Adolescents and oral health service utilization in Canterbury, New Zealand: A geospatial cross-sectional study.

LEE, Joanne Jia Min <http://orcid.org/0000-0001-6886-9245>, SCHLUTER, Philip J <http://orcid.org/0000-0001-6799-6779>, HODGETT, Matthew, DENG, Bingyu <http://orcid.org/0000-0002-0847-2622> and HOBBS, Matthew <http://orcid.org/0000-0001-8398-7485>

Received: 8 August 2022 | Revised: 24 December 2022 | Accepted: 20 March 2023

DOI: 10.1111/cdoe.12858

ORIGINAL ARTICLE

Community Dentistry and Oral Epidemiology WILEY

Adolescents and oral health service utilization in Canterbury, New Zealand: A geospatial cross-sectional study

Joanne Jia Min Lee[1,2,3] | Philip J. Schluter[3,4,5] | Matthew Hodgett[6] | Bingyu Deng[2,3] | Matthew Hobbs[2,3,7]

[1]Sydenham Dental Centre and Essential Dental, Christchurch, Canterbury, New Zealand

[2]GeoHealth Laboratory, Geospatial Research Institute, Te Whare Wānanga o Waitaha, University of Canterbury, Christchurch, Canterbury, New Zealand

[3]Te Kaupeka Oranga, Faculty of Health, Te Whare Wānanga o Waitaha, University of Canterbury, Christchurch, Canterbury, New Zealand

[4]Te Kāhui Pā Harakeke, Child Well-being Research Institute, Te Whare Wānanga o Waitaha, University of Canterbury, Christchurch, Canterbury, New Zealand

[5]School of Clinical Medicine, Primary Care Clinical Unit, The University of Queensland, Brisbane, Queensland, Australia

[6]Tatauranga Aotearoa | Statistics New Zealand, Christchurch, Canterbury, New Zealand

[7]The Cluster for Community and Urban Resilience (CURe), University of Canterbury, Christchurch, Canterbury, New Zealand

Correspondence
Joanne Jia Min Lee, Faculty of Health and GeoHealth Laboratory, Geospatial Research Institute, University of Canterbury, Christchurch, Canterbury, New Zealand.
Email: joanne.lee@pg.canterbury.ac.nz

Abstract

Objective: Non-utilization of dental care during adolescence can result in poorer oral health and subsequently higher expenditures on dental services. This study examined the geospatial and epidemiological factors associated with utilization of the publicly funded Adolescent Oral Health Services (AOHS) in Canterbury, Aotearoa New Zealand (NZ).

Methods: A secondary analysis of prospectively collected routine data from AOHS visits of adolescents in school Year 9 (13–14 years) for the financial year 2019–2020. Geographic information systems examined distance from home to dental practices. Multilevel mixed-effects Poisson regression models investigated associations between geospatial, demographic and clinical factors and non-utilization of dental services. Models were adjusted for sex, ethnicity, area-level deprivation, rural/urban classification, previous caries experience and the distance from home address to dental practice referred.

Results: Dental practices were concentrated in large urban areas and in the least deprived neighbourhoods, with several service area gaps identified. Rural areas and the most deprived areas of Christchurch City had the highest non-utilization rates. After adjustment, adolescents residing in the most deprived areas had a higher risk of non-utilization (adjusted risk ratio [aRR] = 1.38; 95% CI 1.26–1.51) compared to adolescents in the least deprived areas. Adolescents in remote areas also had an increased risk of non-utilization (aRR = 1.36; 95% CI 1.20–1.54) compared to adolescents in urban core areas. Finally, Māori (aRR = 1.37; 95% CI 1.29–1.46) and Pasifika (aRR = 1.46; 95% CI 1.35–1.59) adolescents had significantly higher risks of non-utilization compared to their NZ European counterparts.

Conclusion: Inequitable utilization of dental services exists among adolescents in Canterbury, NZ, and is associated with Māori, Pasifika and those living in rural and most deprived areas. Adolescents at the greatest oral health risk are geographically underserved by current oral health services. The current health system should also explore the possibility of partnering with Māori and Pasifika communities to provide services within culturally appropriate settings.

KEYWORDS
access to dental care, adolescent, dental care utilization, geographic information systems, health service mapping, New Zealand, oral health

1 | INTRODUCTION

Despite being largely preventable, oral diseases are estimated to affect 3.5 billion people globally with serious health and economic burdens for those affected.[1] The prevalence of untreated dental caries in permanent dentition worldwide is highest among those aged 15–19 years.[1] Poorer oral health during adolescence (defined as people aged between 13 and 17 years) can result in a higher disease burden during adulthood[2] and higher expenditures on dental services.[3] In high-income countries, the prevalence of dental caries in children and adolescents has generally reduced in the last 40 years.[1] However, geographic inequality of dental services and socioeconomic inequities have restricted access to dental care for particular population groups, resulting in the cumulative burden of oral diseases carried into adulthood.[1,4] Recent evidence suggests that the imbalanced distribution of dentists in market-driven private practices has caused a profound impact on dental service utilization worldwide, with unmet needs in remote, rural and lower socioeconomic areas.[4]

In Aotearoa New Zealand (NZ), adolescents are less likely to utilize dental care compared to younger children despite the availability of publicly funded dental services since 1921.[5,6] Children from birth to school Year 8 (age 12–13 years) currently receive free routine dental care in community-based clinics.[5] In school Year 9 (age 13–14 years), adolescents are transferred on to Adolescent Oral Health Services (AOHS) and continue to receive routine care until their 18th birthday from dental providers contracted by local District Health Boards (DHBs).[5] Although public expenditure on dental services is substantial, costing NZ$140.59 million in the year 2017/2018,[7] changes in oral health outcomes for children and adolescents are modest.[7] A lack of early disease management significantly contributes towards preventable hospital admissions,[3] costing the health system NZ$49.68 million in hospital dental services in 2017/2018.[7] Māori (NZ's indigenous people) and Pasifika children and adolescents experience nearly double the rates of oral diseases compared to their non-Māori/non-Pasifika counterparts.[5]

Barriers to dental care utilization among NZ adolescents have been identified at the individual, family and community level, with most evidence qualitative or anecdotal in nature.[8–10] Specifically, a lack of oral health literacy, incorrect perceptions of costs associated with dental care, and parents' oral health beliefs, behaviours and values have been cited as potential barriers.[8–11] The transition from structured appointments on school grounds to adolescents having to arrange their own appointments in private practices also resulted in adolescents reporting increased difficulty in attending appointments.[8,10,11] Transportation was a significant hurdle associated with deprived families.[8,10] Literature has also detailed the pervasiveness of ethnic discrimination and the lack of culturally safe environments within the health system,[12] which is associated with reduced quality of care and poorer health outcomes experienced by Māori, Pasifika and ethnic minority groups.[8,12,13] Similar to other countries,[4] NZ has an uneven distribution of dental practices, where dental care is mostly concentrated in urban areas of higher socioeconomic status.[14] Moreover, the lowest dental practice/adult population ratios were found in areas with the highest population density of Māori and Pasifika people.[14]

Canterbury is one of the 16 regions in NZ. At the time of the study, its healthcare provision was covered by Canterbury DHB, which was the second largest DHB in terms of population and area (roughly 594 320 residents or 12% of NZ's population) with the fastest-growing Māori population in NZ.[15] In Canterbury, utilization rates among adolescents have been consistently lower than the national average, remaining relatively stagnant at around 66.8% from the year 2001 to 2011.[6] There is a dearth of contemporary, locally-specific and robust quantitative evidence for this age group to inform policy changes at a regional level. Furthermore, the broader evidence base across NZ is limited by a lack of up-to-date, information-rich datasets and a standardized methodology. This study is the first to use both geospatial and epidemiological methods to identify factors associated with non-utilization for adolescents at the regional level. The aims were to: (1) visually explore the distribution of dental practices providing AOHS in Canterbury by area-level deprivation, rural/urban classification and geospatial access to services; (2) geospatially map non-utilization rates across Canterbury; and (3) measure the extent of association between non-utilization and sociodemographic and other variables. This knowledge will facilitate more nuanced oral health policies and provide guidance on developing locally-specific strategies in engaging adolescents.

2 | METHODS

2.1 | Study design

This is a retrospective geospatial cross-sectional study using prospectively collected routine data for adolescents in school Year 9 for the financial year 2019–2020.

2.2 | Participants and setting

Adolescents who received dental care through Community Dental Services (CDS) within the Canterbury DHB (CDHB) region in school Year 8 over 2018 and eligible for enrolment in AOHS[16] in school Year 9 over 2019–2020. Those residing in Chatham Islands and South Canterbury were excluded due to differences in service provision, population demographics and geographical remoteness, and separate jurisdictional management, respectively (see Figure 1).

2.3 | Primary measures

Dental records were retrieved from two primary sources: Titanium and Proclaim. Titanium is an electronic software used by CDS in delivering dental services for children up to school Year 8 (https://www.montage.co.nz/customers/canterbury-district-health-board). Proclaim is an administrative software used to process data for AOHS from school Year 9 up to their 18th birthday (https://nsfl.health.govt.nz/accountability/performance-and-monitoring/performance-measures/final-draft-performance-measures). By deterministically matching each participant's National Health Index (NHI) number (a unique code allocated to residents who have interacted with NZ health services [https://www.health.govt.nz/our-work/health-identity/national-health-index]), Titanium data at school Year 8 over 2018 were joined to corresponding Proclaim data at school Year 9 over 2019–2020. The primary dataset was de-identified and anonymized by CDHB prior to its release.

Dental service utilization at school Year 9 was determined by whether or not dental treatment was claimed by their dental provider through Proclaim, and categorized as: utilized and completed dental care, partially utilized dental care and did not utilize dental care. Due to small numbers associated with partially utilized dental care (n = 141, 1.1%), it was combined with adolescents who did not utilize dental care, forming a dichotomous variable.

2.4 | Sociodemographic and clinical variables

Sex (male, female), ethnicity and previous dental caries experience were derived from the primary dataset. Ethnicity was based on parental/caregiver report at the child's birth, which allows for multiple identifications. Based on the Ministry of Health's ethnicity protocols, children with multiple identifications were assigned a single ethnicity via a prioritization hierarchy.[17] Final categories used were

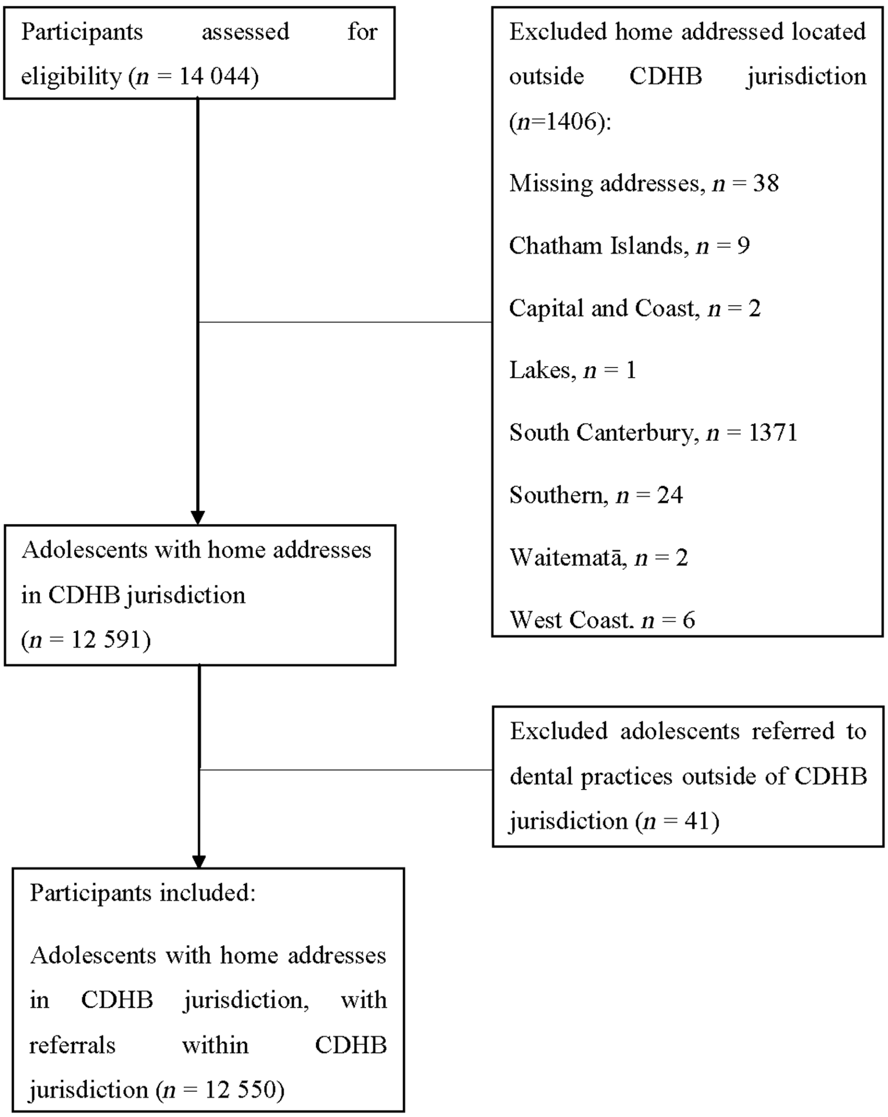

FIGURE 1 Participant flow diagram.

Māori, Pasifika, Asian, NZ European and Other. Missing, undisclosed and unidentifiable ethnic data were categorized as Unknown.

Each adolescent's previous caries experience was measured based on clinical records at school Year 8 using the decayed, missing and filled teeth (DMFT) index.[18] The 12-year-old indicator age group, as defined by World Health Organization,[18] was used as this is the closest age group to the study participants. DMFT scores were classified as: very low (0–1.1), low (1.2–2.6), moderate (2.7–4.4), severe (4.5–6.5) and very severe (6.6 or higher).[18]

2.5 | Geospatial variables

Data on geographical attributes were retrieved from national-level datasets and open-access sources. The NZ road network layer was sourced from the GeoHealth Laboratory website.[19] Geographic boundary datasets as defined by territorial authorities and regional councils were downloaded from the Statistics NZ website for area units of DHBs, functional urban area (FUA), wards, Statistical Area 2 (SA2), Statistical Area 1 (SA1) and 2018 Meshblocks.[20] The 2018 New Zealand Deprivation Index (NZDep2018),[21] used as a basis of measure of socioeconomic disadvantage, was aggregated to the meshblock level, the smallest geographical unit for which statistical data is collected. All data were downloaded in October 2021 and geocoded to each adolescent's home address using QGIS software (Open Source Geospatial Foundation Project). All adolescents' home addresses were geocoded and only the longitude and latitude of each address were stored.

2.5.1 | Area-level deprivation

NZDep2018[21] provides an area-based measure of disadvantage by integrating seven domains of deprivation: employment, income, crime, housing, health, education and access to services.[22] An ordinal scale was used, ranging from one (least deprived) to five (most deprived) in quintiles. This was converted to a sample-specific deprivation index to compare deprivation quintiles between study participants rather than the whole of NZ, as Canterbury has less overall variation in area-level deprivation scores.[22]

2.5.2 | Rural/urban classification

A modified functional urban area indicator (IFUA)[23] was used. Urban and rural spaces were classified according to its number of residents and commuting patterns.[23] Urban cores are defined as urban areas with more than 5000 residents; secondary urban cores are urban areas where at least 40% of workers commute to the urban core; satellite urban areas are small urban areas where at least 40% of workers commute to the urban core/secondary urban core; and hinterlands are rural settlements where at least 40% of workers commute to urban spaces.[23] For visual clarity, secondary urban core and satellite urban areas were combined as urban (other), while land area outside functional urban area was labelled remote.

2.5.3 | Dental practice locations

Addresses of dental practices providing AOHS were obtained from the CDHB website (https://www.cdhb.health.nz/health-services/community-dental-service). These were cross-checked with dental practices that adolescents were referred to at school Year 8 and/or attended at school Year 9. The longitude and latitude of each address were obtained through Google Maps.

2.6 | Geospatial methods

QGIS was used for spatial analyses. Data were visualized at the geographic scale of wards, which are large geographic boundaries originally set up within Territorial Authorities with a population of at least 20000 people for electoral purposes.[20]

2.6.1 | Network analysis

Two distances were calculated for each adolescent using the R package stplanr[24]: from their home address to the dental practice they were referred to at school Year 8, and from their home address to the dental practice they actually attended at school Year 9. This was done by calculating the shortest paths along the road network[19] between the nodes closest to the home address and the dental practice, which provided the distance in meters, respectively, for each path.

2.6.2 | Geospatial access to dental care

The distribution of dental practices was mapped in relation to[1]: area-level deprivation by categorizing all meshblock areas to their associated NZDep2018 quintile,[2] rural/urban classification using a modified IFUA[23] and[3] service area accessibility using the isochrones function by OpenRouteService (ORS) Tools (http://openrouteservice.org).

2.6.3 | Non-utilization rates across Canterbury

The percentages of non-utilization of dental care in each ward was calculated and classed by equal counts to display wards with higher concentrations of non-utilization.

2.7 | Statistical methods

Statistical analyses were conducted using Stata SE version 17.0 (StataCorp, College Station), using robust variance estimators, and a two-tailed $\alpha = .05$ defined significance. Reporting of the study findings were informed by the spatial lifecourse standards outlined in the ISLE-ReST statement[25] and REporting of studies Conducted using Observational Routinely-collected Data (RECORD).[26]

Recognizing that conventionally employed logistic regression models produce odds ratios with inflated estimates of relative risks (RRs) when the outcome of interest is not rare,[27] an alternative approach was taken. A modified Poisson regression models with log-link function and robust variance estimators were used to estimate risk factors' RRs directly.[28,29] Complete case multilevel mixed-effects models were employed, treating SA2 as random intercept effects and adolescents nested within SA2 clusters, to investigate the association between dental service utilization and key variables. For the crude analysis, only the primary variables were investigated. Adjusted analyses were controlled for sociodemographic, clinical and area-level variables. In the spirit of Sun and colleagues,[30] no variable selection was made within these adjusted analyses.

Regression diagnostics was assessed using the modified Lemeshow-Hosmer goodness-of-fit statistic, and predictive capability assessed via the area under the curve (AUC) estimate.[31] AUC of 0.5 represents a model with predictive ability that is no better than chance, 0.7–0.8 is considered acceptable, 0.8–0.9 is considered excellent and more than 0.9 is considered outstanding.[31]

2.8 | Ethics

Ethical approval was obtained from the CDHB Research Office and Te Komiti Whakarite. The study was developed in consultation with CDHB and Ngāi Tahu Consultation and Engagement Group.

3 | RESULTS

3.1 | Participant flow

A total of 14 044 patient records were supplied, of whom 12 550 adolescents (89.4%) were eligible for analysis (Figure 1).

3.2 | Descriptive analysis

Table 1 describes the participants' characteristics.

Using prioritized ethnic categorization, 9.2% of adolescents were Māori, 3.9% were Pasifika, 9.0% were Asian and 70.1% were NZ European. There was an underrepresentation in this sample distribution compared to the population distribution for children aged 10–14 in 2018 population estimates within the CDHB region, where 10.5% were Māori, 4.1% were Pasifika and 15.9% were Asian.[32]

Similar to the population distribution for children aged 10–14 years in 2018 in Canterbury,[33] there were slightly more male (51.6%) than female (48.4%) adolescents in the study. Most adolescents (34.8%) resided in least deprived areas (Q1). The majority also lived in main urban (64.3%) and secondary urban (16.2%) areas. Consistent with this age group,[2] the previous caries experience of most adolescents (85.9%) was very low (DMFT = 0–1.1).

TABLE 1 Descriptive statistics of study participants (n = 12 550).

Variables	*n*	(%)
Ethnicity		
NZ European	8791	(70.1)
Māori	1155	(9.2)
Pasifika	490	(3.9)
Asian	1123	(9.0)
Other Ethnicity	231	(1.8)
Unknown	760	(6.1)
Sex[a]		
Male	6471	(51.6)
Female	6072	(48.4)
Area-level deprivation (quintiles)[b]		
Q1 (least deprived)	2583	(20.6)
Q2	2471	(19.7)
Q3	2530	(20.2)
Q4	2487	(19.8)
Q5 (most deprived)	2478	(19.8)
Rural/urban classification[c]		
Urban core	8069	(64.3)
Urban (other)	2036	(16.2)
Hinterland	1252	(10.0)
Remote	1193	(9.5)
Previous caries experience at school Year 8 (DMFT[d])		
Very low (0–1.1)	10 777	(85.9)
Low (1.2–2.6)	499	(4.0)
Moderate (2.7–4.4)	318	(2.5)
Severe (4.5–6.5)	63	(0.5)
Very severe (>6.6)	46	(0.4)
Unknown	847	(6.8)
Utilization of dental care at Year 9		
Non-utilization[e]	5177	(41.2)
Accessed and completed dental care	7373	(58.8)

[a]Missing data for seven participants (0.06%).
[b]Home address of 1 participant had no associated area-level deprivation (NZDep2018).
[c]Based on a modified Functional Urban Area Indicator (IFUA),[24] where secondary urban core and satellite urban areas were combined as Urban (other), while land area outside functional urban area was labelled Remote.
[d]Decayed, missing and filled teeth.
[e]Adolescents who did not access dental care (n = 5036, 40.13%) and adolescents who only partially utilized dental care (n = 141, 1.12%) were combined under non-utilization.

Overall, from the 12 550 adolescents analysed in this study, 7373 (58.8%) utilized and completed dental care at school Year 9, while 5036 (40.1%) did not utilize dental care, and 141 (1.1%) partially utilized dental care.

3.3 | Geospatial analysis

3.3.1 | Geospatial access to dental care

Distribution of dental practices by area-level deprivation

Figure 2 shows the location of 96 dental practices providing AOHS across the greater Christchurch area by area-level deprivation. There was an uneven spread of dental practices across Christchurch City, with a general concentration in the least deprived areas. The majority were located in Central ($n=17$), Riccarton ($n=9$), Fendalton ($n=8$) and Papanui ($n=8$) wards. Wards with the most deprivation (Q5) were Linwood (55.8%), Burwood (41.3%) and Central (28.1%) (Table S1). Only seven dental practices serviced the three wards located in eastern Christchurch. In contrast, 10 dental practices serviced Cashmere and Fendalton, the two least deprived wards (Q1) within Christchurch City.

Distribution of dental practices by rural/urban classification

Dental practices were highly concentrated in urban areas and sparse in rural areas (Figure 3). Of the 96 dental practices mapped, 77 were located within urban core areas, 13 in urban (other), 2 in hinterland and 4 in remote (Table S2). There was a centralized clustering of dental practices in Christchurch City. There were none servicing West, East, South, Ellesmere and Eastern wards, all of which were hinterland and/or remote areas.

Service area of dental practices by walking/driving

Within Christchurch City, large overlaps of services within 500 m of walking distance were pronounced in wards with higher numbers of dental practices (Central, Riccarton and Fendalton wards) (Figure S1A). The easternmost wards had no service area overlaps within 500 m, and large portions of geographical areas in the outskirts of the city were outside of the 2 km walking range.

While the service areas within 2.5 km of driving distance covered most roads across Christchurch City, the overlap of services were concentrated centrally (Figure S1B). Service gaps of more than 2.5 km by car in the city were identified in pockets of geographical areas within Halswell, Burwood and Linwood wards, indicating lower accessibility for communities in these regions.

Non-utilization rates of AOHS across the Canterbury region

The highest non-utilization rates of 50.1%–58.8% were seen in rural wards (Malvern, Western, Ashburton, Eastern, Area Outside Ward) and in three wards in the greater Christchurch City (Hornby, Central and Linwood) (Figure S2).

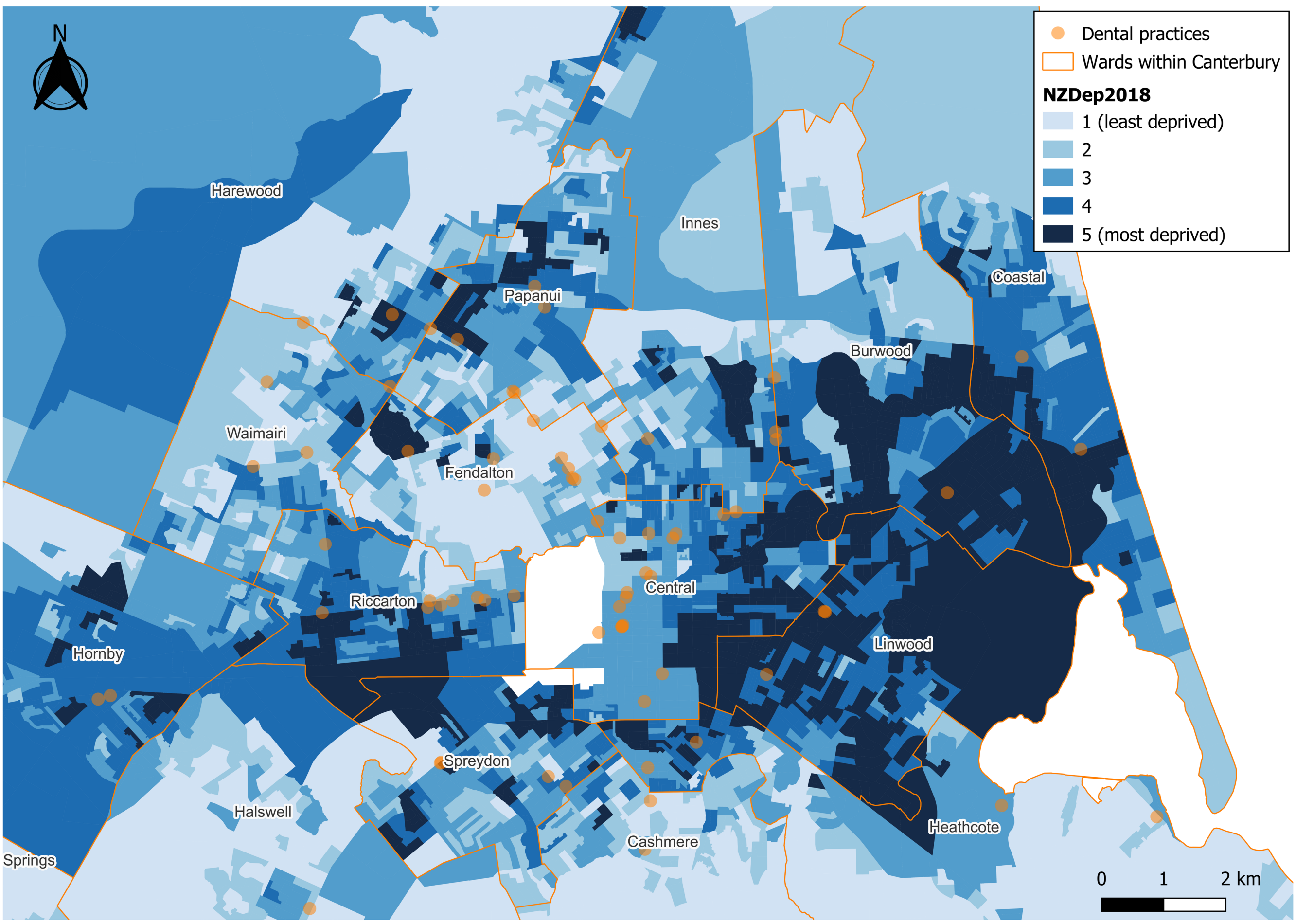

FIGURE 2 Distribution of AOHS dental practices across the greater Christchurch area and area-level deprivation.

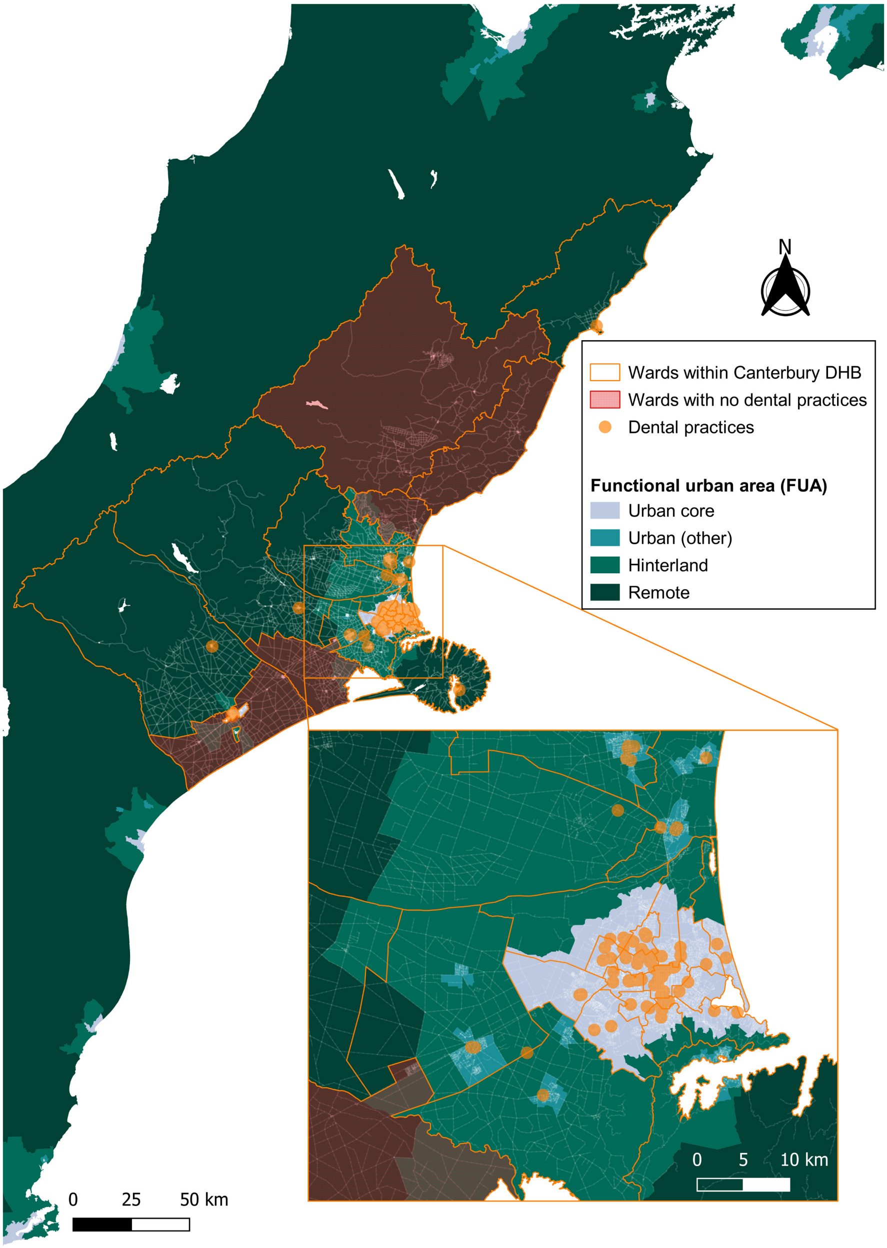

FIGURE 3 Distribution of dental practices providing AOHS by rural/urban classification in Canterbury.

3.4 | Statistical analysis

3.4.1 | Crude analyses

Table 2 presents the association between sociodemographic, clinical and area-level factors and the distribution of non-utilization of dental care at school Year 9 derived from multilevel mixed-effects modified Poisson regression models. There were 258 SA2s in the dataset, with an average of 48.6 adolescents in each (range: 1–162 adolescents).

Briefly, crude models showed that identifying as Māori, Pasifika and Unknown ethnicities, living in areas of mid (Q3), higher (Q4) and highest (Q5) deprivation levels, living in a remote area, and having low, moderate and unknown DMFT scores were associated with significantly higher risks of non-utilization (all $p<.05$). There was no association for sex and the distance from adolescents' home addresses to dental practices they were referred to.

3.4.2 | Adjusted analyses

In the fully adjusted models, the association between ethnicity, area-level deprivation, rural/urban classification and previous caries experience with non-utilization of dental care remained significant (all $p<.05$); see Table 2. Complete data for all variables were available from 12 361 (98.5%) adolescents.

Findings showed that Māori and Pasifika had significantly higher adjusted risks of non-utilization at 1.37 (95% CI: 1.29–1.46) and 1.46 (95% CI: 1.35–1.59) compared to NZ Europeans. In addition, increasing area-level deprivation was associated with increasing

TABLE 2 Distribution of non-utilization of dental care at school Year 9 by categories, together with relative risks (RRs) and associated 95% confidence intervals (CIs) estimates from crude and adjusted complete case multilevel logistic models.

	Total	Non-utilization	Crude	Adjusted[a]
	N	*n* (%)	RR (95% CI)	RR (95% CI)
Sex[b]				
Male	6471	2687 (41.5)	1 (reference)	1 (reference)
Female	6072	2486 (40.9)	0.98 (0.94, 1.02)	0.98 (0.94, 1.02)
Ethnicity				
NZ European	8791	3326 (37.8)	1 (reference)	1 (reference)
Māori	1155	654 (56.6)	1.44 (1.35, 1.53)	1.37 (1.29, 1.46)
Pasifika	490	309 (63.1)	1.57 (1.46, 1.69)	1.46 (1.35, 1.59)
Asian	1123	458 (40.8)	1.08 (0.99, 1.18)	0.99 (0.90, 1.08)
Other Ethnicity	231	92 (39.8)	1.06 (0.89, 1.26)	0.98 (0.82, 1.16)
Unknown	760	338 (44.5)	1.17 (1.08, 1.26)	1.12 (1.03, 1.21)
Area-level deprivation[c]				
Least (Q1)	2583	888 (34.4)	1 (reference)	1 (reference)
Lower	2471	880 (35.6)	1.04 (0.95, 1.14)	1.02 (0.94, 1.11)
Mid	2530	1045 (41.3)	1.20 (1.10, 1.31)	1.14 (1.05, 1.24)
Higher	2487	1089 (43.8)	1.26 (1.14, 1.39)	1.22 (1.11, 1.33)
Most (Q5)	2478	1274 (51.4)	1.45 (1.33, 1.59)	1.38 (1.26, 1.51)
Rural/urban classification[d]				
Urban core	8069	3258 (40.4)	1 (reference)	1 (reference)
Urban (other)	2036	813 (39.9)	1.02 (0.93, 1.12)	1.12 (1.03, 1.22)
Hinterland	1252	508 (40.6)	1.02 (0.91, 1.13)	1.22 (1.09, 1.36)
Remote	1193	598 (50.1)	1.23 (1.12, 1.37)	1.36 (1.20, 1.54)
Previous caries experience (DMFT[e])				
Very low	10777	4232 (39.3)	1 (reference)	1 (reference)
Low	499	232 (46.5)	1.15 (1.04, 1.26)	1.10 (1.00, 1.21)
Moderate	318	162 (50.9)	1.24 (1.10, 1.39)	1.17 (1.05, 1.32)
Severe	63	33 (52.4)	1.23 (0.99, 1.53)	1.14 (0.91, 1.43)
Very severe	46	23 (50.0)	1.17 (0.89, 1.54)	1.02 (0.77, 1.34)
Unknown	847	495 (58.4)	1.47 (1.38, 1.58)	1.42 (1.32, 1.52)
Distance from home address to dental practice referred				
<1379 m	2474	1057 (42.7)	1 (reference)	1 (reference)
1379–2399 m	2476	1015 (41.0)	0.95 (0.87, 1.03)	0.98 (0.90, 1.06)
2400–4356 m	2471	978 (39.6)	0.92 (0.83, 1.01)	0.98 (0.89, 1.07)
4357–10680 m	2474	946 (38.2)	0.91 (0.83, 0.99)	0.96 (0.88, 1.04)
>10680 m	2473	1068 (43.2)	1.00 (0.91, 1.09)	0.95 (0.85, 1.06)

[a]Adjusted for sex, ethnicity, area-level deprivation, functional urban area, previous caries experience, distance from home address to dental practice referred.

[b]Missing data for seven (0.06%) participants.

[c]Missing data for one (0.01%) participant.

[d]Based on a modified Functional Urban Area Indicator (IFUA),[24] where secondary urban core and satellite urban areas were combined as Urban (other), while land area outside functional urban area was labelled Remote.

[e]Decayed, missing and filled teeth.

non-utilization rates, with those in the most deprived areas having an estimated adjusted risk ratio (aRR) of 1.38 (95% CI: 1.26–1.51) compared to adolescents living in the least deprived areas. Similarly, increasing rurality was associated with increasing non-utilization rates, with those residing in remote areas having an increased aRR of 1.36 (95% CI: 1.20–1.54) compared to those living in urban core areas.

Adolescents with moderate DMFT scores had higher adjusted risk of non-utilization (1.17; 95% CI: 1.05–1.32) compared to adolescents with very low DMFT scores. There were non-significant associations between severe and very severe DMFT scores with non-utilization, with measured effect sizes of 1.14 (95% CI: 0.91–1.43) and 1.02 (95% CI: 0.77–1.34), respectively.

In terms of regression diagnosis, there is no evidence for a lack of fit (modified Lemeshow-Hosmer goodness-of-fit statistic, $p=.06$).[31] However, the estimated AUC=0.634 (95% CI: 0.626–0.645) which represents inadequate predictive ability and suggests other important unmeasured factors exist. The variance component associated with the SA random effect in this model was estimated at $\sigma=.202$ (95% CI: 0.168–0.241).

4 | DISCUSSION

This study aimed to empirically quantify factors associated with low utilization rates of publicly funded dental care among adolescents in Canterbury through geospatial and statistical methods. The results show a clustering of dental practices in urban areas and in the least deprived neighbourhoods with several service area gaps. Overall, area-level deprivation, living in rural areas and ethnicity were significantly associated with non-utilization of AOHS. Specifically, Māori and Pasifika adolescents were 37% and 46% significantly less likely to utilize care than NZ European, respectively. Adolescents living in the most deprived areas were 38% less likely to utilize services than those living in the least deprived areas, and adolescents living furthest away in remote areas were 36% less likely to utilize services than those living in urban areas.

Findings support prior literature suggesting there is a geographical inequity of dental services in NZ and worldwide.[4,14] While AOHS is publicly funded in NZ, this service is nonetheless delivered by contracted dental providers generally working in private practices. It is therefore unsurprising that the distribution of dental providers mirrors that of countries adopting a fee-for-service model, where dentists are located in areas where populations have a higher purchasing power.[4] This gives further support to prior literature suggesting that transportation issues and/or the limited number of dental providers in the area may be the reasons behind lower utilization rates in rural and more deprived areas.[14] The study also provides robust evidence of ethnic inequity associated with utilization of dental services for Māori and Pasifika adolescents in Canterbury. Although ethnicity was a key variable used, it is strongly emphasized that the patterns observed here are likely predominantly due to social determinants of health inequities between adolescents rather than intrinsic cultural/ethnic differences. While Māori and Pasifika adolescents are more likely to experience dental caries and lower service utilization, these are influenced by social, economic and environmental factors, together with barriers to healthcare.[12,13] For many Māori people, ethnic discrimination and the lack of culturally safe dental environments have affected their willingness to engage with dental services.[8,13] Pasifika adolescents have also previously identified barriers to seeking routine care, such as negative perceptions of dentists, uncomfortable and unsupportive dental environments, and the lessened cultural emphasis on individual health.[10,11] Therefore, these deeply-rooted historical, cultural and systemic issues, coupled with socio-economic pressures that afflict many families, result in avoidance and even distrust in dental services among Māori and Pasifika.

It has been noted in literature that greater dental caries experience in childhood lead to higher trajectories of dental caries in adulthood.[2] An association between increasing DMFT scores with decreasing utilization rates was not found in this study; rather, only adolescents with 'moderate' and unknown DMFT scores utilized dental care at lower rates than those with 'very low' scores. However, a relatively small proportion of adolescents had 'severe' ($n=63$) or 'very severe' ($n=46$) scores. It is notable that 6.8% of adolescents had no DMFT scores recorded. These adolescents may have had higher disease severity. Such severe dental profiles are likely to result in seeking emergency treatment outside of routine care,[3] prompting negative dental experiences and further patterns of non-attendance.[8,9,11] However, data on each tooth surface was unavailable for analysis. It is thus difficult to affirm if children with higher caries experience were more likely to forego dental care in adolescence.

The main strengths of the study are its novelty in combining geospatial and epidemiological methods and using an information-rich, contemporary and precise dataset with a large sample. The use of GIS in pinpointing service area gaps and areas with low utilization rates can be replicated across the country to identify underserved areas in each region.

Some shortcomings on the methodology should be considered. First, the dental history of adolescents who received dental care outside of Canterbury prior to Year 9 was not accessible. By deterministically matching data from Proclaim to Titanium, this excluded an estimated 140 adolescents new to CDHB jurisdiction in Year 9, thus the utilization rates we found differ slightly from national findings.[6] Second, as this study used cross-sectional data of one specific cohort, it is limited in its ability to make causal inference and findings may not be generalizable to adolescents at different ages or in different settings. There is an underrepresentation of Asians in this sample, reflecting previously reported low attendance patterns where only 62.6% of Asians in Canterbury aged 0–14 visited a dental provider in the past 12 months over 2017–2020.[34] Asians, particularly recent migrants, are less likely than non-Asians to interact with health services.[35] Third, in measuring distances between home addresses and dental practices, there is a small degree of inaccuracy due to the limitation of the R package, where the lengths of the actual distance and the distance between nodes vary up to approximately 250 m on the road network. Lastly, the COVID-19 pandemic may have impacted on service utilization from 25 March 2020.[36] Routine non-urgent appointments were discouraged during lockdown, which may have affected a small proportion of the sample.

The AUC estimates from the adjusted models suggest that other confounding variables have not been measured or captured within this dataset. Unmeasured confounding variables can result in substantial bias in estimated exposure-outcome relationships, particularly if they are uncorrelated with the measured explanatory variables.[37] The dataset was limited by the variables routinely collected clinically. Previous research has detailed other variables that influence utilization which are difficult to capture quantitatively, such as previous negative dental experiences, perceptions of costs, cultural values and oral health beliefs and behaviours.[8–11] A limitation in this study was not knowing where adolescents attended school at Year 9, as a possibility of dental clinic selection is in its proximity to their school location rather than home address. Examining the interaction between dental care utilization and distance from school to dental practices will be an important direction for future research to determine if proximity to schools is associated with higher utilization rates.

This research suggests that there is a pressing need for improved access for adolescents living in rural and deprived areas, and to increase utilization rates for adolescents of Māori and Pasifika descent. While recognizing their potential limitations, it has been argued that evidence from non-randomized population-based associative studies may provide the best available measure of a public health strategy's impact.[38] On this basis, these results suggest that an oral health workforce targeting the service gaps identified should be recruited. As dental providers are likely to continue selecting locations from a business perspective,[4] equitable utilization of services will not be achieved without interventions by the state. This was demonstrated in Australia where policies in service delivery and recruitment were developed to meet the dental needs of underserved rural populations.[39] Introducing dental appointments for adolescents in school-based settings or mobile units in deprived/rural areas may also remove logistic barriers restricting access to care.[8,11] A culturally appropriate oral health care system is also needed at multiple levels to assist in behavioural and systemic changes. Future strategies might also partner with Māori and Pasifika to provide dental services within a culturally sensitive context that involves increasing oral health literacy of both the adolescent and their families. With maraes and churches being a central point for Māori and Pasifika communities, these localities offer unique cultural hubs that have proved successful in previous health initiatives.[8,40]

5 | CONCLUSION

Despite the availability of free dental care in NZ, there is still inequitable utilization among adolescents in Canterbury. This study found that lower utilization rates were associated with Māori, Pasifika and those living in rural and most deprived areas. Policies targeting these groups need to be developed to improve non-utilization rates among adolescents. The current oral health system should explore the possibility of providing services in culturally appropriate settings and placing adequate workforce in underserved areas.

ACKNOWLEDGEMENTS

We gratefully thank Dr Martin Lee, Canterbury District Health Board, for the conceptualization of the research, Riana Clarke, Population Health and Prevention, Ministry of Health, for providing updated data, and the team at GeoHealth Laboratory, University of Canterbury, for their support. Open access publishing facilitated by University of Canterbury, as part of the Wiley - University of Canterbury agreement via the Council of Australian University Librarians.

DATA AVAILABILITY STATEMENT

Data subject to third party restrictions. The data that support the findings of this study are available from Canterbury District Health Board. Restrictions apply to the availability of these data, which were used under licence for this study. Data are available from the authors with the permission of Canterbury District Health Board.

ORCID

Joanne Jia Min Lee https://orcid.org/0000-0001-6886-9245
Philip J. Schluter https://orcid.org/0000-0001-6799-6779
Bingyu Deng https://orcid.org/0000-0002-0847-2622
Matthew Hobbs https://orcid.org/0000-0001-8398-7485

REFERENCES

1. Kassebaum NJ, Smith AGC, Bernabé E, et al. Global, regional, and national prevalence, incidence, and disability-adjusted life years for oral conditions for 195 countries, 1990-2015: a systematic analysis for the global burden of diseases, injuries, and risk factors. *J Dent Res*. 2017;96(4):380-387. doi:10.1177/0022034517693566
2. Broadbent JM, Foster Page LA, Thomson WM, Poulton R. Permanent dentition caries through the first half of life. *Br Dent J*. 2013;215(7):E12. doi:10.1038/sj.bdj.2013.991
3. Whyman RA, Mahoney EK, Stanley J. Admissions to New Zealand public hospitals for dental care: a 20 year review. 2012, Ministry of Health, 42, 234–244.
4. Gabriel M, Cayetano MH, Galante ML, Carrer FC, Dussault G, Araujo ME. A global overview of the geographical distribution of dentists: a scoping review. *JDR Clin Trans Res*. 2018;3(3):229-237. doi:10.1177/2380084418774316
5. Ministry of Health. Our Oral Health: Key Findings of the 2009 New Zealand Oral Health Survey, Ministry of Health. 2010.
6. Ministry of Health. Oral health data and stats. Ministry of Health NZ. Published 2011. Accessed June 21, 2022. https://www.health.govt.nz/nz-health-statistics/health-statistics-and-data-sets/oral-health-data-and-stats
7. Kanagaratnam S, Schluter P. A review of early childhood caries, risk factors and preventive strategies. *N Z Dent J*. 2019;115:132-150.
8. Robson B, Koopu P, Gilmour J, et al. Dissociation of haemoglobin Chesapeake into subunits. *Oranga Waha: Oral Health Research Priorities for Māori – Low Income Adults, Kaumātua and Māori with Disabilites*. Special Needs or Chronic Health Conditions; 2011. https://www.otago.ac.nz/wellington/departments/publichealth/research/erupomare/research/otago019586.html
9. Murray C, Densie IK, Morgan C. Dental attendance, perceptions of cost and self-care of school Year 12 and 13 students: a focus on Southland, New Zealand. *N Z Dent J*. 2015;111(4):133-141.
10. Smith L, Cameron C, Foster Page L, Waqawai A, Richards R. Pasifika adolescents' understandings and experiences of oral health care. *N Z Dent J*. 2018;114:10.
11. Kanagaratnam S, Schluter P. A review of dental caries in adolescents, risk factors and preventive strategies. *N Z Dent J*. 2021;117(1):5-13.
12. Hobbs M, Ahuriri-Driscoll A, Marek L, Campbell M, Tomintz M, Kingham S. Reducing health inequity for Māori people in New

Zealand. *The Lancet*. 2019;394(10209):1613-1614. doi:10.1016/S0140-6736(19)30044-3
13. Talamaivao N, Harris R, Cormack D, Paine SJ, King P. Racism and health in Aotearoa New Zealand: a systematic review of quantitative studies. *N Z Med J*. 2020;133(1521):16.
14. Kruger E, Whyman R, Tennant M. High-acuity GIS mapping of private practice dental services in New Zealand: does service match need? *Int Dent J*. 2012;62(2):95-99. doi:10.1111/j.1875-595X.2011.00096.x
15. Canterbury District Health Board. *About us*. Te Whatu Ora - Health New Zealand. Published 2021. Accessed September 23, 2021. https://www.cdhb.health.nz/about-us/
16. Te Whatu Ora – Health New Zealand. Eligibility checklists and decision trees. Te Whatu Ora. Published September 12, 2022. Accessed December 18, 2022. https://www.tewhatuora.govt.nz/our-health-system/eligibility-for-publicly-funded-health-services/new-content-page-2/eligibility-checklists-and-decision-trees/
17. Ministry of Health. Ethnicity data protocols for the health and disability sector. Ministry of Health. 2004. Accessed June 13, 2022. https://www.fmhs.auckland.ac.nz/assets/fmhs/faculty/tkhm/tumuaki/docs/ethnicity-data-protocols.pdf
18. Petersen PE, Baez RJ, World Health Organization. Oral Health Surveys: Basic Methods. 5th ed. World Health Organization. 2013. Accessed November 24, 2022. https://apps.who.int/iris/handle/10665/97035
19. Beere PC. Creating a road network analysis layer with travel time estimates using open-source data. Published Online 2016. http://www.geohealth.canterbury.ac.nz/working/beere2016.pdf
20. Statistics New Zealand. Stats NZ geographic data service. Stats NZ geographic data service. Published 2021. Accessed October 2, 2021. https://datafinder.stats.govt.nz/
21. Atkinson J, Salmond C, Crampton P. NZDep2018 Index of Deprivation. *University of Otago*. Published Online 2019:65. https://www.otago.ac.nz/wellington/otago823833.pdf
22. Yong R, Browne M, Zhao J, et al. *Profiling New Zealand's 20 District Health Boards Using the New Zealand Index of Multiple Deprivation (IMD) and the 2013 Census*. The University of Auckland Medical and Health Sciences and Health Research Council of New Zealand; 2017. Accessed March 13, 2022. https://hgd.auckland.ac.nz/files/2021/09/20DistrictHealthBoardsReducedSize_2013.pdf
23. Statistics New Zealand. *Functional Urban Areas: Methodology and Classification*. 2021. Accessed June 13, 2022. https://www.stats.govt.nz/methods/functional-urban-areas-methodology-and-classification
24. Lovelace R, Ellison R. Stplanr: a package for transport planning. *R J*. 2019;10(2):7-23. doi:10.32614/RJ-2018-053
25. Jia P, Yu C, Remais JV, et al. Spatial Lifecourse epidemiology reporting standards (ISLE-ReSt) statement. *Health Place*. 2020;61:102243. doi:10.1016/j.healthplace.2019.102243
26. Benchimol EI, Smeeth L, Guttmann A, et al. The REporting of studies conducted using observational routinely-collected health data (RECORD) statement. *PLoS Med*. 2015;12(10):e1001885. doi:10.1371/journal.pmed.1001885
27. Webb P, Bain C, Page A. *Essential Epidemiology: An Introduction for Students and Health Professionals*. 3rd ed. Cambridge University Press; 2017.
28. Zou G. A modified Poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159(7):702-706. doi:10.1093/aje/kwh090
29. Spiegelman D, Hertzmark E. Easy SAS calculations for risk or prevalence ratios and differences. *Am J Epidemiol*. 2005;162(3):199-200. doi:10.1093/aje/kwi188
30. Sun GW, Shook TL, Kay GL. Inappropriate use of bivariable analysis to screen risk factors for use in multivariable analysis. *J Clin Epidemiol*. 1996;49(8):907-916. doi:10.1016/0895-4356(96)00025-X
31. Hosmer DW, Lemeshow S. *Applied Logistic Regression: Hosmer/Applied Logistic Regression*. John Wiley & Sons, Inc.; 2000. doi:10.1002/0471722146
32. Statistics New Zealand. Ethnic group (grouped total responses) and number of ethnic groups specified by age group and sex, for the census usually resident population count, 2006, 2013, and 2018 Censuses (RC, TA, SA2, DHB) [Data file]. Accessed June 2, 2022. https://nzdotstat.stats.govt.nz/
33. Statistics New Zealand. Age and sex by ethnic group (grouped total responses), for census usually resident population counts, 2013, and 2018 censuses (RC, TA, SA2, DHB) [data file]. 2006. Published 2022. Accessed May 9, 2022. http://nzdotstat.stats.govt.nz
34. Ministry of Health. Regional data explorer 2017-20: New Zealand health survey [data file]. Published 2021. Accessed June 9, 2022. https://minhealthnz.shinyapps.io/nz-health-survey-2017-20-regional-update
35. Ministry of Health. *Asian Health Chart Book 2006*. Ministry of Health; 2006.
36. Wilson G, Windner Z, Dowell A, Toop L, Savage R, Hudson B. Navigating the health system during COVID-19: primary care perspectives on delayed patient care. *N Z Med J*. 2021;134(1546):17-27.
37. Fewell Z, Davey Smith G, Sterne JAC. The impact of residual and unmeasured confounding in epidemiologic studies: a simulation study. *Am J Epidemiol*. 2007;166(6):646-655. doi:10.1093/aje/kwm165
38. Schünemann H, Hill S, Guyatt G, Akl EA, Ahmed F. The GRADE approach and Bradford Hill's criteria for causation. *J Epidemiol Community Health*. 2011;65(5):392-395. doi:10.1136/jech.2010.119933
39. Cane RJ, Butler DR. Developing primary health clinical teams for public oral health services in Tasmania. *Aust Dental J*. 2004;49(4):162-170. doi:10.1111/j.1834-7819.2004.tb00068.x
40. Simmons D, Voyle JA, Fou F, Feo S, Leakehe L. Tale of two churches: differential impact of a church-based diabetes control programme among Pacific Islands people in New Zealand. *Diabet Med*. 2004;21(2):122-128. doi:10.1111/j.1464-5491.2004.01020.x

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Lee JJM, Schluter PJ, Hodgett M, Deng B, Hobbs M. Adolescents and oral health service utilization in Canterbury, New Zealand: A geospatial cross-sectional study. *Community Dent Oral Epidemiol*. 2023;51:388-398. doi:10.1111/cdoe.12858