Cureus
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Open Access Original Article

Geographic Disparities in Dental Access in the United States: A County-Level Analysis of Dental Deserts, Sociodemographic Associations, and COVID-19 Pandemic Impact (2019-2024)

Review began 10/26/2026
Review ended 11/16/2026
Published 11/21/2026

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DOI: 10.7759/cureus.120062

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Abstract

Background

This study examined county-level changes in dental workforce distribution across the United States from 2019 to 2024, characterized the sociodemographic correlates of dental deserts, and assessed whether the burden of the coronavirus disease 2019 (COVID-19) pandemic influenced changes in dental access.

Methods

We conducted a cross-sectional analysis of 3,222 US counties using National Provider Identifier (NPI) Registry data validated against American Dental Association workforce statistics. An adjusted hybrid methodology applied state-specific adjustment factors to correct systematic overcounting in NPI data. Counties were classified as dental deserts if the population-to-dentist ratio exceeded 3,000:1 or if no dentists were present. Sociodemographic associations were examined using US Census Bureau American Community Survey data and US Department of Agriculture Rural-Urban Continuum Codes. COVID-19 community transmission data (2021-2022) were merged to assess the pandemic's impact on access changes.

Results

In 2024, 1,551 (48.1%) counties were classified as dental deserts, affecting 41.1 million Americans (12.3% of the population), an increase from 1,486 counties (46.1%) in 2019. Despite 6.9% national workforce growth (220,786 to 236,082 dentists), 184 counties worsened while only 119 improved, resulting in a net deterioration of 65 counties. Compared with non-desert counties, dental deserts had significantly higher poverty (16.7% vs. 13.4%), lower median household income ($59,109 vs. $70,551), higher uninsured rates (10.1% vs. 8.2%), and greater rural prevalence (71.8% vs. 51.3%), with p-values below 0.001 for all four comparisons. Multivariable logistic regression confirmed independent associations for median income (odds ratio (OR)=0.50, 95% confidence interval (CI): 0.43-0.59), uninsured rate (OR=1.43, 95% CI: 1.31-1.57), minority population (OR=1.20, 95% CI: 1.10-1.30), and rural classification (OR=1.50, 95% CI: 1.27-1.78). COVID-19 community transmission burden showed no significant association with access changes (χ^2=1.048, p=0.592).

Conclusions

Geographic inequalities in dental access worsened between 2019 and 2024 despite modest workforce growth. Dentists remained concentrated in urban areas, while rural and economically disadvantaged counties lost ground, indicating that workforce expansion alone is insufficient. The absence of an association with COVID-19 burden suggests that these are structural rather than situational problems that require targeted geographic interventions.

Categories: Public Health, Dentistry
Keywords: dental access, dental deserts, dental workforce, geographic distribution characteristics, health disparities and vulnerable populations, health services accessibility

Introduction

Access to dental care remains a critical public health challenge in the United States, with geographic disparities creating significant barriers to oral health services for millions of Americans [1,2]. Despite the well-documented relationship between oral health and systemic health outcomes, including cardiovascular disease, diabetes complications, and adverse pregnancy outcomes [3-5], substantial variation persists in dental workforce distribution across geographic regions [6,7]. Rural and economically disadvantaged communities experience chronic shortages of dental providers, creating what researchers have termed "dental deserts" -- geographic areas where the ratio of population to dentists exceeds thresholds indicative

of inadequate access [8,9]. In this study, a county was classified as a dental desert when it had more than 3,000 people per dentist (a population-to-dentist ratio above 3,000:1) or no practicing dentist.

The period from 2019 to 2024 encompasses a major public health crisis -- the coronavirus disease 2019 (COVID-19) pandemic -- which disrupted healthcare delivery nationwide. Dental practices faced unique challenges, including aerosol-generating procedures that elevated transmission risk, extended practice closures during initial lockdowns, and subsequent workforce disruptions [10]. Understanding whether observed changes in dental access were driven by pandemic-related factors or represent longer-term structural issues is critical for policy development and targeted interventions.

While temporal changes in dental access are critical for policy planning, understanding the sociodemographic characteristics of dental desert communities is equally important for targeted interventions. Prior research consistently documents associations between inadequate dental access and poverty, low insurance coverage, minority population composition, and rural location [6,7,11]. However, most studies rely on cross-sectional data, proxy measures, or self-reported access rather than validated workforce counts. Whether these established associations persist using rigorously validated workforce data and comprehensive county-level measures remains underexplored.

Methodological challenges in dental workforce research

A significant challenge in dental workforce research involves data quality and validation. The National Provider Identifier (NPI) Registry, maintained by the Centers for Medicare and Medicaid Services, provides the most comprehensive geocoded database of healthcare providers in the United States [12]. However, the NPI Registry includes all providers with active registration numbers, regardless of practice status, including retired dentists maintaining registrations, dentists in non-clinical roles, duplicate registrations, and international dentists with US credentials. This systematic overcount can substantially inflate workforce estimates and underestimate access problems.

The American Dental Association (ADA) Health Policy Institute maintains separate workforce statistics counting only "professionally active dentists" -- those actually practicing clinical dentistry [13]. These ADA counts represent the industry gold standard but are available only at the state level, lacking the county-level granularity essential for geographic analysis. No published study has systematically validated NPI-derived county-level dentist counts against ADA standards, representing a critical gap in dental workforce methodology.

Study objectives and hypotheses

This study aimed to address these gaps through three primary objectives: (1) Quantify county-level dental workforce distribution in the United States for 2019 and 2024 using an adjusted hybrid validation methodology combining NPI geographic granularity with ADA numerical accuracy. (2) Identify and characterize "dental deserts" where access to care is critically limited, and examine sociodemographic correlates, including poverty, income, insurance coverage, minority population, and rural classification. (3) Analyze temporal changes in geographic access disparities and assess whether COVID-19 pandemic burden influenced dental access changes at the county level.

We tested three hypotheses: (1) Hypothesis 1 (temporal change): The proportion of counties classified as dental deserts increased between 2019 and 2024, with counties that worsened outnumbering those that improved. (2) Hypothesis 2 (sociodemographic associations): Dental deserts are significantly associated with higher poverty rates, lower median household income, higher uninsured rates, higher minority population percentages, and rural classification. (3) Hypothesis 3 (COVID-19 Impact): Counties with a higher COVID-19 pandemic burden experienced greater deterioration in dental access than counties with a lower burden.

Materials And Methods

Data sources

Dental Workforce Data

Dentist location data were extracted from the Centers for Medicare & Medicaid Services NPI Registry downloadable bulk data files [12]: the January 2019 full monthly National Plan and Provider Enumeration System (NPPES) file, retrieved via the Internet Archive, and the December 2025 full monthly NPPES file, the most recent complete file available at data collection (January 2026). The Centers for Medicare & Medicaid Services posts only the current monthly file, so a file dated closer to 2024 was not available. County counts from the December 2025 file were scaled to the ADA 2024 state totals. All providers with dental taxonomy codes (122X series) were identified, yielding 312,277 records for 2019 and 378,450 records for 2024. For validation, the ADA Health Policy Institute "Supply of Dentists in the US: 2001-2024" data tables [13] provided state-level counts of professionally active dentists for 2019 (220,786 dentists) and 2024 (236,082 dentists).

Population Data

County-level population estimates were obtained from the US Census Bureau American Community Survey (ACS) five-year estimates, using the Census Bureau's detailed table B01003 (Total Population) [14]. This source table provided 2015-2019 estimates for the 2019 analysis and 2019-2023 estimates for the 2024 analysis. The five-year estimates provide more reliable county-level data than single-year estimates for smaller geographic units. In this section, the identifiers B01003, DP03, and DP05 refer to the original US Census Bureau ACS source tables, not to tables presented in this article.

Sociodemographic Data

County-level sociodemographic characteristics were obtained from ACS five-year estimates (2019-2023). The ACS data profile table DP03 (Selected Economic Characteristics) [14] provided poverty rates (percentage of population with income below the federal poverty level), median household income (inflation-adjusted dollars), and health insurance coverage (percentage uninsured). The ACS data profile table DP05 (ACS Demographic and Housing Estimates) [14] provided race and ethnicity data for calculating the minority population percentage (100% minus the percentage of people who are White alone, not Hispanic or Latino).

Rural-Urban Classification

Rural-urban classification was obtained from the US Department of Agriculture (USDA) Economic Research Service Rural-Urban Continuum Codes (RUCC) 2023 [15]. Counties were dichotomized as rural (RUCC codes 4-9: non-metropolitan) or urban/metropolitan (RUCC codes 1-3), following standard USDA methodology [15] integrating metropolitan statistical area designations with population size and adjacency to metro areas.

COVID-19 Data

COVID-19 community transmission data were obtained from the Centers for Disease Control and Prevention (CDC) dataset "United States COVID-19 County Level of Community Transmission as Originally Posted" (2021-2022) [16]. Variables included cases per 100,000 population (seven-day rolling average), test positivity rate, and community transmission level (categorical: low, moderate, substantial, high). Approximately 1.38 million daily records were aggregated to county-level means across the surveillance period.

Geographic Data

County boundaries were obtained from the US Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER)/Line Shapefiles (2025) [17] for all 50 states, District of Columbia, and Puerto Rico.

Geocoding and data processing

Only the practice location address of each record was used; mailing addresses were not read. Records with no practice city or state, or with a practice address outside the United States, were removed. Deactivated NPIs, which the NPPES file lists with blank taxonomy and address fields, dropped out at these steps. Dentist practice locations were then geocoded using the US Census Bureau Geocoder batch address processing service with batch sizes of 10,000 addresses per request. Match rates were 91.9% for 2019 data and 91.3% for 2024 data. Successfully geocoded addresses were assigned to county FIPS codes. Only records with valid county assignments were included in analysis.

Inclusion and Exclusion Criteria

The analysis included all counties and county-equivalents in the 50 states, the District of Columbia, and Puerto Rico with ACS population estimates (3,220 in 2019 and 3,222 in 2024), and all NPI records with a 122X taxonomy code and a US practice address that was geocoded to a county. The sociodemographic analyses (Hypothesis 2) included the 3,195 counties with complete ACS and RUCC data, and the COVID-19 analyses (Hypothesis 3) included counties with CDC community transmission data for 2021-2022. NPI records with other taxonomy codes (including dental hygienists, dental therapists, and dental assistants) were excluded, as were records with no practice city or state or with a non-US practice address, deactivated NPIs, and records that could not be geocoded to a county (8.1% in 2019 and 8.7% in 2024). The 27 counties without complete sociodemographic data were excluded from the Hypothesis 2 analyses only.

Data validation and adjustment: the hybrid methodology

Problem Identification

Initial comparison of NPI Registry counts to ADA workforce statistics revealed systematic overcounting in NPI data. The 2019 NPI extraction yielded 286,863 geocoded dentists compared with ADA's 220,786 professionally active dentists (30% overcount). The 2024 extraction yielded 345,558 geocoded dentists compared with ADA's 236,082 (46% overcount). This discrepancy results from NPI inclusion of retired

dentists maintaining registrations, dentists in non-clinical roles (administration, insurance, and industry), duplicate registrations, inactive practitioners, and international dentists with US credentials.

Hybrid Validation Approach

To address this systematic bias while preserving geographic granularity, we implemented a hybrid validation methodology: (1) State-level validation: NPI counts were compared to ADA "professionally active dentists" counts for each state. (2) Adjustment factor calculation: State-specific correction factors were calculated as:

$$\text{Adjustment Factor} = \frac{\text{ADA State Total}}{\text{NPI State Total}}$$

(3) County-level application: Adjustment factors were applied proportionally to county counts within each state:

$$\text{Adjusted County Count} = \text{Raw NPI Count} \times \text{State Adjustment Factor}$$

This hybrid approach uses ADA totals as the "gold standard" for numerical accuracy while using NPI geographic distribution to maintain county-level granularity not available from ADA data alone.

Steps to Limit Bias

Record selection used the 122X taxonomy prefix, which leaves out other dental occupations, and locations came from practice addresses only. Scaling each state's county counts to the ADA count of professionally active dentists removed the state-level overcount from retired, non-clinical, and inactive registrants while keeping the NPI distribution within each state. The same selection, cleaning, geocoding, and adjustment steps were applied to both years, so differences between 2019 and 2024 do not reflect changes in method.

Adjustment Results

The mean state adjustment factor was 0.548, indicating a 45% average reduction was required. The 2019 adjustment reduced counts from 286,863 to 220,786 dentists (-23.0%). The 2024 adjustment reduced counts from 345,558 to 236,082 dentists (-31.7%). Adjustment factors varied substantially by state, ranging from 0.13 (Wyoming, 87% overcount) to 0.86 (Louisiana, 14% overcount), with Western and Mountain states generally requiring larger adjustments than Eastern states.

Dental desert classification and threshold justification

Counties were classified as "dental deserts" if they met either criterion: (1) dentist-to-population ratio exceeds 3,000:1, or (2) complete absence of practicing dentists.

Threshold Justification

The federal Health Resources and Services Administration (HRSA) designates dental health professional shortage areas using a threshold of 5,000:1 (or 4,000:1 for high need populations) [18]. Our stricter 3,000:1 threshold was selected to identify emerging access risks before reaching crisis levels. This "adequacy standard" rather than "crisis standard" approach aligns with preventive public health principles by identifying communities where access is inadequate but not yet critical, enabling proactive intervention rather than reactive response. The 3,000:1 threshold also corresponds to recommendations in dental workforce literature for adequate access rather than minimum acceptable access [19,20]. The 3,000:1 value also appears in the federal criteria for dental shortage areas, which treat dentists in contiguous areas with population-to-dentist ratios above 3,000:1 as unable to help relieve a shortage in the area under consideration.

COVID-19 data processing

COVID-19 community transmission data were processed through: (1) aggregation of daily county-level records to county means across the 2021-2022 surveillance period; (2) calculation of average cases per 100,000, average test positivity rate, and average transmission score (coded 1=low, 2=moderate, 3=substantial, 4=high); (3) burden categorization with counties divided into high/low burden based on median transmission score (median=3.53); and (4) quartile classification for sensitivity analyses. COVID data were merged to county change analysis by five-digit FIPS code. The complete data processing and analytical workflow is summarized in Figure *1*.

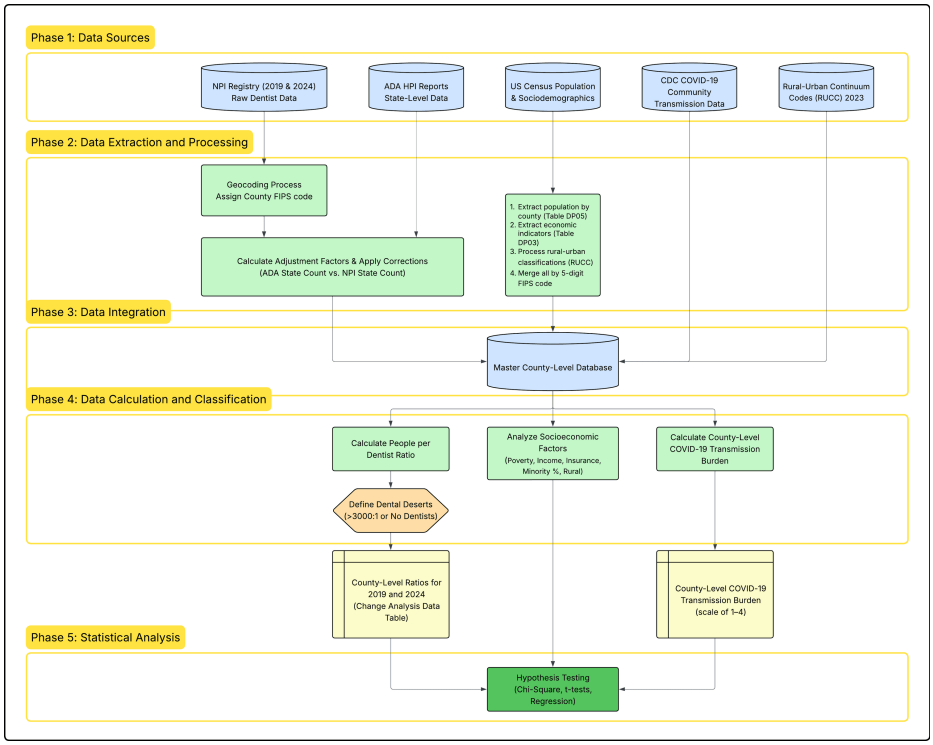


FIGURE 1: Study Data Processing and Analytical Framework

This flowchart illustrates the five-phase workflow: (1) acquisition of raw data from federal and association sources; (2) the hybrid NPI-ADA validation methodology used to correct for NPI overcounting; (3) integration of disparate datasets into a master county-level database; (4) application of classification logic for dental deserts and pandemic burden; and (5) final statistical hypothesis testing.

The flowchart was created by the authors using Lucidchart (Lucid Software Inc., South Jordan, UT, USA).

ADA: American Dental Association; CDC: Centers for Disease Control and Prevention; FIPS: Federal Information Processing Standards; HPI: Health Policy Institute; NPI: National Provider Identifier; RUCC: Rural-Urban Continuum Codes.

Image Credit: Bhanu Prakash Reddy Vakati

Statistical analysis

Temporal Change Analysis (Hypothesis 1)

County-level changes were categorized as IMPROVED (transitioned from desert to non-desert), WORSENED (transitioned from non-desert to desert), or NO CHANGE (maintained status). Chi-square tests assessed significance of proportion changes between time periods. McNemar's test evaluated asymmetry between improving and worsening counties.

Sociodemographic Associations (Hypothesis 2)

Independent samples t-tests with Welch's correction for unequal variances compared dental deserts versus non-deserts on continuous variables (poverty rate, median income, uninsured rate, and minority percentage). Chi-square tests examined rural classification. Effect sizes were calculated using Cohen's d for t-tests and Cramér's V for chi-square. Multivariable logistic regression examined independent associations between sociodemographic factors and dental desert status. Continuous predictors were standardized to z-scores for comparability. Model fit was assessed using Akaike Information Criterion and McFadden's pseudo-R^2. Variance inflation factors assessed multicollinearity.

COVID-19 Impact Analysis (Hypothesis 3)

Chi-square tests assessed association between COVID-19 community transmission burden (binary: high/low based on median split) and status change category. Independent t-tests compared mean COVID burden between counties that improved versus worsened. Quartile analysis examined status change distributions across COVID burden quartiles. All statistical tests were two-tailed with α=0.05.

Cartographic methods

Maps were created using QGIS 3.44 LTS. County boundaries were obtained from US Census Bureau TIGER/Line files (2025) [17]. The NAD83 Conus Albers projection (EPSG:5070) was used for contiguous United States displays. Where shown, Alaska, Hawaii, and Puerto Rico were displayed as insets at independent scales. All maps were exported at 300 DPI resolution for publication quality.

Results

National workforce trends

Table *1* summarizes national dental workforce and access metrics for 2019 and 2024. After ADA validation adjustment, the professionally active dental workforce increased from 220,786 dentists in 2019 to 236,082 in 2024, representing growth of 15,296 dentists (6.9%). During the same period, the US population grew from 328,016,242 to 335,642,425 (2.3% increase). The national dentist-to-population ratio improved slightly from 1,486:1 to 1,449:1 (-2.5%), as workforce growth (6.9%) exceeded population growth (2.3%).

Metric	2019	2024	Change	% Change
Active Dentists (ADA-validated)	220,786	236,082	+15,296	+6.9%
US Population	328,016,242	335,642,425	+7,626,183	+2.3%
National Ratio (people:dentist)	1,486:1	1,449:1	-37	-2.5%
Dental Desert Counties	1,486	1,551	+65	+4.4%
% Counties in Desert Status	46.1%	48.1%	+2.0 pp	+4.3%
Counties With Zero Dentists	281	289	+8	+2.8%
Population in Deserts (millions)	38.9	41.1	+2.2	+5.7%
% Population in Deserts	11.9%	12.3%	+0.4 pp	+3.4%

TABLE 1: National Dental Workforce and Access Metrics, 2019-2024

Dental desert is defined as a >3,000:1 people-per-dentist ratio or zero practicing dentists. Dentist counts adjusted using state-specific American Dental Association (ADA) validation factors.

pp: percentage points.

Dental desert prevalence (hypothesis 1)

Despite improved national averages, county-level access worsened. In 2024, 1,551 counties (48.1%) were classified as dental deserts compared with 1,486 counties (46.1%) in 2019, representing a net increase of 65 dental desert counties (+4.4%). Counties with zero practicing dentists increased from 281 to 289 (+2.8%). The population living in dental deserts increased from 38.9 million (11.9% of US population) to 41.1 million (12.3%), an increase of 2.2 million Americans.

Table *2* presents the transition matrix for county status changes. Among 3,222 counties with complete data, 119 (3.7%) improved (stopped being deserts), 184 (5.7%) worsened (became deserts), and 2,919 (90.6%) maintained their classification. Of counties maintaining status, 1,367 remained deserts, and 1,552 remained non-deserts. McNemar's test revealed significant asymmetry in changes (χ^2=13.05, p<0.001), with 1.5 times more counties worsening than improving.

Status Change Category	Counties (n)	% of Total	Population Affected
IMPROVED (desert → adequate)	119	3.7%	~1.1 million
WORSENED (adequate → desert)	184	5.7%	~3.8 million
Remained Desert	1,367	42.4%	~38.9 million
Remained Adequate	1,552	48.2%	~291.8 million
Net Deterioration	65	2.0%	+2.2 million

TABLE 2: County Status Changes in Dental Access, 2019-2024

McNemar's test for asymmetry: $\chi^2=13.05$, $p<0.001$. Significantly more counties worsened (184) than improved (119). Nine counties with data for only one of the two years (because of county boundary changes) were classified as no change.

Figure 2 displays the statistical summary of these changes, showing the paradoxical finding that county-level access worsened despite national improvement.

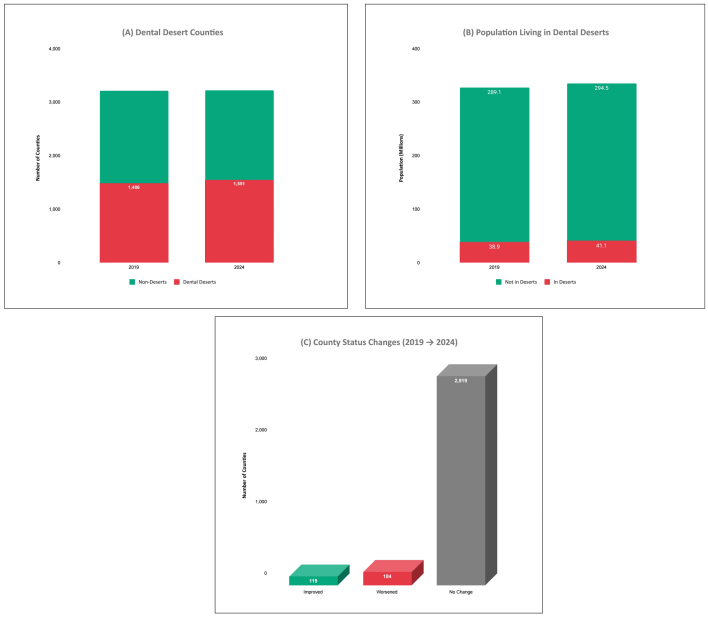


FIGURE 2: Dental Desert Analysis Summary: County-Level Changes (2019-2024)

Three-panel summary of the ADA-validated dental access analysis. (A) The number of dental desert counties increased from 1,486 (46.1%) to 1,551 (48.1%), a net increase of 65 counties. (B) The population living in dental deserts increased from 38.9 million to 41.1 million Americans. (C) Status change breakdown: 119 counties improved, 184 worsened, and 2,919 maintained their status (1,367 remained deserts and 1,552 remained adequate). Despite 6.9% national workforce growth, county-level access declined, consistent with uneven geographic distribution of dentists. The charts were created by the authors in Google Sheets (Google LLC, Mountain View, CA, USA) and exported to a PNG.

ADA: American Dental Association.

Image Credit: Bhanu Prakash Reddy Vakati

These findings confirm Hypothesis 1: dental deserts increased between 2019 and 2024, with significantly more counties worsening than improving.

Geographic distribution of dental deserts

Figure 3 presents side-by-side county-level maps comparing dental desert status in 2019 and 2024. The maps reveal persistent geographic concentration of dental deserts in the Great Plains, rural South, and Mountain West regions. The "dental desert corridor" extending from Montana through the Great Plains to Texas contains the highest concentration of zero dentist counties and severe shortage areas.

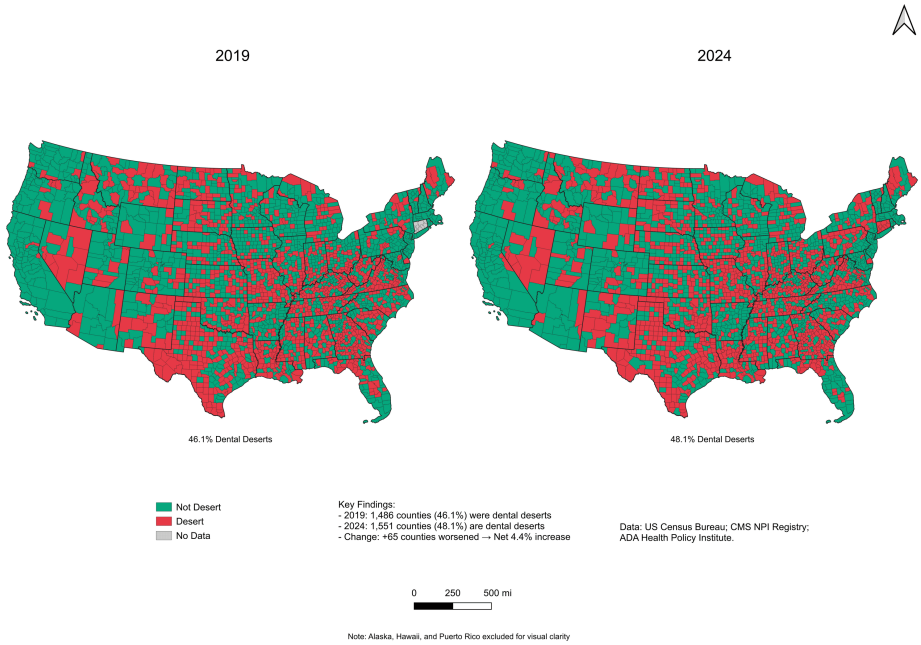


FIGURE 3: Dental Deserts in the United States: 2019 vs. 2024

Side-by-side county-level comparison of dental desert status in the contiguous United States. Left panel: 2019 (1,486 counties, 46.1% dental deserts). Right panel: 2024 (1,551 counties, 48.1% dental deserts). Green indicates adequate access (≤3,000:1 ratio); red indicates a dental desert (>3,000:1 ratio or no dentists); gray indicates no data. Net change: +65 counties (+4.4%). Alaska, Hawaii, and Puerto Rico are excluded from the display but included in the statistical analyses. Data: US Census Bureau; CMS NPI Registry; ADA Health Policy Institute. The maps were created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using the NAD83 Conus Albers projection (EPSG:5070) and public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CMS: Centers for Medicare & Medicaid Services; EPSG: European Petroleum Survey Group; NAD83: North American Datum of 1983; NPI: National Provider Identifier.

Image Credit: FNU Maleha

Figure 4 displays county-level changes between 2019 and 2024, with green indicating improved counties and red indicating worsened counties. Changes were geographically dispersed without clear regional clustering.

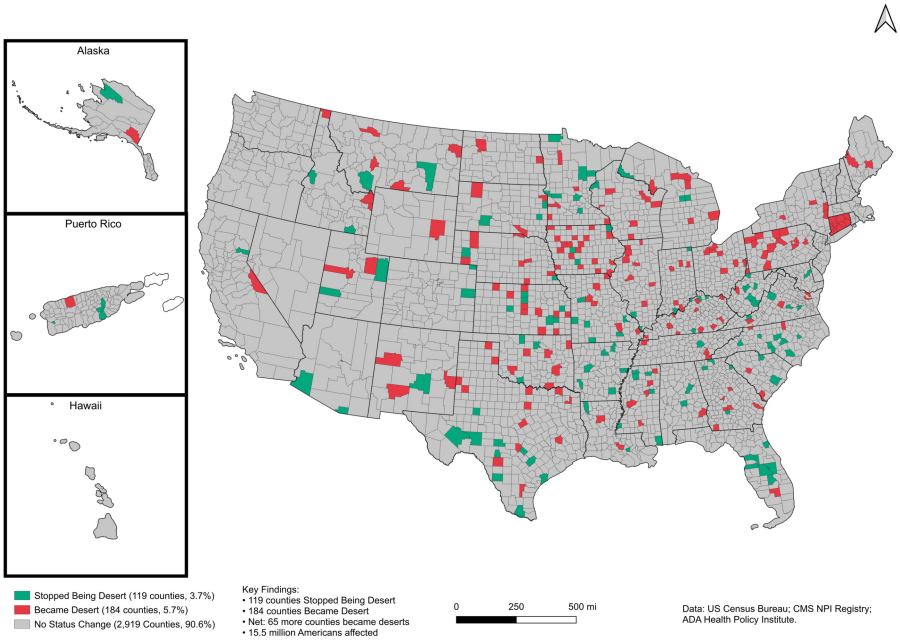


FIGURE 4: County-Level Changes in Dental Access Status, 2019-2024

Geographic distribution of county status changes. Green counties (n=119, 3.7%) changed from dental desert to adequate access. Red counties (n=184, 5.7%) changed from adequate access to dental desert. Gray counties (n=2,919, 90.6%) had no status change. Net deterioration: 65 additional counties classified as dental deserts; 41.1 million Americans lived in dental deserts in 2024. Insets show Alaska, Puerto Rico, and Hawaii at independent scales. Data: US Census Bureau; CMS NPI Registry; ADA Health Policy Institute. The map was created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CMS: Centers for Medicare & Medicaid Services; NPI: National Provider Identifier.

Image Credit: FNU Maleha

Figure *5* presents a choropleth map of 2024 population-to-dentist ratios showing the spectrum of access severity. Dark brown indicates 289 counties with no practicing dentists, while the color gradient from pale yellow (<1,500:1) through dark red (>5,000:1) shows the distribution among counties with dentists.

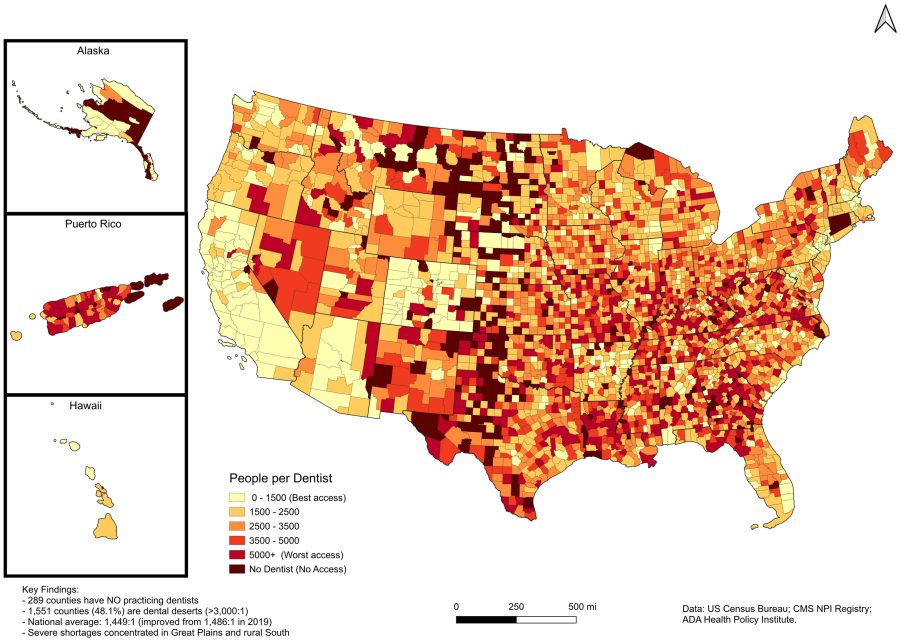


FIGURE 5: Population-to-Dentist Ratios by County, 2024

Choropleth map of people per dentist across 3,222 counties. Dark brown indicates the 289 counties (9.0%) with no practicing dentists. Colors range from pale yellow (≤1,500 people per dentist, best access) to dark red (>5,000, worst access). National average: 1,449:1 (improved from 1,486:1 in 2019). In total, 1,551 counties (48.1%) meet the dental desert definition (>3,000:1), affecting 41.1 million Americans (12.3% of the population). Severe shortages are concentrated in the Great Plains and the rural South. Insets show Alaska, Puerto Rico, and Hawaii at independent scales. Data: US Census Bureau; CMS NPI Registry; ADA Health Policy Institute. The map was created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CMS: Centers for Medicare & Medicaid Services; NPI: National Provider Identifier.

Image Credit: FNU Maleha

Figure *6* presents state-level analysis comparing 2019 and 2024. Notable changes include Connecticut's deterioration from 0% to 100% dental deserts (all eight counties now exceed threshold), representing the most dramatic state-level worsening. Florida improved from 50.7% to 41.8% deserts. Nineteen states have more than 50% of counties classified as dental deserts in 2024.

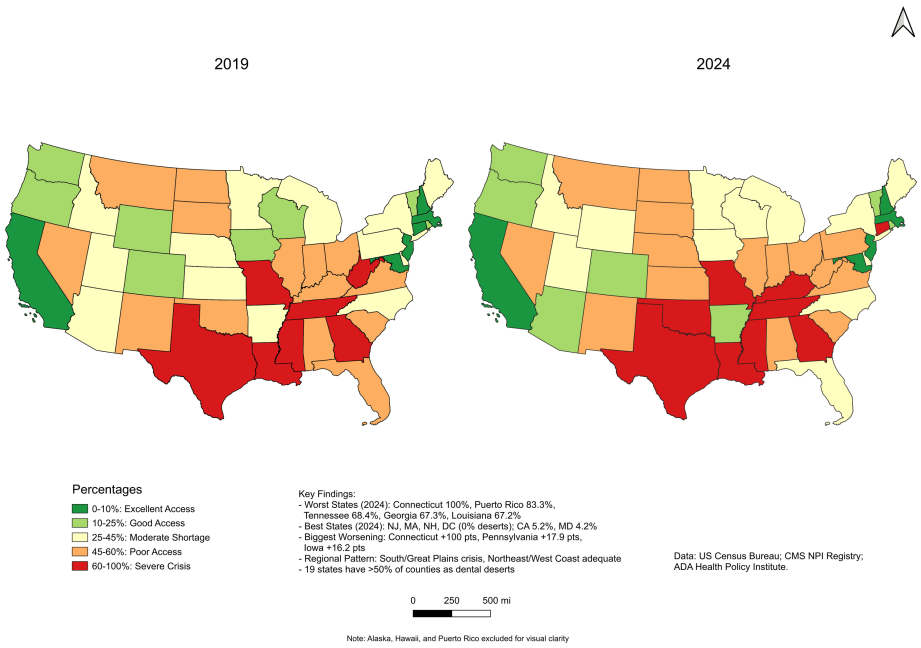


FIGURE 6: State-Level Distribution of Dental Deserts: 2019-2024 Comparison

Choropleth maps showing the percentage of counties classified as dental deserts by state in 2019 (left) and 2024 (right). Color scale: dark green (0%-10%, excellent access), light green (10%-25%, good access), pale yellow (25%-45%, moderate shortage), orange (45%-60%, poor access), and dark red (60%-100%, severe crisis). Connecticut changed from 0% to 100%. Florida improved from 50.7% to 41.8%. Texas, Louisiana, Mississippi, Georgia, Tennessee, and Missouri remained in the 60%-100% category in both years. New Jersey, Massachusetts, New Hampshire, and the District of Columbia had no dental desert counties in 2024. In 2024, 19 states had more than 50% of counties classified as dental deserts. Alaska, Hawaii, and Puerto Rico are excluded from the display. Data: US Census Bureau; CMS NPI Registry; ADA Health Policy Institute. The maps were created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CMS: Centers for Medicare & Medicaid Services; NPI: National Provider Identifier.

Image Credit: FNU Maleha

Sociodemographic associations (hypothesis 2)

Complete sociodemographic data were available for 3,195 counties (99.2% of sample). Table *3* presents descriptive statistics comparing dental deserts versus non-deserts across sociodemographic characteristics.

Variable	Deserts (n=1,551)	Non-Deserts (n=1,671)	Test Statistic	p-value	Effect Size
Poverty Rate (%)	16.7 ± 8.9	13.4 ± 5.7	t=12.16	<0.001	d=0.44
Median Income ($)	59,109 ± 15,577	70,551 ± 19,075	t=-18.70	<0.001	d=-0.65
Uninsured Rate (%)	10.1 ± 5.7	8.2 ± 3.9	t=10.85	<0.001	d=0.39
Minority Population (%)	93.3 ± 13.1	92.9 ± 10.9	t=0.89	0.373	d=0.03
Rural Classification (%)	71.8	51.3	χ^2=141.05	<0.001	V=0.21

TABLE 3: Sociodemographic Characteristics by Dental Desert Status, 2024

Values are means ± standard deviations (SD) for continuous variables and percentages for rural classification. Effect sizes: Cohen's d for t-tests, Cramér's V for chi-square.

Economic Characteristics

Dental desert counties had significantly higher poverty rates (mean 16.7% ± 8.9% vs. 13.4% ± 5.7% in non-deserts; t=12.16, p<0.001, Cohen's d=0.44). Median household income was markedly lower in deserts ($59,109 ± $15,577 vs. $70,551 ± $19,075; t=-18.70, p<0.001, d=-0.65), a difference of $11,442 (16.2% lower). Uninsured rates were significantly higher in deserts (10.1% ± 5.7% vs. 8.2% ± 3.9%; t=10.85, p<0.001, d=0.39).

Demographic Characteristics

Minority population percentage did not differ significantly between dental deserts and non-deserts (93.3% ± 13.1% vs. 92.9% ± 10.9%; t=0.89, p=0.373, d=0.03). This finding contrasts with prior literature and may reflect the high baseline minority representation across all county types in recent Census data.

Rural-Urban Classification

Dental deserts were disproportionately rural: 71.8% of desert counties classified as rural (RUCC 4-9) compared with 51.3% of non-desert counties (χ^2=141.05, p<0.001, Cramér's V=0.21), a 20.5 percentage point difference indicating 1.4-fold higher rural prevalence in deserts.

Multivariable Analysis

Table *4* presents logistic regression results. After controlling for interrelationships among predictors, four of five sociodemographic factors independently predicted dental desert status. Each standard deviation increase in median income decreased desert odds by 50% (OR=0.50, 95% CI: 0.43-0.59, p<0.001). Higher uninsured rate (OR=1.43 per SD, 95% CI: 1.31-1.57, p<0.001), higher minority percentage (OR=1.20 per SD, 95% CI: 1.10-1.30, p<0.001), and rural classification (OR=1.50, 95% CI: 1.27-1.78, p<0.001) all independently predicted desert status. Poverty rate was not independently significant after controlling for income and other factors (OR=0.90, 95% CI: 0.79-1.02, p=0.107), suggesting its bivariate association operates through shared variance with income.

Predictor	Odds Ratio	95% CI	p-value
Poverty Rate (per SD)	0.90	(0.79, 1.02)	0.107
Median Income (per SD)	0.50	(0.43, 0.59)	<0.001
Uninsured Rate (per SD)	1.43	(1.31, 1.57)	<0.001
Minority % (per SD)	1.20	(1.10, 1.30)	<0.001
Rural Classification	1.50	(1.27, 1.78)	<0.001

TABLE 4: Multivariable Logistic Regression Predicting Dental Desert Status

Continuous predictors standardized to z-scores. Rural classification reference category: urban/metropolitan (Rural-Urban Continuum Codes 1-3). n=3,195 complete cases.

CI: confidence interval; SD: standard deviation.

These findings partially confirm Hypothesis 2: dental deserts are significantly associated with lower income, higher uninsured rates, and rural location. The minority population association was significant only in multivariable analysis controlling for economic factors, while poverty was not independently significant.

COVID-19 impact analysis (hypothesis 3)

Table *5* presents COVID-19 community transmission burden by dental access status change. Among 3,222 counties with COVID data, the median transmission score was 3.59, with 1,611 counties in each high/low burden category based on median split.

Status Change	Counties (n)	Mean COVID Burden	Mean Cases/100k	Mean Positivity (%)
IMPROVED	119	3.54	264.4	15.8
WORSENED	184	3.55	266.8	15.9
No Change	2,919	3.53	248.4	14.8

TABLE 5: COVID-19 Community Transmission Burden and Dental Access Changes

Statistical tests: chi-square (status vs. burden): χ^2=1.048, p=0.592 (NS); t-test (improved vs. worsened): t=-0.486, p=0.627 (NS).

NS: not significant.

Counties that improved (n=119) had mean COVID burden of 3.54, compared with 3.55 for counties that worsened (n=184) and 3.53 for counties with no change (n=2,919). The chi-square test for association between COVID burden and status change was not significant (χ^2=1.048, p=0.592). Independent t-test comparing improved versus worsened counties showed no significant difference (t=-0.486, p=0.627, Cohen's d=-0.07). Analysis by COVID quartile revealed similar proportions of improved and worsened counties across all burden levels.

Figure *7* displays the distribution of COVID-19 community transmission burden across counties.

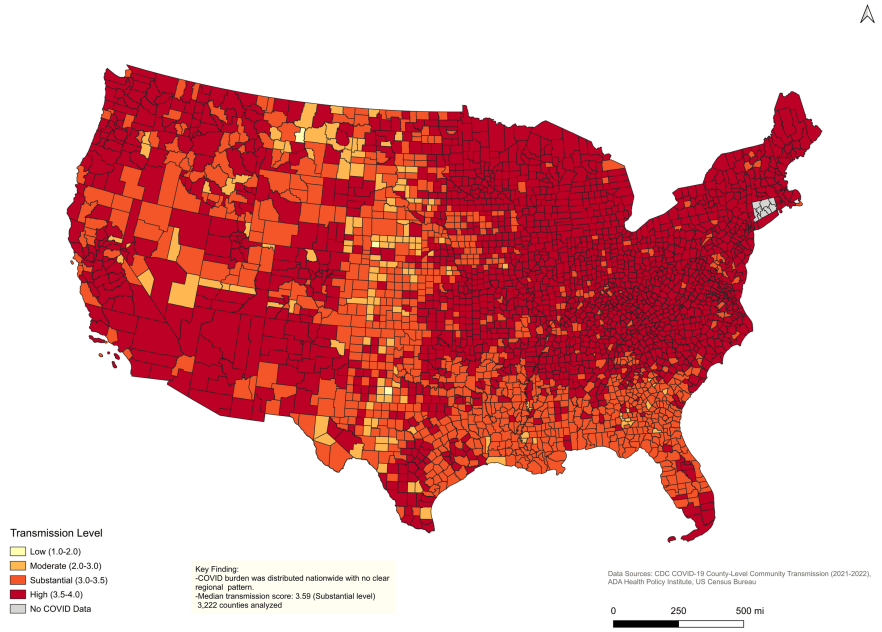


FIGURE 7: COVID-19 Pandemic Burden by County, 2021-2022

Average community transmission level by county, 2021-2022, on a 1-4 scale: pale yellow (low, 1.0-2.0), gold (moderate, 2.0-3.0), orange (substantial, 3.0-3.5), dark red (high, 3.5-4.0), and gray (no COVID-19 data). Median transmission score: 3.59. COVID-19 burden was distributed nationwide with no clear regional pattern. A total of 3,222 counties were analyzed; Alaska, Hawaii, and Puerto Rico are not displayed. Data: CDC COVID-19 County Level of Community Transmission (2021-2022); ADA Health Policy Institute; US Census Bureau. The map was created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CDC: Centers for Disease Control and Prevention.

Image Credit: FNU Maleha

Figure *8* presents the direct comparison of COVID burden versus access changes.

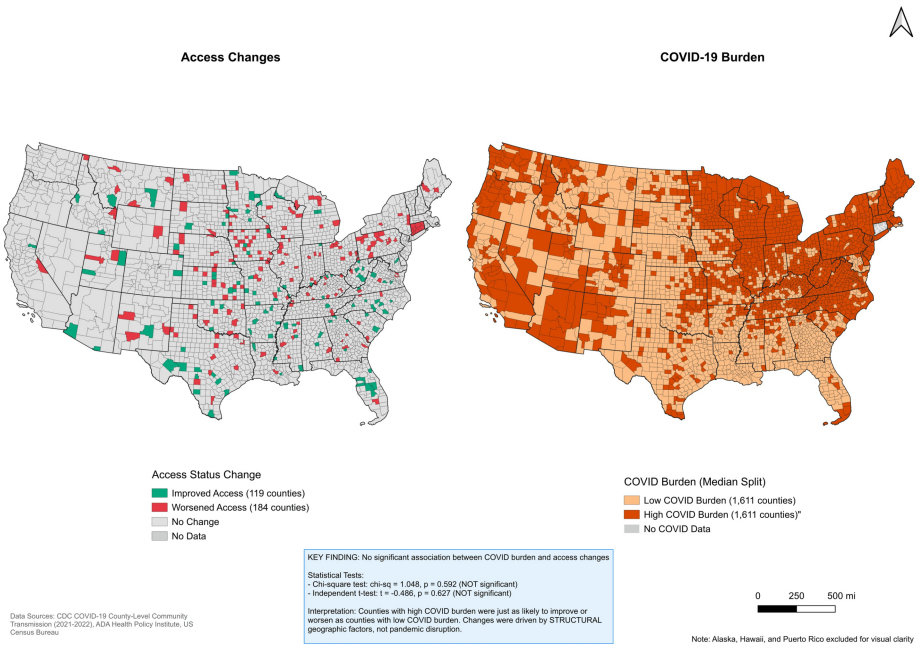


FIGURE 8: COVID-19 Community Transmission Burden vs. Dental Access Changes, 2019-2024

Side-by-side comparison of dental access status changes (left) and COVID-19 burden (right). Left panel: improved access (green, n=119), worsened access (red, n=184), no change (light gray), and no data (gray). Right panel: COVID-19 burden split at the median into low-burden (n=1,611) and high-burden (n=1,611) counties; gray indicates no COVID-19 data. Chi-square test of status change by burden: χ^2=1.048, p=0.592; independent t-test of COVID-19 burden in improved versus worsened counties: t=−0.486, p=0.627 (both not significant). Counties with high COVID-19 burden were as likely to improve or worsen as counties with low burden. Alaska, Hawaii, and Puerto Rico are excluded from the display. Data: CDC COVID-19 County Level of Community Transmission (2021-2022); ADA Health Policy Institute; US Census Bureau. The maps were created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CDC: Centers for Disease Control and Prevention.

Image Credit: FNU Maleha

Figure *9* stratifies access changes by COVID burden quartile, showing similar patterns across all quartile levels.

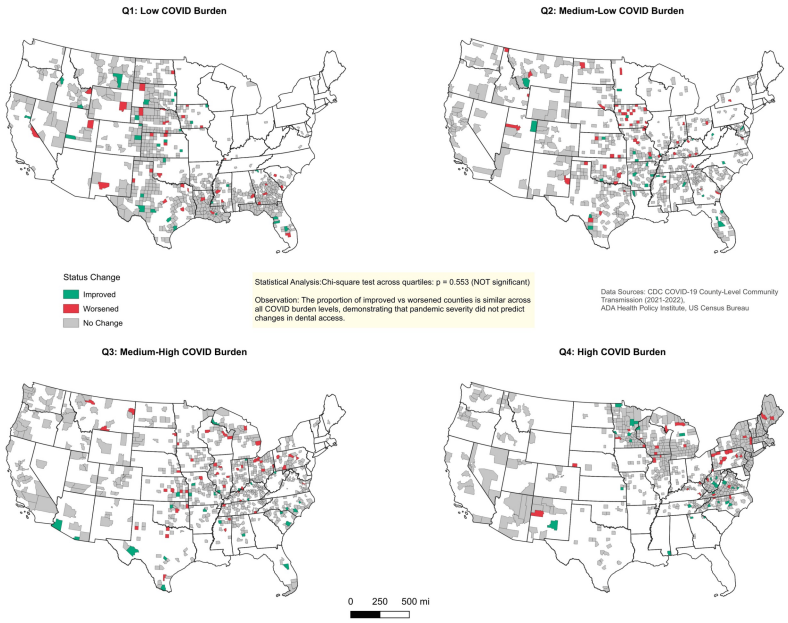


FIGURE 9: County Access Changes by COVID Burden Quartile, 2019-2024

Dental access status changes are mapped separately for each COVID-19 burden quartile, from Q1 (lowest burden) to Q4 (highest burden). Green: improved; red: worsened; gray: no change; white: counties in other quartiles. The proportion of improved versus worsened counties was similar across quartiles (chi-square test across quartiles: χ^2=4.93, df=6, p=0.553; not significant). Pandemic severity did not predict changes in dental access at the county level. Alaska, Hawaii, and Puerto Rico are not displayed. Data: CDC COVID-19 County Level of Community Transmission (2021-2022); ADA Health Policy Institute; US Census Bureau. The maps were created by the authors in QGIS version 3.44.15 (QGIS Development Team, Open Source Geospatial Foundation) using public-domain US Census Bureau TIGER/Line county boundaries.

ADA: American Dental Association; CDC: Centers for Disease Control and Prevention.

Image Credit: FNU Maleha

These findings reject Hypothesis 3: COVID-19 pandemic burden showed no significant association with dental access changes at the county level.

Data validation results

Table *6* summarizes the NPI-to-ADA adjustment methodology. The systematic overcount in NPI data ranged from 14% (Louisiana) to 87% (Wyoming), with Western and Mountain states generally requiring larger adjustments. Without validation, analysis would have overestimated the workforce by 109,476 dentists in 2024 (+46%), substantially underestimating the severity of access problems.

Year	Raw NPI Count	ADA Validated	Overcount	Adjustment Factor
2019	286,863	220,786	+66,077 (+30%)	0.770
2024	345,558	236,082	+109,476 (+46%)	0.683

TABLE 6: NPI-to-ADA Data Validation Summary

State adjustment factors ranged from 0.13 (Wyoming) to 0.86 (Louisiana); mean=0.548. Western/Mountain states showed a 60%-87% overcount; Eastern states showed a 14%-30% overcount.

ADA: American Dental Association; NPI: National Provider Identifier.

Discussion

Principal findings

This study reveals a worsening crisis in geographic access to dental care in the United States. Between 2019 and 2024, despite 6.9% national workforce growth, the number of dental desert counties increased by 4.4%, affecting an additional 2.2 million Americans. The divergence between improving national averages (1,486:1 to 1,449:1 ratio) and deteriorating county-level access (net +65 desert counties) represents an "access paradox" highlighting the inadequacy of aggregate workforce statistics for assessing geographic equity.

Three key findings emerge: (1) temporal analysis confirmed that county-level access worsened despite national workforce growth, with 1.5 times more counties deteriorating than improving; (2) sociodemographic analysis confirmed that dental deserts cluster in economically disadvantaged and rural communities, with income, insurance status, and rural location independently predicting desert status; (3) COVID-19 analysis revealed no association between pandemic burden and access changes, suggesting observed deterioration reflects structural rather than pandemic-related factors.

The access paradox: national improvement, local deterioration

The paradoxical finding that national dental access improved while county-level access worsened has critical policy implications. National workforce growth (6.9%) exceeded population growth (2.3%), improving the overall ratio. However, new dentists concentrated in already well-served urban areas while rural and underserved counties lost dentists or failed to gain proportionally. This geographic maldistribution means that aggregate statistics mask critical local disparities.

This pattern reflects market dynamics in dental workforce distribution. Dental education debt averaging over $312,700 for 2024 graduates creates economic pressure to locate in areas with higher-income populations and better reimbursement [21]. Rural communities typically cannot sustain the patient volume and income potential needed to attract and retain practitioners [7,22]. Unlike primary care, where substantial federal programs (National Health Service Corps, rural training tracks, and J-1 visa waivers) provide recruitment incentives, dental workforce development lacks comparable infrastructure [23,24].

Sociodemographic disparities and health equity implications

Our finding that dental deserts cluster in economically disadvantaged and rural communities has profound health equity implications. The $11,442 lower median household income in desert counties (16% reduction), combined with 1.9 percentage points higher uninsured rates, indicates dental desert residents face "double jeopardy": inadequate provider access combined with limited financial resources to overcome access barriers.

The rural concentration of dental deserts (71.8% rural vs. 51.3% in non-deserts) reflects well-documented market failures in rural workforce distribution [6,7,22]. The 1.5-fold higher odds of desert status in rural counties, after adjusting for economic factors, quantify this rural-urban inequality. Unlike urban areas where multiple providers may compete for patients, rural counties often depend on single practitioners whose retirement or relocation can immediately create access crises.

The unexpected null finding for minority population in bivariate analysis ($p=0.373$) contrasts with prior literature documenting access disparities in minority communities. This may reflect changes in demographic composition since earlier studies, multicollinearity with economic variables, or the county-level ecological analysis obscuring within-county variation. The significant association in multivariable models (OR=1.20, $p<0.001$) suggests minority population does predict desert status after controlling for economic factors, but the effect operates differently than previously understood.

From a health equity perspective, our findings demonstrate that dental access problems are not randomly distributed but systematically concentrated in already disadvantaged communities. This pattern violates principles of distributive justice and risks exacerbating health inequalities. Communities facing the highest oral disease burden have the least access to care -- a textbook example of the inverse care law [25,26].

COVID-19 impact: a null finding with important implications

The lack of significant association between COVID-19 community transmission burden and dental access changes is itself an important finding with clear policy implications.

Structural, Not Situational Problems

Access deterioration reflects long-term geographic maldistribution rather than temporary pandemic disruption. Counties that worsened likely had fragile access infrastructure even before COVID-19, suggesting pre-existing vulnerability rather than pandemic causation.

Continued Workforce Concentration

Geographic concentration of dentists in urban areas continued regardless of local pandemic severity. Dentist location decisions appear driven primarily by economic factors (population density, income, and reimbursement) rather than health crisis burden.

Policy Direction

Solutions must address fundamental distribution issues through structural interventions, not merely pandemic recovery programs. The null finding argues against COVID-specific dental workforce initiatives in favor of sustained geographic redistribution efforts.

Methodological contributions

This study makes important methodological contributions to dental workforce research. The hybrid NPI-ADA validation approach addresses a critical gap: NPI provides geographic granularity essential for county-level analysis but overcounts active dentists by 30%-46%; ADA provides accurate workforce totals but only at state level. Our methodology preserves the strengths of both sources while mitigating limitations.

The finding that NPI overcount varies dramatically by state (14%-87%) has implications for all NPI-based dental workforce research. Studies using uncorrected NPI data likely underestimate access problems substantially, potentially by 46% or more based on our 2024 findings. The state-level adjustment factors, we calculated, can be applied by other researchers until improved primary data sources become available.

Policy implications

Current policies are insufficient to address dental access disparities. Our findings suggest several policy directions.

Targeted Workforce Incentives

General workforce expansion benefits already well-served areas [7,22]. Incentives must be geographically targeted to shortage areas through enhanced loan repayment, higher Medicaid reimbursement, and practice subsidies in rural counties [23,24].

Alternative Delivery Models

Traditional practice models may be economically unsustainable in many rural areas. Mobile dental clinics, tele-dentistry for screening and triage, mid-level providers (dental therapists) in shortage areas, and school-based programs may provide more sustainable access solutions [27,28].

Rural Pipeline Programs

Dentists from rural backgrounds are more likely to practice in rural areas [22,29]. Expanding rural dental education pathways and residency programs in underserved areas could address long-term workforce distribution.

Structural Interventions

Since COVID burden did not predict changes, solutions must address fundamental economic and infrastructure barriers. Practice sustainability support (guaranteed patient volume and infrastructure investment) may be necessary in areas where market forces alone cannot maintain access.

Limitations

Several limitations should be considered when interpreting these findings. First, the hybrid methodology assumes uniform overcount within states when applying adjustment factors proportionally to counties. True variation may exist among counties, though state level factors (licensing and practice patterns) support this assumption as reasonable. Future research using state dental board data could provide county-level validation.

Second, the dentist-to-population ratio does not capture all dimensions of access, including practice hours (full-time vs. part-time), specialization patterns, insurance acceptance (particularly Medicaid participation), or cultural and linguistic barriers [19,30]. A county with adequate ratio may still have access problems if providers do not accept public insurance or serve particular populations.

Third, county boundaries are fixed geographic units that may not reflect actual care-seeking patterns or commuting zones. Residents of desert counties may access care in neighboring counties, partially mitigating measured shortages. Conversely, within-county variation means adequate county ratios may mask localized shortages.

Fourth, COVID-19 transmission data represent the 2021-2022 surveillance period and may not fully capture early pandemic practice disruptions or later recovery patterns. The null finding for COVID association should be interpreted as absence of detectable effect at the county level during the study period, not necessarily absence of any pandemic impact on dental access.

Fifth, the cross-sectional sociodemographic analysis cannot establish temporal precedence. Whether sociodemographic disadvantage precedes or follows dental access deterioration requires longitudinal investigation.

Strengths

This study has several important strengths. The adjusted hybrid NPI-ADA validation methodology represents the first published approach to validate county-level dentist counts against industry-standard workforce data, addressing a critical methodological gap. The comprehensive national scope (3,222 counties) with county-level granularity reveals disparities masked in state-level aggregates. The longitudinal design with consistent methodology enables valid temporal comparison. Integration of sociodemographic and COVID-19 data provides multi-dimensional analysis of access determinants. Finally, transparent methodology with documented adjustment factors enables reproducibility and extension by other researchers.

Conclusions

Geographic access to dental care in the United States deteriorated at the county level over the study period, even as the national dental workforce grew faster than the population. More counties lost adequate access than gained it, and dental deserts remained concentrated in rural and economically disadvantaged communities, where lower household income, higher uninsured rates, and rural location independently predicted desert status. Pandemic burden showed no association with changes in access, indicating that the observed deterioration reflects long-standing structural patterns in how dentists are distributed rather than disruption caused by COVID-19.

These findings show that national workforce totals can mask worsening local access, and that validating provider registry counts against professionally active workforce data is essential for accurate county-level assessment. Expanding the overall supply of dentists is unlikely, by itself, to close these gaps. Interventions that are geographically targeted to underserved counties, together with alternative models of care delivery and support for practice sustainability in rural areas, are needed to achieve equitable access to dental care across communities.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Fnu Maleha

Acquisition, analysis, or interpretation of data: Fnu Maleha, Bhanu Prakash Reddy Vakati

Drafting of the manuscript: Fnu Maleha

Critical review of the manuscript for important intellectual content: Fnu Maleha, Bhanu Prakash Reddy Vakati

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Acknowledgements

The authors acknowledge data provided by the American Dental Association Health Policy Institute, the U.S. Centers for Medicare & Medicaid Services, the U.S. Census Bureau, the U.S. Department of Agriculture Economic Research Service, and the Centers for Disease Control and Prevention. Geocoding services were provided by the U.S. Census Bureau Geocoder. Maps were created using QGIS, an open-source geographic

information system software. Generative artificial intelligence (AI) tools were used in the preparation of this manuscript. Claude (Anthropic, San Francisco, CA, USA) and Gemini (Google LLC, Mountain View, CA, USA) were used to assist with writing and debugging Python code for geocoding, data processing, statistical analysis, and map generation; drafting and language editing of manuscript text; and formatting of references. The authors reviewed and executed all AI-assisted code, verified all outputs and analyses, and edited and approved all text. The authors take full responsibility for the content of this article.

References

1. U.S. Department of Health and Human Services: Oral health in America: a report of the Surgeon General . (2000). Accessed: October 22, 2026: https://profiles.nlm.nih.gov/spotlight/nn/catalog/nlm:nlmuid-101584932X142-doc.
2. National Institutes of Health: Oral health in America: advances and challenges . (2021). Accessed: October 22, 2026: https://www.nidcr.nih.gov/research/oralhealthinamerica.
3. Sanz M, Marco Del Castillo A, Jepsen S, et al.: Periodontitis and cardiovascular diseases: consensus report . J Clin Periodontol. 2020, 47:268-88. 10.1111/jcpe.13189
4. Sanz M, Ceriello A, Buysschaert M, et al.: Scientific evidence on the links between periodontal diseases and diabetes: consensus report and guidelines of the joint workshop on periodontal diseases and diabetes by the International Diabetes Federation and the European Federation of Periodontology. J Clin Periodontol. 2018, 45:138-49. 10.1111/jcpe.12808
5. Ide M, Papapanou PN: Epidemiology of association between maternal periodontal disease and adverse pregnancy outcomes--systematic review. J Periodontol. 2013, 84:S181-94. 10.1902/jop.2013.134009
6. Rural Health Information Hub: Oral health in rural communities . (2026). Accessed: October 22, 2026: https://www.ruralhealthinfo.org/topics/oral-health.
7. CareQuest Institute for Oral Health: New report: rural populations have worse oral health care access, utilization, and outcomes compared to urban areas. (2024). Accessed: October 22, 2026: https://carequest.org/press-release/new-report-rural-populations-have-worse-oral-health-care-access-utilization-and-o....
8. Rahman MS, Blossom JC, Kawachi I, Tipirneni R, Elani HW: Dental clinic deserts in the US: spatial accessibility analysis. JAMA Netw Open. 2024, 7:e2451625. 10.1001/jamanetworkopen.2024.51625
9. National Rural Health Association: National Rural Oral Health Initiative brief 1: rural oral health workforce . (2022). Accessed: October 22, 2026: https://www.ruralhealth.us/getmedia/757e074a-a8f1-4ca4-9d4b-cd52c4cbffd4/NROHI-Workforce-Topic-Paper-Jan-2022.pdf.
10. AMN Healthcare: The growing dentist shortage: challenges, trends, and recruitment strategies . (2025). Accessed: October 22, 2026: https://www.amnhealthcare.com/amn-insights/physician/blog/the-growing-dentist-shortage-challenges-trends-and-recruitm....
11. Vujicic M, Nasseh K: A decade in dental care utilization among adults and children (2001-2010) . Health Serv Res. 2014, 49:460-80. 10.1111/1475-6773.12130
12. Centers for Medicare & Medicaid Services: Data dissemination: National Plan and Provider Enumeration System (NPPES) downloadable file. (2026). Accessed: October 22, 2026: https://www.cms.gov/medicare/regulations-guidance/administrative-simplification/data-dissemination.
13. American Dental Association Health Policy Institute: Supply of dentists in the U.S.: 2001-2024 . (2025). Accessed: October 22, 2026: https://www.ada.org/resources/research/health-policy-institute/dentist-workforce.
14. U.S. Census Bureau: American Community Survey 5-year data: detailed table B01003 and data profile tables DP03 and DP05. (2024). Accessed: October 22, 2026: https://www.census.gov/data/developers/data-sets/acs-5year.html.
15. U.S. Department of Agriculture Economic Research Service: Rural-urban continuum codes . (2024). Accessed: October 22, 2026: https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/.
16. Centers for Disease Control and Prevention: United States COVID-19 county level of community transmission as originally posted - archived. (2022). Accessed: October 22, 2026: https://data.cdc.gov/Public-Health-Surveillance/United-States-COVID-19-County-Level-of-Community-T/8396-v7yb/about_data.
17. U.S. Census Bureau: TIGER/Line Shapefiles. (2025). Accessed: October 22, 2026: https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.
18. Health Resources and Services Administration: Health workforce shortage areas . (2026). Accessed: October 22, 2026: https://data.hrsa.gov/topics/health-workforce/shortage-areas.
19. Mertz EA, Grumbach K: Identifying communities with low dentist supply in California . J Public Health Dent. 2001, 61:172-7. 10.1111/j.1752-7325.2001.tb03386.x
20. Guay AH: The differences between dental and medical care: implications for dental benefit plan design . J Am Dent Assoc. 2006, 137:801-6. 10.14219/jada.archive.2006.0293
21. American Dental Education Association: Dentists of tomorrow 2024: an analysis of the results of the 2024 ADEA survey of U.S. dental school seniors, summary report. (2024). Accessed: October 22, 2026: https://www.adea.org/home/publications/research-and-data/graduating-oral-health-students/dentists-of-tomorrow-2024.
22. Surdu S, Mertz E, Langelier M, Moore J: Dental workforce trends: a national study of gender diversity and practice patterns. Med Care Res Rev. 2021, 78:30S-9S. 10.1177/1077558720952667
23. Health Resources and Services Administration: National Health Service Corps. (2026). Accessed: October 22, 2026: https://nhsc.hrsa.gov/.
24. Goodfellow A, Ulloa JG, Dowling PT, Talamantes E, Chheda S, Bone C, Moreno G: Predictors of primary care physician practice location in underserved urban or rural areas in the United States: a systematic literature review. Acad Med. 2016, 91:1313-21. 10.1097/ACM.0000000000001203
25. Hart JT: The inverse care law. Lancet. 1971, 297:405-12. 10.1016/s0140-6736(71)92410-x
26. Cookson R, Doran T, Asaria M, Gupta I, Mujica FP: The inverse care law re-examined: a global perspective .

Lancet. 2021, 397:828-38. 10.1016/S0140-6736(21)00243-9

27. Koppelman J, Vitzthum K, Simon L: Expanding where dental therapists can practice could increase Americans' access to cost-efficient care. Health Aff (Millwood). 2016, 35:2200-6. 10.1377/hlthaff.2016.0844
28. Chi DL, Masterson EE, Carle AC, Mancl LA, Coldwell SE: Socioeconomic status, food security, and dental caries in US children: mediation analyses of data from the National Health and Nutrition Examination Survey, 2007-2008. Am J Public Health. 2014, 104:860-4. 10.2105/AJPH.2013.301699
29. Forsyth AR, Melkonyan AA, Kerns K, Flake NM, Greene RM, Roberts FA: Training a rural oral health workforce: effects of rural background on dentist practice choice. J Dent Educ. 2025, 89:177-85. 10.1002/jdd.13713
30. Nasseh K, Vujicic M: Dental care utilization steady among working-age adults and children, up slightly among the elderly. (2016). Accessed: October 22, 2026: https://www.ada.org/-/media/project/ada-organization/ada/ada-org/files/resources/research/hpi/hpibrief_1016_1.pdf.