areas) [7]. Four rural counties including Charles City County, King and Queen County, Surry County, and Sussex County did not have a single licensed dentist [7].

However, limited studies examine geospatial disparities in dental care access, especially in rural areas and small-sized cities. The existing studies also lack investigation into different accessibility levels in terms of the mode of transit (e.g. driving, public transit, and walking). For example, most studies only apply driving distance and time to measure geospatial accessibility, despite the fact that driving may not be an option for everyone, especially for those who do not have private vehicles or are unable to drive [8]. Thus, other modes of transit, including public transit, should be taken into consideration.

Insurance types also play an important role in access to dental care. Only 43% of dentists nationwide participate in Medicaid/CHIP, reflecting burdensome administrative barriers, low reimbursement rates, and missed appointments from patients [9, 10]. This barrier would add a layer of difficulties for patients enrolled in Medicaid to access dental care. In Virginia, only 27% of practicing dentists have treated patients enrolled in Medicaid or Family Access to Medical Insurance Security (FAMIS) in 2022 [11]. Around 50% of Virginians whose household income is below \$35 000 per year did not visit a dentist in 2022 compared with one-third among all Virginians [12]. Given the disparities in accessibility and different healthcare-seeking behaviours, there has not been a measure of geospatial accessibility among patients using Medicaid insurance considering the use of public transit, given that Medicaid users are more likely to take public transit [13].

To address this knowledge gap, this study aimed to identify vulnerable areas and populations of limited access to dental care in Virginia, through a transit-based accessibility model, which adheres to public transit schedules and stops. Here, public transit includes fixed-route transit services, such as commute buses and metros. The aim was measured through two specific objectives: (1) to calculate travel time and accessibility scores to dental care in Virginia using a transit-based accessibility model for all dental clinics and dental clinics participating in the Medicaid dental program and (2) to estimate factors associated with the accessibility to dental clinics participating in the Medicaid dental program in Virginia.

2 | Methods

2.1 | Study Region

The study comprised nine regions within Virginia, including Greenville, Altavista, Lynchburg, Winchester, Williamsburg, Staunton-Harrisonburg, Hampton, Richmond, and Northern Virginia (including Alexandria, Arlington, Fairfax County, Loudoun County, and Prince William County). The total population living in our study area is 5 968 587, which is about 69% of the entire population living in Virginia in 2021. Although it would be ideal to include the entire state, many regions in Virginia do not maintain sufficiently detailed public transit data, especially in rural areas. The nine regions were selected as related transit data was available. Each region represented a diverse array of geographical locations and urban–rural mix. Small cities like Greenville and Altavista offered a contrast to the bigger and more urban settings of Richmond, Northern Virginia, and Hampton. Lynchburg, Williamsburg, Winchester, and Staunton-Harrisonburg are middle-sized areas. This combination provided us with a comprehensive overview of varying geographic contexts within Virginia.

2.2 | Data

The study used data from various sources to build a realistic public transit model that plays a key role in accurately assessing transit-based dental care accessibility. First, in terms of the public transit model, general transit feed specification (GTFS) data were compiled [14], which is essential for analysing public transit schedules and routes from multiple sources, such as primarily public transit websites and public repositories [15]. The GTFS files contained detailed information about transit routes, schedules, and stops, which are crucial for computing accurate transit-based travel time between origins and destinations [16]. The GTFS files of nearby transit agencies were aggregated to reflect the real-world transit service coverage area.

To measure the spatial accessibility to dental care services, the study utilised building footprints, a polygon or set of polygons that show the total area of a building, assuming that individuals depart their transit trips from each building footprint to dental care services. Building footprints were used since they are the finest spatial resolution units that can be considered to be occupied by humans. The footprint data were obtained from the Virginia Geographic Information Network (VGIN) [17]. Regarding the destination information, the study used comprehensive dental clinic data, including location and participation in Medicaid in each clinic, from the American Dental Association (ADA) 2022 Office Database [18]. This database includes dentists that participate in pediatric Medicaid or CHIP programs based on a roster of dentists listed in the Insure Kids Now website maintained by the Centers for Medicare and Medicaid Services [19].

2.3 | Statistical Analysis

Next, using *r5r*, an R package designed for transit network analysis [20], the research team created a high-resolution schedule-aware transit network for the study area. For each subregion in

the study area, a comprehensive transit network was built, and then a transit-based origin–destination travel time matrix was computed. The origin included all the geographic coordinates (longitude and latitude) of the centroid of the building footprints in each region, and the destination consisted of the geographic coordinates of the dental care facilities in these regions. Note that the transit-based origin–destination travel time matrices include detailed trip information, such as in-vehicle travel time (i.e. ride time) as well as out-of-vehicle travel time (e.g. walking to the bus stop or home and waiting time for the bus). Detailed information on travel time estimation was provided in the Data S1.

As a result, accessibility scores were calculated by counting the number of dental clinics that can be reached within 60 min of travel time. The 60-min threshold was selected considering that it is an acceptable travel time for people using public transit and indicates the point at which accessing healthcare via public transit may impose an undue burden [21, 22]. The accessibility metrics evaluated how easily people could reach dental clinics using public transit [22]. Two accessibility scores were computed and aggregated to the census block group level: (1) access to all dental clinics; (2) access to dental clinics participating in Medicaid. Next, this study examined how residents' primary socio-economic factors are associated with each accessibility score but focused on dental clinics participating in Medicaid using multiple linear regression models. This group was chosen based on a higher likelihood of Medicaid patients than overall residents taking public transit. Also, only six regions were selected from the included nine regions for this analysis due to the small number of census block groups in Greenville, Altavista, and Lynchburg. Dependent variables were the accessibility scores at the census block group level. Independent variables included primary socio-economic factors in each region, including population density, poverty percentage and non-White population that were extracted from the 2021 American Community Survey (ACS) data [23]. R version 4.2.1 was used to conduct rapid transit network analysis and all regression analyses. ArcGIS Pro version 3.2.1 from Esri was used to visualise the accessibility score across the selected cities. The significance level was set at 0.05.

3 | Results

3.1 | Travel Time to the Nearest Dental Care Clinic for All Dental Clinics and Those Participating in Medicaid

Table 1 shows the descriptive statistics of one-way transit-based travel times to the nearest dental clinic in the study area. The findings demonstrated substantial differences in travel times to dental clinics across different cities. For example, the average transit travel time to the closest dental clinic was 38 min in Greenville (one of the smallest cities in rural Virginia). Medium-sized cities like Winchester and Staunton-Harrisonburg reported average travel times of 29 and 33 min, respectively. In contrast, Richmond, a significantly larger city, had an average travel time of 29 min, which is shorter than other small- and medium-sized cities. Across nine cities, residents spent a considerable portion of their trips outside vehicles (i.e. walking and waiting), ranging from 78% to 89%, indicating challenges in accessing public transit. For instance, in Richmond, 80% of transit travel times consisted of

out-of-vehicle travel. Moreover, the percentage of relatively short trips that can be made only by walking was calculated. This metric indicated another piece of evidence of inadequate accessibility to dental clinics. For instance, larger cities like Hampton Roads and Northern Virginia showed a higher prevalence of walking-only trips, approximately 53%–60%, in contrast to smaller cities such as Greenville and Altavista with 19% and 13%, respectively. Overall, these findings highlight travel times to dental care substantially vary across different cities, with larger cities benefiting from more densely located dental clinics, well-developed sidewalks favourable to walking access and well-covered public transit networks. In terms of Medicaid users, the travel times to dental clinics were consistently more prolonged than overall residents, suggesting more travel burden faced by Medicaid users.

3.2 | Transit-Based Accessibility to All Clinics and Clinics Participating in Medicaid

Table 1 and Figure 1 further show the accessibility scores for dental care clinics in the different cities within Virginia. Figure 1 illustrated that people living closer to regional centers (e.g. downtown) had better transit-based access to dental clinics compared to those living in suburban or peripheral regions because of more densely concentrated clinics, more frequent transit services and better coverage of transit networks, regardless of regions in the study area. Similar to the travel time results described above, accessibility scores varied substantially by city size. Smaller cities like Greenville and Altavista generally had the lowest accessibility to dental clinics, with an average of 1.5 and 0.8 dental clinics reachable within a 60 min travel radius, respectively. For these two cities, only 50.3% (Greenville) and 21.1% (Altavista) of residents had access to at least one clinic within 60 min of transit trips. On the contrary, larger cities generally had better overall accessibility to dental clinics. For instance, Northern Virginia stood out with an average of 122 dental clinics being accessible within 60 min of transit trips, and 83.1% of residents had access to at least one clinic.

In comparison, the accessibility to dental clinics participating in Medicaid was notably lower in smaller regions, with an average accessibility score of 0.898 and 0.178 in Greenville and Altavista, respectively. On the other hand, bigger cities such as Richmond, Hampton Roads and Northern Virginia showed relatively higher accessibility to dental clinics participating in Medicaid compared to other smaller cities, with an average accessibility score of 10.108, 6.204, and 51.241, respectively. Regardless of city size, accessibility to dental clinics participating in Medicaid was significantly lower than all dental clinics.

3.3 | Socio-Economic Inequality in Transit-Based Accessibility to Dental Clinics Participating in Medicaid

Table 2 presented the results of multiple linear regression models that examined the association between transit-based dental care accessibility scores and primary socio-economic factors for the dental clinics participating in Medicaid in each of the six selected cities and entire regions. The results revealed that population density had a consistently positive relationship with accessibility scores for almost all the regions except for Williamsburg.

TABLE 1 | Transit-based accessibility to all dental clinics and those participating in the Medicaid dental program of the nine selected regions in Virginia.

	Region	Travel time ^a (min), Mean (SD)	% Out-of-vehicle travel time	% Walk-only trips	Accessibility score ^b , Mean (SD)	% Populations with accessibility score ≥ 1
Accessibility to all dental clinics						
Small-sized region	Greenville	37.881 (5.120)	89	19	1.516 (1.582)	50.3
	Altavista	32.160 (11.892)	78	13	0.832 (1.264)	21.1
Medium-sized region	Winchester	28.817 (14.332)	88	26	10.328 (15.604)	41.0
	Williamsburg	42.015 (12.909)	86	36	3.568 (4.879)	59.2
	Lynchburg	37.142 (12.241)	78	36	6.911 (7.870)	73.1
Large-sized region	Staunton-Harrisonburg	32.535 (13.971)	86	26	7.511 (11.067)	50.1
	Richmond	29.185 (12.576)	80	55	24.226 (32.148)	71.2
	Hampton roads	33.635 (11.359)	83	60	19.520 (18.324)	83.9
	Northern Virginia	29.486 (13.887)	85	53	122.08 (133.400)	83.1
Accessibility to dental clinics participating in Medicaid dental program						
Small-sized region	Greenville	42.441 (2.487)	86	9	0.898 (0.882)	46.8
	Altavista	28.508 (0.038)	63	4	0.178 (0.343)	1.6
Medium-sized region	Winchester	26.578 (12.634)	84	22	3.222 (4.780)	36.2
	Williamsburg	42.141 (10.719)	85	17	0.931 (1.500)	32.8
Large-sized region	Lynchburg	37.945 (10.565)	75	27	3.113 (3.394)	66.8
	Staunton-Harrisonburg	41.525 (10.576)	82	13	1.809 (2.608)	40.2
	Richmond	31.184 (12.666)	78	43	10.108 (13.092)	61.1
	Hampton Roads	39.168 (10.923)	79	34	6.204 (6.064)	73.1
	Northern Virginia	31.089 (12.814)	83	42	51.241 (60.916)	76.2

Abbreviation: SD, standard deviation.

^aTravel time: Average one-way transit-based travel time to the nearest dental clinic.

^bAccessibility score: Average number of dental clinics that are reachable within 60 min of transit-based travel time.

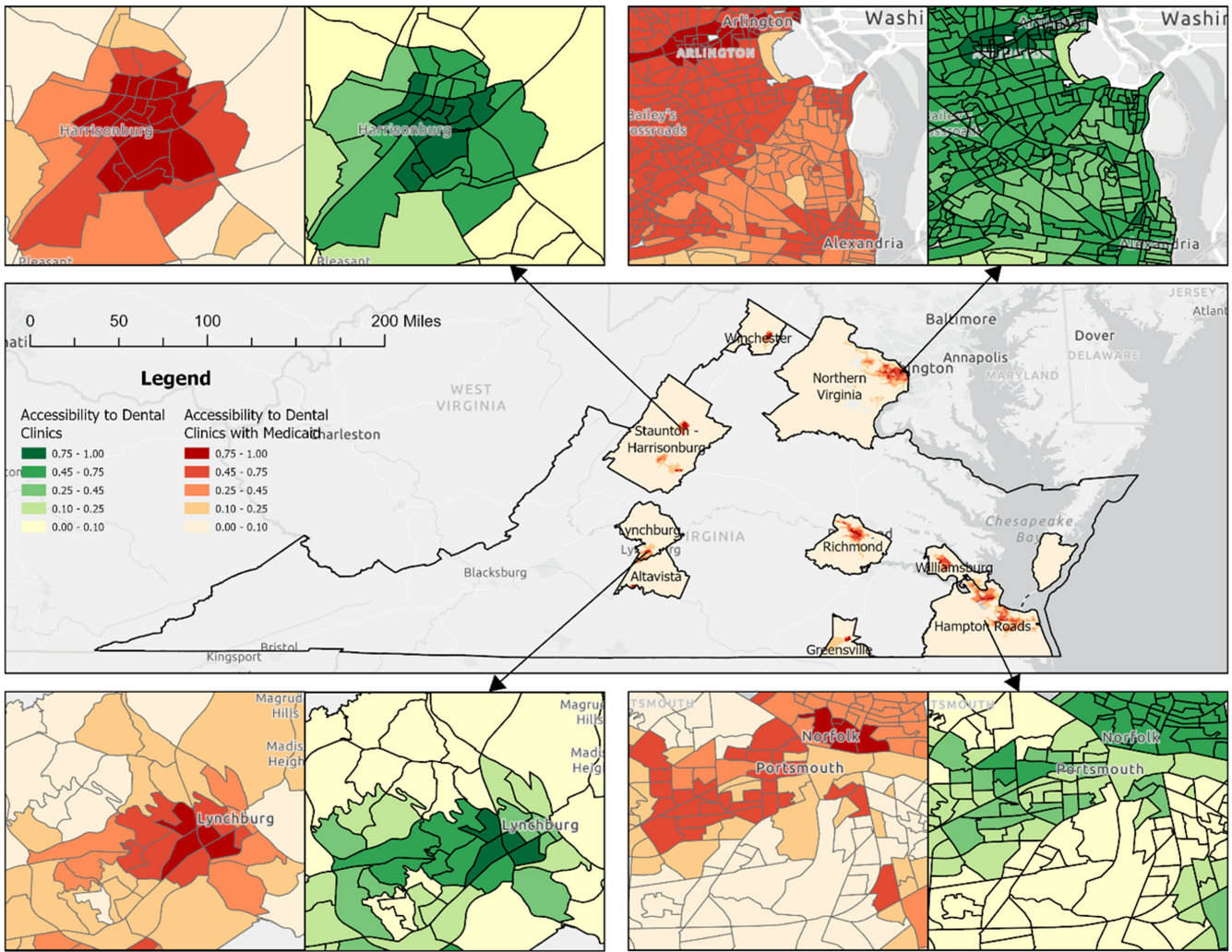


FIGURE 1 | Transit-based accessibility score to dental clinics participating in Medicaid (red colour) and all dental clinics (green colour) of nine regions in Virginia (Accessibility scores are normalised for each region to create consistent visualisations).

On the contrary, the poverty variable showed mixed results. For instance, a positive association was found between poverty percentage and accessibility in Northern Virginia [Coefficient: 0.975; standard error (SE): 0.164] and Richmond [Coefficient: 0.262; SE: 0.036], indicating that higher accessibility to dental clinics that participate in Medicaid can be found in the regions with a higher proportion of low-income populations. However, the association was weaker or did not exist in other areas, such as Winchester (no association). Similarly, the relationship between non-White population percentage and accessibility scores also varied across different regions. For example, a positive association was found in Winchester, indicating that a higher percentage of non-White populations had better accessibility to dental clinics than participating in Medicaid [Coefficient: 0.140; SE: 0.041]. In contrast, a negative association was observed in regions like Northern Virginia [Coefficient: -0.552 ; SE: 0.068] and Richmond [Coefficient: -0.078 ; SE: 0.017], suggesting that a higher percentage of non-White populations living in these areas had lower accessibility to dental clinics participating in Medicaid. In addition to the regional differences, the results also underscore the distinction between individual regions and all regions, with the results in each region capturing the unique socio-demographic

and geographic contexts of a specific area, while the results in all selected regions offer a broader but less nuanced view.

4 | Discussion

This study analysed transit-based dental care accessibility, represented by total travel time and its breakdown (e.g. time spent walking and waiting) to the nearest dental clinics and the number of dental clinics that can be reached within 60 min, and examined the associated socio-economic factors across various regions in Virginia. People who resided in smaller regions with smaller population sizes faced longer travel times and lower accessibility to dental clinics by public transit compared to those residing in larger regions. These findings were consistent with previous research that measured geospatial accessibility to dental care using driving time and straight-line distance in other states in the USA [24, 25]. However, people choosing to take public transit in Virginia needed to spend a significantly longer time travelling to dental clinics, given that more than three-fourths of the time was spent waiting for public transit and walking to dental clinics. The extra out-vehicle travel time might add additional

TABLE 2 | Results of the multiple linear regression models on the association between transit-based accessibility scores to dental clinics participating in the Medicaid dental program and sociodemographic characteristics at the census block group level among the six selected regions in Virginia.

	Winchester	Williamsburg	Staunton-Harrisonburg	Richmond	Hampton roads	Northern Virginia	All-included regions
Coefficient (Standard Error)							
Population density	1.072*** (0.307)	0.103 (0.143)	0.892*** (0.087)	5.773*** (0.436)	1.465*** (0.139)	25.323*** (0.942)	15.821*** (0.484)
Poverty percentage	-0.044 (0.051)	0.044* (0.022)	0.036* (0.011)	0.262*** (0.036)	0.046** (0.015)	0.975*** (0.164)	-0.118 (0.063)
Non-White percentage	0.140*** (0.041)	-0.007 (0.011)	0.015 (0.011)	-0.078*** (0.017)	0.043*** (0.007)	-0.552*** (0.068)	-0.220*** (0.031)
Intercept	-4.797*** (1.589)	0.172 (0.850)	-3.472*** (0.405)	-29.392*** (2.947)	-6.679*** (0.958)	-119.692*** (6.647)	-74.971*** (3.240)
Adjusted R ²	0.388	0.020	0.559	0.303	0.195	0.321	0.217
Number of census block groups	80	94	184	635	1111	1693	3918

Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

burden to seek dental care and reduce people's willingness to take public transit for dental care.

People who used Medicaid would be more likely to rely on public transit for their mobility needs [26, 27]. It is unsurprising that accessing dental care for Medicaid enrollees is more challenging. The study reported notably lower accessibility to dental clinics participating in Medicaid compared with all dental clinics. The long transit travel time to those dental clinics may decrease patients' willingness to seek care or lead to missed appointments. Many states including Virginia have started to increase the investment in Medicaid program to expand the coverage of eligible enrollees and increase reimbursement rates for healthcare providers. However, it has not shown a notable improvement regarding the availability and accessibility of dental care. For example, Virginia expanded Medicaid coverage to include comprehensive adult dental benefits in July 2021 and offered a better reimbursement rate for dental care providers since July 2022 [28, 29]. However, the impact of new policies on improving health outcomes might take years, and a longitudinal analysis might provide additional insights into the effectiveness of those policies. Additionally, though 41% of the dentists enrolled in Medicaid program in Virginia, only 27% of dentists treated Medicaid/FAMIS enrollees [11]. Also, the study only measured accessibility to the nearest dental clinic, which may not be the real choice for everyone as clinics may not accept all types of private insurance and people often have personal preferences in selecting dental care providers. Thus, the actual accessibility may be underestimated compared to those demonstrated in this study.

Considering the long transit travel time found in the study, several strategic interventions could be considered. For example, these potential interventions include the development of public transit systems, location choices of new dental clinics, and availability of school-based dental clinics or co-location with other medical and social services. Referring to the various relationships between sociodemographic factors and transit-based accessibility scores across different regions, tailored interventions should be applied, considering sociodemographic and geographic characteristics of each region to improve local dental care access [30].

There are several limitations that future studies can address. First, this study's approach to assessing transit-based accessibility did not consider the potential mismatch between demand (i.e. the number of dental care users) and supply (i.e. the number of available doctors). In bigger cities, although there are more dental clinics available than in smaller cities, more potential dental care users may compete for the same services. Therefore, the actual accessibility score that considers the supply-demand mismatch, in reality, might be different from the results reported in this study. Also, a recent study introduced the concept of 'feels-like' accessibility, which considers the different impacts of perceived travel time on accessibility regarding different transit trip segments (e.g. in-vehicle vs. out-vehicle travel time) [32]. Future studies can address these issues by utilising advanced accessibility models that account for both the demand and supply, and their complex interactions captured by travel time, such as the two-step floating catchment area (2SFCA) methods, or 'feels-like' accessibility metrics [31, 32]. Second, this study did not consider the temporal variability of transit schedules across time of day and seasons. For instance, smaller cities with high

rates of college populations (e.g. Staunton–Harrisonburg) might have transit schedules that are substantially different between semesters and breaks [33]. Additionally, the study calculated transit travel time based on the assumption that transit operated according to its schedule on time, which may not be the case in reality [34]. Fourth, since building footprint data did not include whether buildings are residential or non-residential which might impact the study results. For instance, neighbourhoods that have adequate levels of transit services in commercial corridors might overestimate transit-based accessibility despite fewer people living in those neighbourhoods. Future studies can consider obtaining high-quality land use data to mitigate this challenge. Lastly, this study did not investigate the potential association between dental health accessibility scores and oral health outcomes, which would be explored in a subsequent study.

5 | Conclusion

Disparities in dental care accessibility exist depending on the size of cities and Medicaid participation in Virginia. People in smaller cities experience longer travel times to dental clinics by public transit compared to those who reside in larger cities. Those who are enrolled in Medicaid also face more serious challenges compared to the general population. The disproportionate amount of time spent waiting for public transit and walking to destinations affects all residents regardless of where they live and what type of insurance they have. To increase accessibility to dental care using public transit, stakeholders should consider the improvement of public transit systems, location choices of new dental clinics, and the availability of school-based dental clinics or co-location with other medical and social services, taking into account the socio-demographic and geographic characteristics of each region.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.