

Area-Level Social Disadvantage and Geographic Availability of General and Specialist Dental Workforce in the United States: A National Study of 26,285 ZIP Code Tabulation Areas

Collins Gaba¹

Boston University

Anna-Lena Asiedu²

anna-lena.asiedu@ucsf.edu

University of California, San Francisco School of Dentistry

Research Article

Keywords: dental workforce, access to dental care, area deprivation index, dental deserts, workforce distribution, rural health, oral health equity, United States

Posted Date: September 2nd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10819780/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Workforce shortages limit access to essential public health services and contribute to health inequities. In oral health, the dental workforce is unevenly distributed, but how general and specialist workforce availability varies across neighborhood social disadvantage nationally remains unclear.

Methods

We conducted a cross-sectional ecological study of 26,285 ZIP Code Tabulation Areas (ZCTAs) across the 50 United States and the District of Columbia, linking 270,136 dentists from the National Plan and Provider Enumeration System to American Community Survey population estimates and three neighborhood disadvantage indices. The Area Deprivation Index (ADI) was the primary exposure. Workforce availability was measured as dentists per 10,000 residents within a 15-mile catchment; dental deserts were ZCTAs with no dentist within 15 miles. Mixed-effects negative binomial and logistic models were adjusted for rurality with state random intercepts.

Results

Each 10-percentile increase in ADI was associated with 5.9% lower nearby workforce availability (rate ratio 0.941, 95% CI 0.939–0.944), approximately 38% lower availability at the 90th versus the 10th percentile. Overall, 1,178 ZCTAs (1.70 million residents) were dental deserts, rising from 1.4% of ZCTAs in the least to 8.4% in the most disadvantaged quartile (odds ratio 1.38, 95% CI 1.32–1.44). Disparities were greater for specialty care: specialist availability was approximately 54% lower at the 90th versus the 10th ADI percentile, compared with 34% lower general dentist availability. Overall, 24.3 million residents lacked a specialist within 15 miles, and specialist deserts increased from 6.5% to 52.8% across ADI quartiles (odds ratio 1.50, 95% CI 1.46–1.53). Rural ZCTAs were 14 times more likely than metropolitan ZCTAs to be dental deserts. Findings were consistent across catchment sizes but attenuated under alternative indices, and within-ZCTA measures reversed the gradient.

Conclusions

Socially disadvantaged and rural communities have substantially lower nearby dental workforce availability, with disparities markedly greater for specialty than general dental care. Workforce planning should account for these differences and use travel-relevant measures of availability, as administrative-boundary measures may obscure geographic shortages.

Trial registration

Not applicable. This study used publicly available, de-identified data and did not involve human participants.

Background

An adequate and well-distributed health workforce is vital to ensuring equitable access to healthcare and maintaining resilient public health systems (1). However, workforce shortages remain a persistent public health challenge, limiting access to essential services and contributing to health inequities (2). Oral healthcare is no exception. Despite advances in preventive and therapeutic dental care, access to dental services remains uneven because the dental workforce is disproportionately concentrated in urban and socioeconomically advantaged communities (3). Consequently, many rural and socioeconomically disadvantaged populations continue to experience limited access to dental providers, resulting in delayed care, poorer oral health outcomes, and persistent disparities (4). Addressing these workforce shortages requires a better understanding of where they occur and which communities are most affected to guide equitable workforce planning and resource allocation.

Neighborhood social disadvantage has emerged as an important determinant of healthcare access and workforce distribution (5, 6). Communities with greater socioeconomic disadvantage often face multiple barriers to obtaining dental care, including fewer nearby providers, transportation challenges, and limited affordability or dental insurance coverage (3, 7). To identify populations with the greatest need, researchers and policymakers increasingly rely on composite measures of neighborhood disadvantage, including the Area Deprivation Index (ADI) (8), Social Deprivation Index (SDI) (9), and Social Vulnerability Index (SVI) (10). Although these indices capture related dimensions of social and economic disadvantage, they differ in their conceptual frameworks and intended applications (11). Whether these measures identify similar patterns of dental workforce distribution, particularly when workforce availability is defined using different geographic catchment areas, remains unclear.

Previous studies have demonstrated associations between neighborhood disadvantage and oral health outcomes, dental service utilization, and geographic access to dental care (3, 12, 13). National studies have also documented poorer spatial accessibility in rural and socioeconomically deprived communities and substantial geographic disparities in access to dental specialists (3, 14). However, less is known about how general and specialist dental workforce availability varies across the neighborhood disadvantage gradient nationally, or whether these associations are consistent across alternative measures of neighborhood disadvantage and geographic availability. Addressing these gaps can help identify communities where workforce shortages and social disadvantage intersect and inform strategies to strengthen the equitable distribution of the dental workforce.

Therefore, this study examined how neighborhood social disadvantage is associated with dental workforce availability across U.S. ZIP Code Tabulation Areas (ZCTAs). Using the Area Deprivation Index as the primary measure of neighborhood disadvantage and a 15-mile catchment as the primary measure of nearby workforce availability, we assessed whether more disadvantaged communities had lower availability of general dentists and dental specialists and a greater likelihood of being dental deserts. We further examined whether these patterns differed across the urban–rural continuum and whether they were consistent across alternative measures of neighborhood disadvantage and geographic catchment size. Finally, we examined which dimensions of social vulnerability were most strongly associated with nearby dentist availability and explored whether state Medicaid policy characteristics were associated with dentist supply and dental deserts. Together, these analyses identify where dental workforce shortages overlap with social disadvantage and provide evidence to inform equitable workforce planning, resource allocation, and strategies to strengthen the dental workforce.

Methods

Study design

We conducted a cross-sectional ecological study of ZIP Code Tabulation Areas (ZCTAs) across the 50 United States and the District of Columbia. U.S. territories were excluded because complete neighborhood disadvantage measures were unavailable. The study used only publicly available data containing no individually identifiable information and therefore did not constitute human-subjects research. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (15).

Data sources

Dentists with active NPIs were identified from the National Plan and Provider Enumeration System (NPPES) Full Replacement File (July 2026) (16). Population estimates were obtained from the 2020–2024 American Community Survey (ACS) 5-year estimates (17). Rurality was classified using the 2020 Rural-Urban Commuting Area (RUCA) ZIP Code approximation file (18), and geographic coordinates for each ZCTA were obtained from the 2025 U.S. Census Gazetteer (19).

Neighborhood disadvantage was measured using three widely used composite indices: the Area Deprivation Index (ADI), Social Deprivation Index (SDI), and Social Vulnerability Index (SVI). ADI data were obtained from the Neighborhood Atlas (2024 release, version 4.0.1) (8), and SDI from the Robert Graham Center (2019 release; based on the 2015–2019 ACS) (20), and SVI from the CDC Agency for Toxic Substances and Disease Registry (2022 release) (10).

Dental workforce measures

Dental providers were identified using National Provider Identifier (NPI) taxonomy codes representing general dentistry and the 12 American Dental Association-recognized dental specialties (Supplementary Table S1) (21). We included individual providers with an active NPI and a practice address located in one of the 50 states or the District of Columbia. Providers were de-duplicated using their NPI and classified according to the first eligible taxonomy code.

To assess dental workforce availability, we calculated catchment-based supply measures using circular catchments centered on each ZCTA. The primary measure was the number of dentists per nearby population within a 15-mile radius. Catchments were defined by great-circle distance between ZCTA internal-point coordinates; for each ZCTA, dentists and residents were summed across all ZCTAs whose coordinates fell within the radius, including the index ZCTA itself. Distances therefore approximate straight-line rather than road travel. Sensitivity analyses used 10-mile and 25-mile catchments. Catchments were calculated using all U.S. ZCTAs so that providers and residents from excluded ZCTAs continued to contribute to neighboring catchments. We also calculated within-ZCTA dentist density (dentists per 10,000 residents living in the same ZCTA) for use in sensitivity analyses to assess whether findings depended on measuring supply within administrative boundaries rather than within travel distance.

Dental deserts were defined as ZCTAs with no dentists located within the specified catchment radius, with the 15-mile definition serving as the primary outcome. Specialist deserts were similarly defined as ZCTAs without any dental specialist within 15 miles.

To assess the completeness of the NPPES provider file, state-level counts of dental providers identified in NPPES were compared with counts of dentists working in dentistry reported by the American Dental Association Health Policy Institute for 2024 (22). Detailed comparisons are provided in Supplementary Tables S2 and S3.

Neighborhood disadvantage measures

The Area Deprivation Index (ADI) was designated as the primary measure of neighborhood disadvantage based on its use in previous national dental workforce studies and our prior statewide analyses (3, 23). The Social Deprivation Index (SDI) and Social Vulnerability Index (SVI) were examined as comparison measures to evaluate whether findings were consistent across alternative measures of neighborhood disadvantage.

SDI and SVI were available directly at the ZCTA level. Because ADI is reported at the census block-group level, block-group national rankings were linked to ZCTAs using the GeoCorr 2022 population-weighted crosswalk (24) and summarized as population-weighted median scores. All three indices were expressed as percentile ranks, with higher values representing greater neighborhood disadvantage, and associations were scaled per 10-percentile increase. Agreement between indices was assessed using Spearman correlation coefficients.

Population, rurality, and analytic sample

Population denominators were obtained from the 2020–2024 ACS 5-year estimates. Rurality was categorized using RUCA codes as metropolitan (1–3), micropolitan (4–6), small town (7–9), and rural (10).

Among 33,772 ZCTAs identified in the ACS, we excluded U.S. territories, ZCTAs with zero population, populations below 500 residents, or missing SDI values. Providers whose practice ZIP codes could not be matched to Census ZCTAs were also excluded. In total, 26,285 ZCTAs across the 50 states and the District of Columbia were eligible for analysis. Sample selection is summarized in Figure S1.

Statistical analysis

The primary analysis evaluated the association between neighborhood disadvantage, measured using the ADI, and dental workforce availability within a 15-mile catchment. Parallel analyses using SDI and SVI and alternative catchment sizes (10 and 25 miles) assessed the robustness of the primary findings.

Mixed-effects negative binomial regression models (25) estimated associations between neighborhood disadvantage and dentist availability. Dentist counts were modeled with the logarithm of the corresponding population as an offset, neighborhood disadvantage percentile (per 10-percentile increase) as the primary exposure, RUCA category as a fixed-effect covariate, and state-specific random intercepts. Results are presented as rate ratios (RRs) with 95% confidence intervals. Because overlapping catchments induce spatial correlation between nearby ZCTAs beyond that captured by state random effects, confidence intervals from catchment-scale models should be interpreted as anti-conservative. Accordingly, interpretation emphasized the magnitude, direction, and consistency of associations across geographic scales and alternative specifications rather than statistical significance alone.

Random-slope models estimated state-specific disadvantage gradients. Dental deserts and specialist deserts were analyzed using mixed-effects logistic regression.

Specialist workforce analyses examined general dentist availability, specialist availability, and the proportion of specialists within the local dental workforce by modeling specialist counts with the logarithm of total nearby dentists as the offset, restricted to catchments containing at least one dentist.

To identify which dimensions of social vulnerability were most strongly associated with nearby dentist availability, we decomposed the SVI into its four constituent themes: socioeconomic status, household characteristics, racial and ethnic minority status, and housing type and transportation (10). Using the primary 15-mile catchment, we estimated separate models for each theme and then modeled all four themes simultaneously to obtain mutually adjusted associations. Models used the same covariates, population offset, and state random-intercept structure as the primary analyses. Associations are reported as rate ratios per 10-percentage-point increase in each SVI theme's percentile ranking. Intercorrelations among themes were assessed using Spearman correlation coefficients. Because the themes describe population characteristics rather than determinants of provider location, these analyses were interpreted as descriptive.

State-level analyses examined whether state Medicaid policy characteristics were associated with dental workforce supply. Three measures were obtained from the American Dental Association Health Policy Institute (26): adult Medicaid dental benefit generosity (2025), the percentage of dentists enrolled as Medicaid/CHIP providers (2024), and adult Medicaid fee-for-service reimbursement relative to private insurance (2024), the last of which was available for the 42 states with adult fee-for-service benefits. Two state-level outcomes were computed from the study data: dentists per 10,000 residents and the percentage of ZCTAs classified as dental deserts. Associations were assessed using Spearman rank correlations, with benefit generosity coded ordinally (enhanced > limited > emergency-only or none). Correlations were reported both unadjusted and adjusted for the share of each state's population living in rural or small-town areas, derived from RUCA categories, given its potential relationship with both Medicaid policy and workforce supply. Rurality-adjusted associations were estimated using partial Spearman correlations. Benefit generosity was additionally compared across its three categories using the Kruskal–Wallis test. Because these analyses were based on 51 jurisdictions and involved multiple correlations, they were considered exploratory and descriptive; the cross-sectional ecological design cannot establish causality or the direction of the associations observed.

All analyses were conducted using R version 4.5.1. Mixed-effects models were fitted using the glmmTMB package (25), and fixed-radius catchment neighbor searches were performed using the dbscan package (27).

Results

Sample characteristics

The study assembled national datasets on dental providers, population, neighborhood disadvantage, and geographic characteristics across the 50 United States and the District of Columbia. The National Plan and Provider Enumeration System identified 270,136 active dentists, while the American Community Survey included 33,772 ZIP Code Tabulation Areas (ZCTAs). After applying the eligibility criteria, 26,285 ZCTAs remained, encompassing 332.4 million residents (approximately 99% of the U.S. population) and 264,345 active dentists, of whom 82.1% were general dentists and the remainder represented the 12 recognized dental specialties.

Because a small proportion of ZCTAs lacked a valid score on individual disadvantage indices, the number contributing to each analysis varied slightly. A total of 26,285 ZCTAs had a valid SDI score, which was used to define the initial analytic frame at the ZCTA level; 26,123 (99.4%) had a valid ADI score and were included in the primary analyses, and 26,156 (99.5%) had a valid SVI score. Analyses directly comparing all three indices were restricted to the 26,097 ZCTAs (99.2%) with valid scores on all three. Characteristics of the ZCTAs included in the

primary ADI analyses are presented in Table 1.

Table 1. Characteristics of ZCTAs included in the primary ADI analyses, by ADI disadvantage quartile.

ADI quartile	ZCTAs, n	Population	Dentists, n	General dentists per 10,000 within 15 miles	Specialists per 10,000 within 15 miles	Specialist share of nearby workforce	Dental deserts, %	Specialist deserts, %
Q1 (least)	6,585	141.1M	139,579	7.39	1.75	17.8%	1.4%	6.5%
Q2	6,554	96.7M	70,505	5.67	1.05	13.3%	3.6%	18.6%
Q3	6,757	59.3M	36,642	4.78	0.66	9.6%	4.9%	34.7%
Q4 (most)	6,227	34.9M	16,141	4.08	0.44	6.8%	8.4%	52.8%

Based on the 26,123 ZCTAs with a valid ADI score. Deserts: no dental provider (or no specialist) within 15 miles of the ZCTA centroid. Densities are means of ZCTA-level 15-mile catchment values.

Neighborhood disadvantage and dental workforce availability

Communities with greater neighborhood disadvantage consistently had lower dental workforce availability than more advantaged communities. This inverse relationship was observed across the national distribution of the Area Deprivation Index (ADI), indicating that socially disadvantaged communities had substantially fewer nearby dentists available relative to their population.

In the primary analysis using a 15-mile catchment, each 10-percentile increase in ADI was associated with a 5.9% reduction in nearby dental workforce availability (RR 0.941, 95% CI 0.939–0.944; Figure 1). Comparing communities at the 90th and 10th percentiles of neighborhood disadvantage, this translated to approximately 38% lower dental workforce availability in the most disadvantaged communities.

The association remained consistent across alternative catchment sizes, although its magnitude varied modestly with geographic scale. The estimated reduction in workforce availability per 10-percentile increase in ADI was 6.5% using a 10-mile catchment (RR 0.935, 95% CI 0.932–0.938) and 4.8% using a 25-mile catchment (RR 0.952, 95% CI 0.951–0.954), demonstrating that the relationship persisted regardless of the geographic definition of workforce availability (Figure 1).

Dental workforce availability across the urban–rural continuum

Dental workforce availability declined substantially across the urban–rural continuum. At the primary 15-mile catchment scale, mean workforce availability decreased from 7.9 dentists per 10,000 residents in metropolitan ZCTAs to 5.4 in micropolitan areas, 4.6 in small-town communities, and 4.3 in rural communities, demonstrating progressively lower nearby dental workforce availability with increasing rurality.

Geographic disparities were particularly evident in access to nearby dental services. Although only 0.9% of metropolitan ZCTAs had no dentist within 15 miles, this proportion increased to 13.0% among rural ZCTAs—an

approximately 14-fold difference. Rural communities accounted for 70.4% of all dental deserts and approximately 1.13 million of the 1.70 million residents living in dental deserts nationwide.

Specialty dental workforce availability was even more geographically concentrated. Two-thirds of rural ZCTAs (66.8%) and more than half of small-town ZCTAs (56.5%) had no dental specialist within 15 miles, compared with only 8.7% of metropolitan ZCTAs. However, specialist shortages were not exclusively a rural phenomenon. Of the 24.3 million U.S. residents without a dental specialist within 15 miles, 10.4 million lived in rural communities, while an additional 4.5 million resided in metropolitan areas, indicating that specialty workforce shortages affect both rural and urban populations.

Neighborhood disadvantage and dental deserts

Communities with greater neighborhood disadvantage were substantially more likely to be dental deserts. Overall, 1,178 ZCTAs (4.5%) representing approximately 1.70 million residents had no dentist within 15 miles. The likelihood of being a dental desert increased progressively across the neighborhood disadvantage gradient. Desert prevalence rose from 1.4% in the least disadvantaged ADI quartile to 8.4% in the most disadvantaged quartile, corresponding to 151,015 and 750,499 affected residents, respectively (Figure 2). After accounting for rurality and state-level clustering, each 10-percentile increase in neighborhood disadvantage was associated with a 38% increase in the odds of being a dental desert (OR 1.38, 95% CI 1.32–1.44).

These findings indicate that communities experiencing greater neighborhood disadvantage were not only served by fewer dentists overall but were also substantially more likely to have no nearby dental provider, demonstrating the overlap between socioeconomic disadvantage and limited geographic availability of dental care.

Specialist workforce availability

Inequities in workforce availability were considerably greater for specialty dental care than for general dentistry. At the primary 15-mile catchment scale, each 10-percentile increase in neighborhood disadvantage was associated with a 9.3% reduction in nearby specialist availability (RR 0.907, 95% CI 0.904–0.911), compared with a 5.0% reduction in general dentist availability (RR 0.950, 95% CI 0.948–0.952). Across the neighborhood disadvantage gradient, this corresponded to approximately 54% lower specialist availability and 34% lower general dentist availability in communities at the 90th versus the 10th percentile of ADI (Figure 3A).

Neighborhood disadvantage was also associated with a progressively smaller specialist component of the local dental workforce. The proportion of specialists among nearby dentists declined significantly with increasing disadvantage (RR 0.975 per 10-percentile increase, 95% CI 0.973–0.977), decreasing descriptively from 17.8% of the local workforce in the least disadvantaged ADI quartile to 6.8% in the most disadvantaged quartile.

These disparities translated into substantial inequities in access to specialty care. Overall, 7,283 ZCTAs (27.9%), representing approximately 24.3 million residents, had no dental specialist within 15 miles. Specialist desert prevalence increased dramatically from 6.5% in the least disadvantaged ADI quartile to 52.8% in the most disadvantaged quartile (Figure 3B). After accounting for rurality and state-level clustering, each 10-percentile increase in neighborhood disadvantage was associated with a 50% increase in the odds of being a specialist desert (OR 1.50, 95% CI 1.46–1.53), indicating that a majority of the nation's most disadvantaged communities lacked nearby access to specialty dental care.

Which dimensions of social vulnerability track workforce availability

The overall SVI showed a near-null association with nearby workforce availability at the 15-mile scale (RR 1.006, 95% CI 1.004–1.008 per 10 percentiles), but its four themes showed associations in opposing directions (Table 2). Socioeconomic status (Theme 1) and household characteristics (Theme 2) were associated with lower nearby workforce availability, whereas racial and ethnic minority status (Theme 3) and housing type and transportation (Theme 4) were associated with greater availability. Associations became more pronounced in both directions when all four themes were modeled simultaneously, particularly for socioeconomic status (RR 0.963, 95% CI 0.961–0.965) and racial and ethnic minority status (RR 1.058, 95% CI 1.055–1.061). The four themes were moderately correlated with one another (Spearman ρ = 0.39–0.51; Supplementary Table S4).

Table 2. Association between SVI themes and nearby dental workforce availability at the 15-mile scale (rate ratio per 10-percentage-point increase in SVI percentile ranking, 95% CI).

SVI theme	Single-theme model	All themes modeled simultaneously
Theme 1: Socioeconomic status	0.990 (0.988–0.992)	0.963 (0.961–0.965)
Theme 2: Household characteristics	0.998 (0.996–1.000)	0.990 (0.988–0.993)
Theme 3: Racial and ethnic minority status	1.043 (1.041–1.046)	1.058 (1.055–1.061)
Theme 4: Housing type and transportation	1.019 (1.017–1.021)	1.023 (1.021–1.026)

Mixed-effects negative binomial models with RUCA adjustment, state random intercepts, and 15-mile catchment population offsets. Rate ratios are per 10-percentage-point increase in the corresponding SVI theme's percentile ranking; RR < 1 indicates lower workforce availability with greater vulnerability on that theme. For reference, the overall SVI yielded RR 1.006 (95% CI 1.004–1.008). SVI themes describe population characteristics and are not interpreted as causal determinants of provider location.

Sensitivity to index choice and geographic scale

Agreement among the three indices was modest (Spearman ρ = 0.40 for ADI–SDI, 0.22 for ADI–SVI, and 0.79 for SDI–SVI; Supplementary Table S5), indicating that they capture related but distinct dimensions of disadvantage.

The association between ADI and dental workforce availability was consistent across geographic catchment sizes but varied across measures of neighborhood disadvantage. Under the ADI, the inverse association was present at every catchment size, with a slightly steeper gradient at 10 miles and modest attenuation at 25 miles (Table 3). Associations differed in magnitude across indices: at 15 miles the SDI gradient was null (0.998) and the SVI gradient marginally positive (1.006), while at 25 miles both were inverse (0.993 and 0.998). At the 15- and 25-mile scales, no index indicated greater workforce availability in more disadvantaged communities, and all three agreed in direction at the widest scale. These differences are consistent with the SVI theme-level analyses, in which socioeconomic status and household characteristics were associated with lower workforce availability, whereas racial and ethnic minority status and housing type and transportation were associated with greater availability.

By contrast, analyses based on within-ZCTA dentist density produced index-dependent and, under SDI and SVI, reversed gradients (Table 3), with state-specific gradients flipping direction between ADI and SDI in 35 of 51 jurisdictions. These positive gradients attenuated monotonically as the catchment radius widened, a pattern

consistent with dental practices being concentrated in commercial areas whose resident populations score highly on renter occupancy, vehicle access, and housing-type measures, rather than with greater workforce availability in disadvantaged communities. Measuring supply within administrative boundaries therefore risk obscuring, and in some cases inverting, geographic inequities that are apparent at travel-relevant scales.

Table 3. Association between neighborhood disadvantage and dental workforce availability by disadvantage index and supply measurement scale (rate ratio per 10 percentiles, 95% CI).

Supply scale	ADI	SDI	SVI
Within-ZCTA	0.884 (0.877–0.891)	1.048 (1.042–1.054)	1.099 (1.092–1.107)
10-mile	0.935 (0.932–0.938)	1.011 (1.008–1.013)	1.024 (1.021–1.027)
15-mile	0.941 (0.939–0.944)	0.998 (0.996–1.000)	1.006 (1.004–1.008)
25-mile	0.952 (0.951–0.954)	0.993 (0.991–0.994)	0.998 (0.997–1.000)

Mixed-effects negative binomial models with RUCA adjustment, state random intercepts, and population offsets. RR < 1 indicates less workforce availability with greater disadvantage. CIs do not account for spatial dependence between overlapping catchments.

State-level correlates of dental workforce supply

Dentist supply varied more than twofold across states, from 5.3 to 12.2 dentists per 10,000 residents. The proportion of a state's ZCTAs with no dentist within 15 miles ranged from 0% in nine jurisdictions, including Connecticut, Massachusetts, and Vermont, to 44% in Alaska.

States with more generous adult Medicaid dental benefits had higher dentist supply, with a median of 8.0 dentists per 10,000 residents compared with 6.5 in states with limited benefits and 7.1 in states with emergency-only or no adult benefits (Figure 4A). This association was consistent before and after adjustment for state rural composition ($p = 0.52$ and 0.56 , respectively; both $p < 0.001$) and was the only association that remained significant after correction for multiple comparisons. Benefit generosity was not associated with the proportion of ZCTAs without a nearby dentist, and the pattern across benefit categories was not monotonic. Neither dentist participation in Medicaid/CHIP nor Medicaid reimbursement relative to private insurance was associated with dentist supply or dental desert prevalence, before or after accounting for state rural composition (Supplementary Table S6).

Rural composition was associated with dental desert prevalence: states with a larger share of their population living in rural or small-town areas had a greater proportion of ZCTAs without a nearby dentist ($p = 0.37$, $p = 0.007$; Figure 4B). Rural population share was not significantly associated with dentists per 10,000 residents ($p = -0.24$, $p = 0.09$).

Taken together, these exploratory findings show that states with more generous Medicaid dental benefits had higher overall dentist supply, whereas no Medicaid measure was associated with where dental deserts occurred; geographic context was more closely related to the presence of shortage.

Discussion

In this national study, greater neighborhood disadvantage was associated with substantially lower nearby dental workforce availability, with larger disparities in specialty care. Communities at the 90th percentile of the Area Deprivation Index had approximately 38% lower overall workforce availability than those at the 10th percentile, while specialist availability was approximately 54% lower. More than half of ZCTAs in the most disadvantaged quartile had no dental specialist within 15 miles, and rural ZCTAs were approximately 14 times more likely than metropolitan ZCTAs to have no nearby dentist. These findings are important because an adequate national supply of dentists does not ensure equitable geographic availability when providers are concentrated away from populations that may already face barriers to care.

Geographic availability is an important component of healthcare access because distance can increase transportation costs, time away from work or school, and the burden of completing multiple visits (7). These barriers may be particularly consequential for communities with fewer resources to overcome them, allowing workforce maldistribution to compound existing social disadvantage (4, 5). This may be especially important for specialty care, given the pronounced geographic concentration of dental specialists and resulting travel burden for some populations (14). The substantially steeper disadvantage gradient for specialists suggests that analyses treating the dental workforce as a single group may underestimate important geographic inequities in access to specialized services. More than half of ZCTAs in the most disadvantaged ADI quartile had no specialist within 15 miles, indicating that improving general dentist availability alone may not address geographic gaps in specialty dental care.

Our findings extend previous national evidence of geographic disparities in dental care. Rahman et al. reported that approximately 1.7 million U.S. residents lived more than a 30-minute drive from a dental clinic, with poorer spatial accessibility in rural and socioeconomically deprived communities (3). Using different provider data and geographic methods, we identified approximately 1.70 million residents living in ZCTAs with no dentist within 15 miles. Although these estimates are not directly comparable because they use different definitions and measures of geographic availability, they converge on a similar population-scale burden of geographic isolation from dental services. Recent national evidence has also demonstrated pronounced geographic disparities in access to dental specialists, including substantially longer travel times in rural communities (14). Our study extends these findings by demonstrating a graded association between neighborhood disadvantage and workforce availability and showing that this gradient is substantially steeper for specialists than for general dentists.

Several factors may contribute to these patterns, although the cross-sectional design cannot establish why dentists locate in particular communities. Rural background and training experiences may influence where dentists establish practice (28). Rurality was strongly associated with workforce shortage but did not fully explain the disadvantage gradient, suggesting that rural geography and social disadvantage represent related but distinct dimensions of workforce availability.

The sensitivity analyses also demonstrate that conclusions about workforce inequality depend on how disadvantage and geographic availability are measured. Although the overall SVI showed little association with nearby workforce availability, its component themes operated in opposing directions, and ADI, SDI, and SVI produced different gradients. Higher racial and ethnic minority-status vulnerability was associated with greater nearby supply, which may reflect the co-location of diverse populations and dental practices in metropolitan areas rather than better realized access to care. Geographic scale also mattered: within-ZCTA measures produced gradients under SDI and SVI that attenuated or reversed as surrounding areas were incorporated. Together, these findings suggest that composite disadvantage indices are not interchangeable, consistent with

previous comparisons of area-level disadvantage measures (11, 29). Administrative-boundary provider ratios may also inadequately represent the workforce available to surrounding communities.

These findings have implications for workforce planning and may help refine the geographic targeting of existing workforce programs by identifying communities where social disadvantage and limited workforce availability overlap. The exploratory Medicaid findings further suggest that financial and geographic access should not be treated as interchangeable: states with more generous adult dental benefits had greater overall dentist supply, but Medicaid measures were not associated with dental-desert prevalence. Although these ecological findings cannot establish causality, they suggest that financing policies alone may not determine where dentists practice.

This study has several strengths, including national coverage of approximately 99% of the U.S. population, publicly available and reproducible data, multiple geographic catchments and disadvantage indices, and separate assessment of general and specialist workforces. Limitations include reliance on NPPES registration rather than verified clinical activity; use of straight-line distance rather than road travel time; and potential sensitivity to the geographic units used to aggregate population and neighborhood characteristics. Because neighboring ZCTAs have overlapping catchments, observations are spatially correlated beyond the clustering captured by state random intercepts, which may result in confidence intervals that are too narrow. We therefore emphasize the magnitude, direction, and consistency of associations across alternative catchment sizes and disadvantage measures rather than statistical significance alone. The ecological, cross-sectional design precludes causal or individual-level inference, and geographic availability does not capture other dimensions of access, including insurance acceptance, affordability, appointment availability, or transportation.

In conclusion, socially disadvantaged and rural communities across the United States had substantially lower nearby dental workforce availability, with the largest disparities in specialty care. The findings also demonstrate that estimates of workforce inequality depend on how neighborhood disadvantage and geographic availability are measured. Workforce planning may therefore benefit from considering both community social context and provider availability beyond administrative boundaries.

Abbreviations

ACS: American Community Survey

ADI: Area Deprivation Index

ATSDR: Agency for Toxic Substances and Disease Registry

CDC: Centers for Disease Control and Prevention

CHIP: Children's Health Insurance Program

CI: Confidence interval

FFS: Fee-for-service

HPI: Health Policy Institute

IQR: Interquartile range

NPI: National Provider Identifier

NPPES: National Plan and Provider Enumeration System

OR: Odds ratio

RR: Rate ratio

RUCA: Rural-Urban Commuting Area

SDI: Social Deprivation Index

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

SVI: Social Vulnerability Index

ZCTA: ZIP Code Tabulation Area

Declarations

Ethics approval and consent to participate

This study used publicly available, aggregate, de-identified data and did not involve human participants or identifiable private information. Therefore, it did not constitute human subjects research and ethics committee approval and informed consent were not required.

Consent for publication

Not applicable.

Availability of data and materials

All data analyzed in this study are publicly available from the sources described in the Methods. The corresponding URLs are provided in the reference list. The R analysis code is available at <https://github.com/cogaba/us-dental-workforce-disadvantage> and archived at Zenodo (<https://doi.org/10.5281/zenodo.21988349>). Redistribution restrictions apply to the Area Deprivation Index (available from the Neighborhood Atlas following free registration) and the American Dental Association Health Policy Institute data tables (copyrighted); both are freely obtainable from the sources cited.

Competing interests

The authors declare that they have no competing interests.

Funding

No external funding was received for this study.

Authors' contributions

CG: Conceptualization, methodology, data analysis, data curation, visualization, writing of original draft–review and editing.

ALA: Conceptualization, investigation, visualization, interpretation of data, writing–review and editing. Both authors read and approved the final manuscript.

Acknowledgements

The authors gratefully acknowledge the University of California, San Francisco Library for its guidance and support in journal selection.

References

1. World Health Organization. Health workforce [Internet]. Geneva: World Health Organization; [cited 2026 Aug 9]. Available from: <https://www.who.int/health-topics/health-workforce>
2. Boniol M, Kunjumen T, Nair TS, Siyam A, Campbell J, Diallo K. The global health workforce stock and distribution in 2020 and 2030: a threat to equity and 'universal' health coverage? *BMJ Glob Health*. 2022;7(6):e009316. doi:10.1136/bmjgh-2022-009316
3. Rahman MS, Blossom JC, Kawachi I, Tipirneni R, Elani HW. Dental clinic deserts in the US: spatial accessibility analysis. *JAMA Network Open*. 2024;7(12):e2451625. doi:10.1001/jamanetworkopen.2024.51625
4. Northridge ME, Kumar A, Kaur R. Disparities in access to oral health care. *Annu Rev Public Health*. 2020;41:513–35. doi:10.1146/annurev-publhealth-040119-094318
5. Staloff JA, Morenz AM, Hayes SA, Bhatia-Lin AL, Liao JM. Area-level socioeconomic disadvantage and access to primary care: a rapid review. *Health Aff Sch*. 2025;3(4):qxaf066. doi:10.1093/haschl/qxaf066
6. Mbonu I, Tai S, Bartels CM, Putman M. Association between neighborhood deprivation and number of rheumatology providers. *Arthritis Care Res (Hoboken)*. 2023;75(1):9–13. doi:10.1002/acr.25036
7. Kim J, Roy I, Martinez-Mier EA, Shukla A, Weir P. Impact of lack of transportation on access to dental care. *Heliyon*. 2024;10(23):e40657. doi:10.1016/j.heliyon.2024.e40657
8. Kind AJH, Buckingham WR. Making neighborhood-disadvantage metrics accessible — the Neighborhood Atlas. *N Engl J Med*. 2018;378(26):2456–8. doi:10.1056/NEJMp1802313. Data: University of Wisconsin School of Medicine and Public Health. Area Deprivation Index, version 4.0.1 [Internet]. Downloaded from <https://www.neighborhoodatlas.medicine.wisc.edu/> [cited 2026 Jul 21]
9. Butler DC, Petterson S, Phillips RL, Bazemore AW. Measures of social deprivation that predict health care access and need within a rational area of primary care service delivery. *Health Serv Res*. 2013;48(2 Pt 1):539–59. doi:10.1111/j.1475-6773.2012.01449.x
10. Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry, Geospatial Research, Analysis, and Services Program. CDC/ATSDR Social Vulnerability Index 2022 database, United States [Internet]. [cited 2026 Aug 9]. Available from: <https://www.atsdr.cdc.gov/place-health/php/svi/index.html>
11. Rollings KA, Noppert GA, Griggs JJ, Melendez RA, Clarke PJ. Comparison of two area-level socioeconomic deprivation indices: implications for public health research, practice, and policy. *PLoS One*.

- 2023;18(10):e0292281. doi:10.1371/journal.pone.0292281
12. Asiedu AL, Gaba C. Neighborhood social vulnerability and oral health outcomes in California: a census-tract ecological analysis [Preprint]. Research Square; 2026 Jul 28. doi:10.21203/rs.3.rs-10453462/v1
 13. Benavidez GA, Crouch E, Nelson J, Martin A. Congruence between county dental health provider shortage area designations and the Social Vulnerability Index. *Prev Chronic Dis.* 2024;21:E48. doi:10.5888/pcd21.230315
 14. Rahman MS, Martinez A, Elani HW. Geographic Access to Dental Specialists in the United States. *J Dent Res.* 2026;105(7):875–882. doi:10.1177/00220345251388919.
 15. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet.* 2007;370(9596):1453–7. doi:10.1016/S0140-6736(07)61602-X
 16. Centers for Medicare & Medicaid Services. NPPES data dissemination: NPPES Full Replacement Monthly File, July 2026 [Internet]. [cited 2026 Aug 12]. Available from: <https://www.cms.gov/medicare/regulations-guidance/administrative-simplification/data-dissemination>
 17. U.S. Census Bureau. American Community Survey 5-year estimates, 2020–2024. Table B01003: total population [Internet]. [cited 2026 Aug 12]. Available from: <https://data.census.gov>
 18. U.S. Department of Agriculture, Economic Research Service. Rural-Urban Commuting Area codes: 2020 ZIP code file [Internet]. [cited 2026 Aug 12]. Available from: <https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes>
 19. U.S. Census Bureau. 2025 Gazetteer files: ZIP Code Tabulation Areas [Internet]. [cited 2026 Aug 12]. Available from: <https://www.census.gov/geographies/reference-files/time-series/geo/gazetteer-files.html>
 20. Robert Graham Center. Social Deprivation Index (SDI): 2019 ZCTA file [Internet]. [cited 2026 Aug 12]. Available from: <https://www.graham-center.org/maps-data-tools/social-deprivation-index.html>
 21. National Uniform Claim Committee. Health Care Provider Taxonomy Code Set, version 26.1 [Internet]. [cited 2026 Aug 12]. Available from: <https://nucc.org>
 22. American Dental Association, Health Policy Institute. Supply of dentists in the U.S. [Internet]. Chicago: American Dental Association; 2025 [cited 2026 Aug 12]. Available from: <https://www.ada.org/resources/research/health-policy-institute/dentist-workforce>
 23. Asiedu AL, Gaba C. Association between area deprivation and dental provider density in California: a cross-sectional ecological study [Preprint]. medRxiv; 2026. doi:10.64898/2026.07.04.26357261
 24. Missouri Census Data Center. Geocorr 2022: geographic correspondence engine [Internet]. [cited 2026 Aug 12]. Available from: <https://mcdc.missouri.edu/applications/geocorr2022.html>
 25. Brooks ME, Kristensen K, van Benthem KJ, Magnusson A, Berg CW, Nielsen A, et al. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. *R J.* 2017;9(2):378–400. doi:10.32614/RJ-2017-066
 26. American Dental Association, Health Policy Institute. Dental care in Medicaid programs: data tables, December 2025 [Internet]. Chicago: American Dental Association; 2025 [cited 2026 Aug 12]. Available from: <https://www.ada.org/resources/research/health-policy-institute/coverage-access-outcomes/dental-care-in-medicaid-programs>
 27. Hahsler M, Piekenbrock M, Doran D. dbscan: fast density-based clustering with R. *J Stat Softw.* 2019;91(1):1–30. doi:10.18637/jss.v091.i01

28. 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(2):177–85. doi:10.1002/jdd.13713.

29. Ramgopal S, Crowe RP, Misra AJ, Cash RE. Comparison of the Social Vulnerability Index, Area Disadvantage Index, and Social Deprivation Index for adults with out-of-hospital emergencies. Public Health Rep. 2025;140(5-6):522–30. doi:10.1177/00333549251357818.

Figures

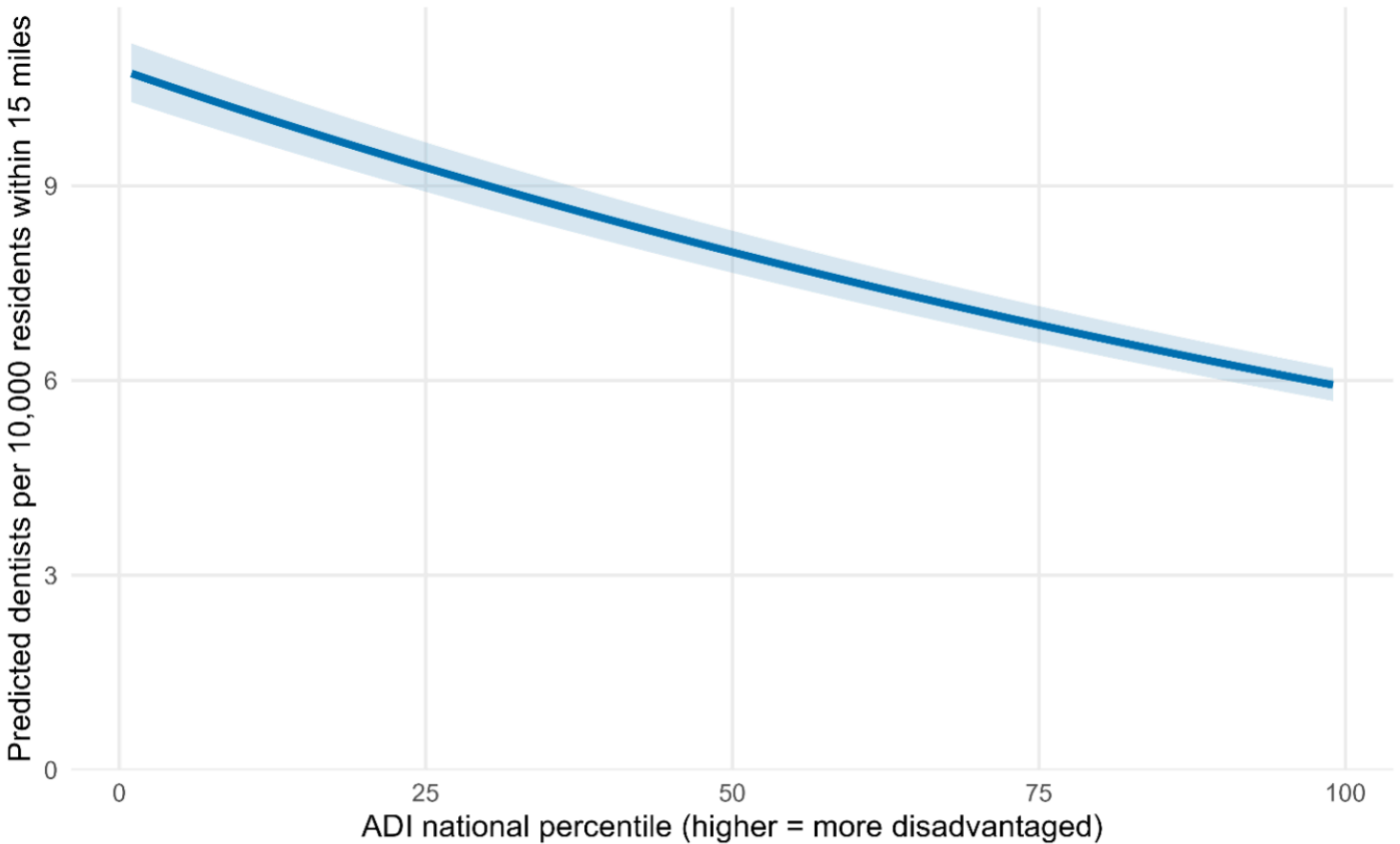


Figure 1

Nearby dental workforce availability across the national ADI distribution.

Model-predicted dental workforce availability within a 15-mile catchment (dentists per 10,000 residents) across the national Area Deprivation Index percentile distribution, from a mixed-effects negative binomial model adjusted for rurality with state-specific random intercepts (metropolitan reference). Availability was approximately 38% lower at the 90th than at the 10th ADI percentile. Shaded band shows 95% confidence intervals, which do not account for spatial dependence between overlapping catchments.

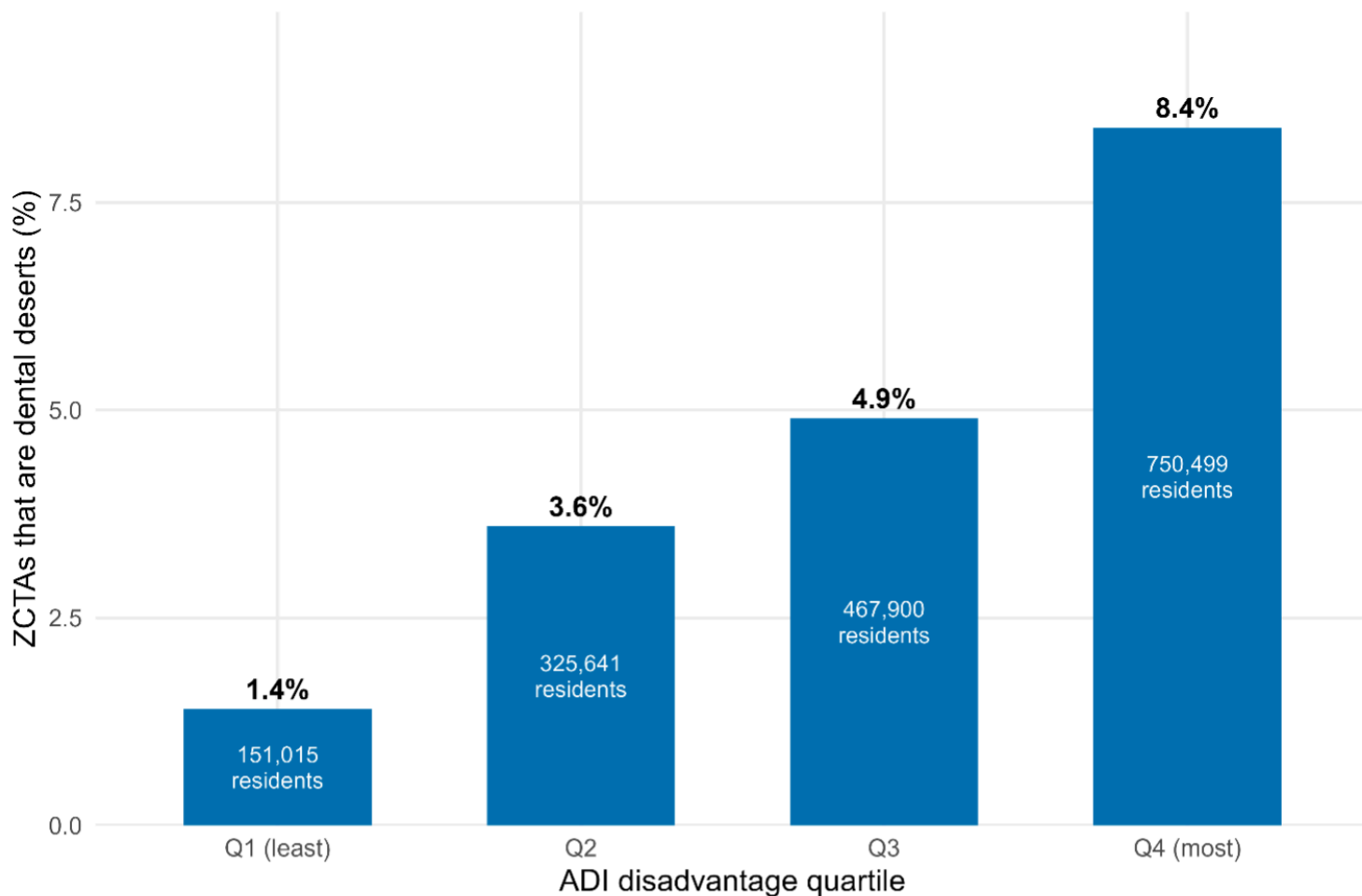


Figure 2

Dental deserts by ADI disadvantage quartile.

Percentage of ZCTAs classified as dental deserts, defined as having no dental provider within 15 miles of the ZCTA centroid, by quartile of the Area Deprivation Index. Labels show the percentage of ZCTAs in each quartile and the number of residents living in dental deserts.

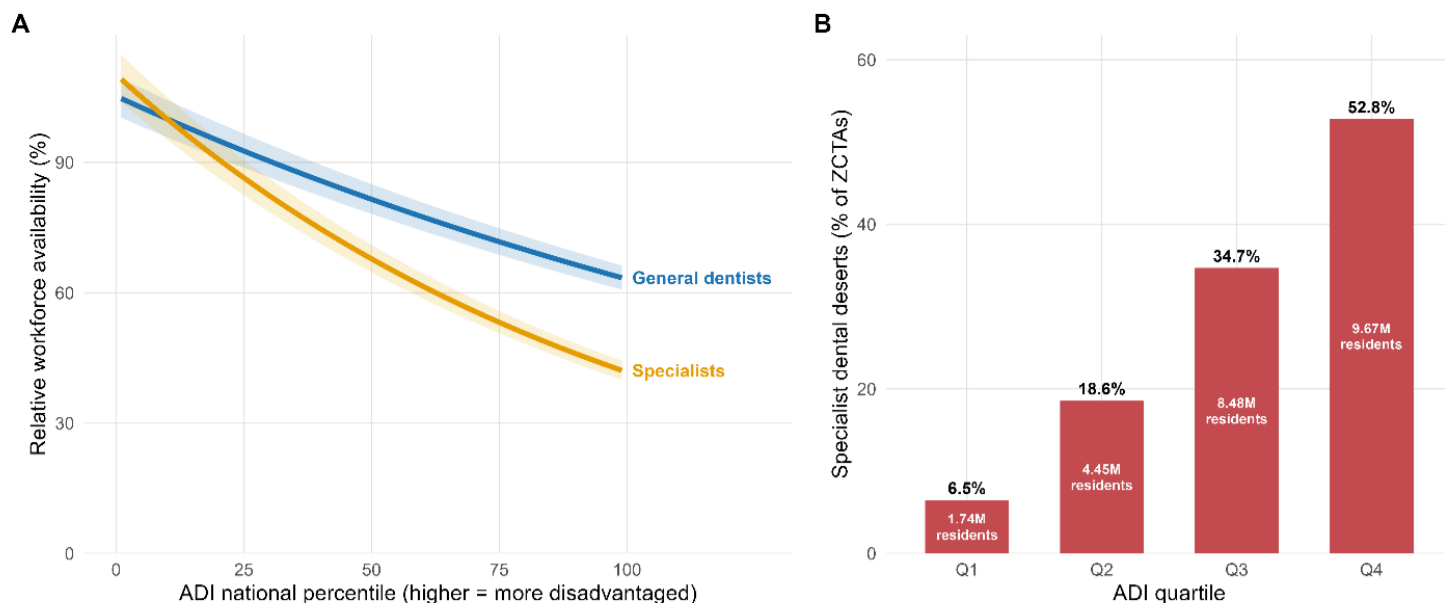


Figure 3

General and specialist dental workforce availability by neighborhood disadvantage

(A) Model-predicted availability of nearby general dentists (blue) and dental specialists (orange) within a 15-mile catchment across the national ADI distribution, with each group indexed to 100% at its predicted value at the 10th ADI percentile; availability at the 90th versus the 10th percentile was approximately 34% lower for general dentists and 54% lower for specialists. Shaded bands show 95% confidence intervals and do not incorporate uncertainty in the normalization reference. (B) Percentage of ZCTAs classified as specialist dental deserts, defined as having no dental specialist within 15 miles, by ADI quartile; labels show the percentage of ZCTAs and the number of affected residents. In total, 24.3 million U.S. residents lived in specialist dental deserts.

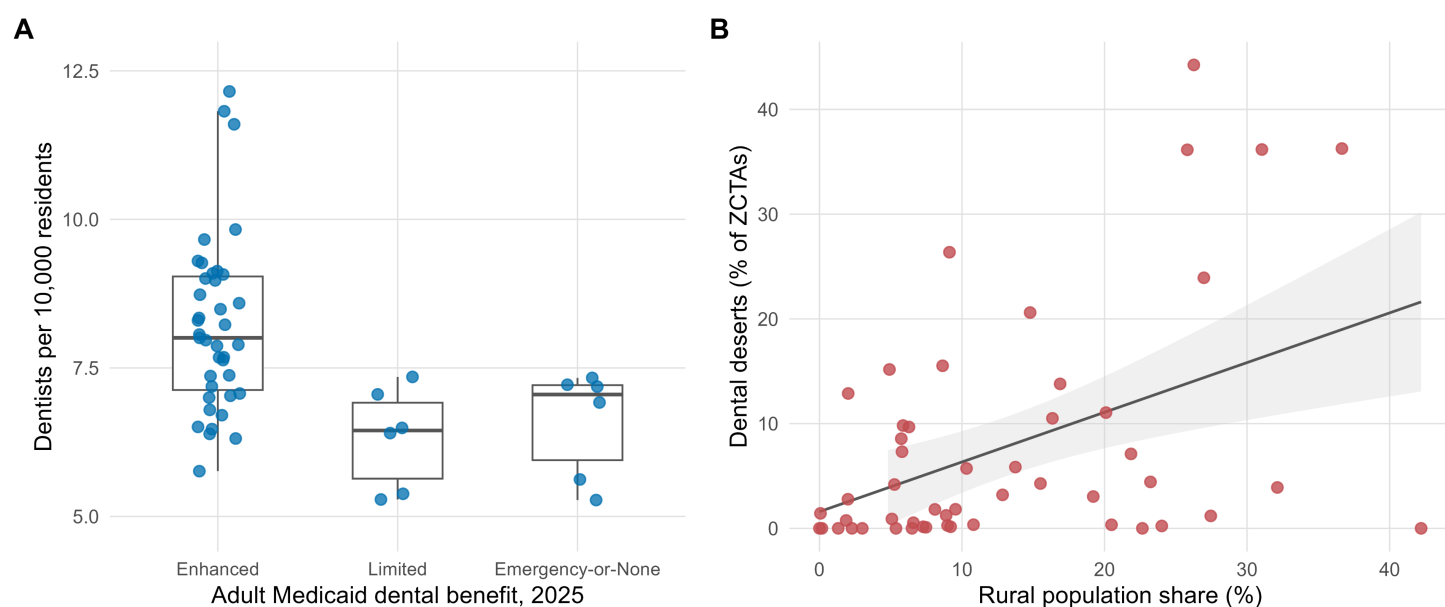


Figure 4

State Medicaid policy, rural composition, and dental workforce supply.

Dentists per 10,000 residents by state adult Medicaid dental benefit level, 2025; each point is a state and boxes show medians and interquartile ranges (IQR). (B) Percentage of ZCTAs classified as dental deserts (no dental provider within 15 miles) by the share of each state's population living in rural or small-town areas. Associations are exploratory and cannot establish direction; dentist participation in Medicaid/CHIP and Medicaid reimbursement relative to private insurance were not associated with either outcome.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryMaterial.docx](#)