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Oral health inequities over time among older adults of different racial/ethnic backgrounds: a comparative decomposition analysis across Australia and the United States

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Abstract

Background Although the prevalence of poor oral health among older populations in Australia and the United States is higher, the contribution of ethnicity status is unknown. We aimed to estimate the contribution of social inequalities in oral health among older populations in Australia and the United States.

Methods Cross-sectional study design using data from Australia's National Survey of Adult Oral Health (NSAOH 2004–06 and 2017–18) and the United States' National Health and Nutrition Examination Survey (NHANES 2003–04 and 2011–16). Participants included in the analysis were aged 65 + years. Oaxaca-Blinder type decomposition analysis was used to assess the contribution of demographic (age, sex), socioeconomic position (educational attainment, household income) and dental behaviors (last dental visit) to changes in prevalence of edentulism and non-functional dentition, and mean number of missing teeth by ethnicity status over time in Australia and the United States.

Results The number of participants aged 65 + years who provided clinical and sociodemographic/dental behaviour data was 1043 and 1269 in NSAOH 2004–06 and 2017–18, and 1372 and 1328 in NHANES 2003–04 and 2011–16 respectively. The prevalence of edentulism was from 13 percent (NHANES 2011–16) to 28 percent (NSAOH 2004–06), while the prevalence of non-functional dentition was from 41 percent (NSAOH 2017–18 and NHANES 2011–16) to 61 percent (NHANES 2003–04). The mean number of missing teeth was from 11 (NSAOH 2017–18) to 18 (NHANES 2003–04). The prevalence of edentulism and non-functional dentition, and the mean number of missing teeth were higher among older Australians identifying as White and the opposite results were observed among older Americans identifying as Non-White. For older adults in Australia, risk factors with the greatest impact on oral health outcomes by ethnicity status were educational attainment and household income. For older adults in the United States, the most dominant risk factor for non-optimal oral health outcomes by ethnicity status was last dental visit.

Conclusions There are important policy translation implications from our findings, as they indicate that social and structural systems in Australia and the United States operate differently in the context of oral health over time among culturally diverse older citizens. This information will help inform initiatives that both target effective oral health promotion for older, culturally-diverse populations and provide evidence for the distribution of resources in the public dental health setting for this age group and cultural demographic.

Keywords Edentulism, Missing teeth, Older adults, Decomposition analysis

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Introduction

The oral health of older populations at a global level has undergone substantial improvements over time, due to advancements in and access to dental care, public health interventions, increased knowledge of oral health and changes in societal expectations [1]. In the early twentieth century, the oral health of older populations was generally poor, with high levels of tooth loss and untreated dental decay [2]. This was attributed to lack of access to preventive services, poor oral hygiene practises and limited knowledge of the importance of oral health [3]. The introduction of fluoride in water, dentrifices and other topical fluoride applications played a fundamental role in shifting the population burden of poor oral health among older adults, as did the expansion of public health programs and dental insurance coverage (for example, Medicaid in the United States) that provided care to underserved populations [3], and an increase in dental insurance schemes. However, not all older population groups benefitted from these improvements equally, with inequities in both access to dental services and provision of comprehensive, rehabilitative-focussed care. The inequities are socially patterned, with older adults from low socio-economic backgrounds, racial and ethnic minority groups, and those residing in medically under-served areas (for example, non-metropolitan locations), bearing a disproportionate share of the burden [4].

Given evidence of the associations between poor oral health and chronic conditions prevalent in older age including type 2 diabetes, cardiovascular disease, chronic kidney disease and cognitive decline, maintaining and improving the oral health of older populations is a priority area in many countries [5]. This is particularly relevant given the increased longevity of most population groups across the world, with a larger proportion of this older age group retaining their teeth [6]. Li and colleagues [7] used data from the Global Burden of Disease study to identify the contribution of different factors to changes in the prevalence of edentulism among older adults between 1990 and 2017. The authors reported that improvements in access to dental care and changes in oral hygiene practises were the primary drivers of the decline in edentulism over this period. Dye and colleagues [8] examined trends in tooth loss among older adults in the United States between 1999 and 2014. The findings indicated that changes in dental care utilisation, education level and income were the main contributors in the decline of complete tooth loss over this time. Alobaidi and colleagues [9] analysed ethnic inequalities in oral health with data from the United Kingdom by using a decomposition approach and found that older adults with low socio-economic position or from low socio-economic areas were the main contributors in the non-functional dentition (< 21 teeth). The prevalence of non-functional dentition was higher in White British adults (19.7%) than in Black Caribbean (14.9%), Black African (6.9%) and Chinese populations (2.2%), but lower than in Irish (33.1%).

The proportions of the aging population in the United States and Australia are similar. Recent data suggests that approximately 4.2 million (16% of Australia's total population) is aged 65 and over [10], while in the United States, the proportion of people aged 65 and over is around 17% (58 million) of the total population [11]. Both countries are experiencing significant demographic shifts due to the aging of their populations, influenced by factors such as increased life expectancy and socioeconomic development. These factors have also led to a significant improvement in population oral health, such as reducing the proportion of complete tooth loss from 6.5% in 2004–06 [12] to 4.0% in 2017–18 [13] among Australian adults; and from 6.5% in 1999–2002 to 4.9% in 2009–12 among American adults [14]. On the contrary, these two countries have different levels of healthcare systems, dental public health infrastructure, and social support for dental care. These similarities and differences in the aging population indicates the relevance of comparative studies on issues such as oral health disparities between these two countries.

The purpose of this study was to utilise data from national oral health surveys across two time points and two countries (Australia and the United States) – each with different levels of health care systems, dental public health infrastructure and social support for dental care – and to implement decomposition analysis [15] to examine contributing factors driving oral health inequities among the older populations in both countries, with a specific focus on ethnicity. Decomposition analysis enables the contributions of different factors in each outcome to be quantified. The generated findings provide useful evidence to facilitate cost-effective and equitable dental public health policy both in the countries involved and more globally.

Methods

This study is reported according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Study design and sample selection

Australia

Data were from two population-based cross-sectional surveys of Australian adult oral health conducted in 2004–06 and 2017–18 [12, 13]. In each survey, representative samples of adults were drawn through a three-stage, stratified sample design within metropolitan and regional

areas in each state/territory. The first stage selected a sample of postcodes from all in-scope postcodes in Australia. The second stage selected households within sampled postcodes, with adults aged 15 years and over being randomly selected from each sample household to participate in the final stage. Data were weighted following standard procedures for clustered samples. In this study, only participants aged 65 + years were included in analysis. Both NSAOH 2004–06 and NSAOH 2017–18 were reviewed and approved by the University of Adelaide Human Research Ethics Committee.

United States

We used sequential cross-sectional, deidentified data for adults, aged 65 years and older, from NHANES 2003–04 and 2011–16. NHANES is a complex, multistage probability sample of the non-institutionalized US population. NHANES protocols were approved by the National Center for Health Statistics Ethics Review Board. Additional information on NHANES is available at http://www.cdc.gov/nchs/nhanes.htm.

Participants received an information sheet explaining the study and provided informed consent. Participants signed a consent form prior to undergoing a dental examination.

Data collection

Australia

Self-reported information about oral health and related characteristics were collected using a computer-assisted telephone interview (CATI) in 2004–06, and CATI or online questionnaire in 2017–18. Information about dental clinical status was collected during standardised oral epidemiological examinations conducted by registered and calibrated oral health professionals. All teeth present in the mouth, including third molars, were assessed during clinical examination. All examiners were tested in the field against a gold standard examiner to estimate inter-examiner reliability.

United States

A household interview was undertaken to collect information about demographics and oral health prior to oral health examination in 2003–04 and 2011–16 using a computer-assisted personal interviewing (CAPI) methodology. Persons aged 16 + years of age were interviewed directly. Oral health assessments were conducted in mobile examination units by dentists who were trained prior to and monitored during NHANES data collection to ensure consistent assessment standards. The tooth count was recorded during oral health exam (including third molars). Internal quality control data review indicated that data quality was acceptable.

Variables

Sociodemographic and dental behaviour characteristics across both countries included age, sex, ethnicity, educational attainment, household income and last dental visit. Age was categorized into'65 to 74 years' and '75 + years'. Sex was categorized as 'male' or 'female'. Ethnicity was categorized as 'White' or 'Non-White'. In Australia, 'White' included being Australian-born and English being the primary language spoken at home, or overseas-born (including New Zealand, UK and Ireland, Europe and USA/Canada) and English being the primary language spoken at home. In the United States, 'White' included being 'non-Hispanic white'. Educational attainment was dichotomized into 'University/College or equivalent' or 'non-University/College'. Annual household income was divided into quartiles: 'Lowest', 'Lower', 'Higher' or 'Highest' (see Supplementary Table S1). In Australia, last dental visit was assessed by the question: 'How long ago did you last see a dental professional about your teeth, dentures or gums?', with responses categorized into 'less than one year' and 'one year or more'. In the United States, last dental visit was assessed by the question 'when did you last visit a dentist', with responses dichotomized into 'less than one year' and 'one year or more'.

Outcome measures

Number of teeth was collected during the clinical examination which was then used to derive the following outcome measures: prevalence of edentulism, prevalence of non-functional dentition (< 21 teeth) and mean number of missing teeth.

Data analysis

Descriptive analyses were conducted to examine the distributions and difference in the primary oral health outcomes (% edentulism, % non-functional dentition and mean number of missing teeth) between timepoints 1 and 2 across the two countries. In addition, cross-tabulation tables were generated to show the prevalence or mean of oral health outcomes by ethnicity status. Multivariable log-Poisson regression models (unadjusted and adjusted) were applied to estimate relationships between oral health outcomes and other covariates. Prevalence Ratios (PRs) and their 95% confidence intervals (95%CI) were calculated for the prevalence of edentulism and non-functional dentition, while mean ratios (MRs) and

their 95%CI were calculated for mean number of missing teeth.

Oaxaca-Blinder type decomposition analysis was used to assess the contribution of demographic (age, sex), socioeconomic position (educational attainment, household income) and dental behaviors (last dental visit) to changes in prevalence of edentulism and non-functional dentition, as well as mean number of missing teeth between 2004–06 and 2017–18 in Australia, and between 2003–04 and 2011–16 in the United States, by ethnicity status. Blinder-Oaxaca decomposition is a statistical technique that decomposition analysis enables the contributions of different factors in a given outcome to be quantified. It is a method that can be applied to examine patterns in oral health outcomes and to identify factors driving these patterns [15]. It is a type of analysis that is counterfactual, that is, it allows investigation into what happened while simultaneously explaining what would have happened if no intervention had taken place. By understanding such factors and their relative contributions, policy makers and public health practitioners can develop more equitable strategies to improve oral health outcomes among older groups. In the current study, it explains the change in the prevalence of edentulism and non-functional dentition, and mean number of missing teeth over time when the White or Non-White individual is set to have, for example, 'non-University or equivalent education level' or 'last dental visit over one year ago'. All analyses were conducted using the oxaca command in Stata 14. Weights were used to account for the complex sampling methodology of all surveys across both countries and time points.

Results

The sample characteristics (frequency and percentage, mean) are shown in Table 1. Across both countries and timepoints, more than half were in the younger age group (65–74 years) and female, with more than 90% and around 80% were White group in Australia and the

Table 1 Sample characteristics and prevalence of poor oral health between Australians and Americans aged 65 + years across two time points (weighted)

	Time point 1		Time point 2	
	Australia (2004–06) (*N* = 3012)	**United States (2003–04) (*N* = 1494)**	**Australia (2017–18) (*N* = 4103)**	**United States (2011–16) (*N* = 1500)**
	Exam (*n* = 1043)	**Exam (*n* = 1372)**	**Exam (*n* = 1269)**	**Exam (*n* = 1328)**
Age				
65–74 years	52.4 (50.1–54.7)	55.0 (50.4–59.5)	56.7 (54.8–58.7)	58.7 (52.7–64.8)
75 + years	47.6 (45.3–49.9)	45.0 (40.5–49.6)	43.3 (41.3–45.2)	41.3 (35.2–47.3)
Sex				
Male	44.9 (43.0–46.9)	43.2 (40.8–45.6)	46.7 (44.9–48.7)	44.8 (42.2–47.4)
Female	55.1 (53.1–57.0)	56.8 (54.4–59.2)	53.3 (51.3–55.2)	55.2 (52.6–57.8)
Ethnicity				
White	**96.4 (95.6–97.2)**	**82.8 (76.8–88.7)**	**91.4 (89.9–92.8)**	**76.1 (69.9–82.3)**
Non-White	**3.6 (2.8–4.4)**	**17.2 (11.3–23.2)**	**8.6 (7.2–10.1)**	**23.9 (17.7–30.1)**
Educational attainment				
University or equivalent	13.7 (12.0–15.4)	17.1 (14.1–20.1)	**12.1 (10.9–13.4)**	**32.6 (24.9–40.4)**
Non-University of equivalent	86.3 (84.6–88.0)	82.9 (79.7–85.9)	**87.9 (86.6–89.1)**	**67.4 (59.6–75.1)**
Household income				
Lowest	16.1 (14.5–17.7)	18.4 (14.0–22.8)	14.5 (12.9–16.1)	12.8 (10.7–15.0)
Lower	**38.1 (35.8–40.3)**	**23.2 (19.2–27.1)**	**37.2 (35.0–39.4)**	**20.4 (15.5–25.3)**
Higher	**21.2 (19.3–23.0)**	**29.5 (25.9–33.1)**	27.4 (25.3–29.4)	25.8 (20.1–31.6)
Highest	24.6 (22.2–27.0)	28.9 (23.4–34.4)	**20.9 (18.9–22.9)**	**40.10 (30.6–51.3)**
Last dental visit				
12 + months ago	45.8 (43.4–48.3)	46.5 (39.7–53.3)	41.5 (39.2–43.7)	32.2 (27.6–36.8)
< 12 months ago	54.2 (51.7–56.6)	53.5 (46.7–60.3)	58.5 (56.3–60.8)	67.7 (63.2–72.4)
Total number for exam	1043	1372	1269	1328
% Edentulism	27.6 (25.6–29.6)	27.3 (21.1–33.5)	15.2 (13.8–16.6)	13.4 (9.7–17.1)
% Non-functional dentition	48.4 (44.4–52.4)	61.0 (53.5–68.4)	41.4 (37.0–45.8)	40.8 (34.1–47.6)
Mean number of missing teeth	**13.2 (12.7–13.6)**	**18.1 (17.5–18.7)**	**10.9 (10.5–11.2)**	**13.5 (12,9–14.0)**

Black bold: Difference statistically significant as denoted by non-over-lapping 95% confidence intervals

United States respectively. A higher proportion of participants had non-university-equivalent educational attainment and last dental visit < 12 months. The prevalence with edentulism was from 13 percent (NHANES 2011–16) to 28 percent (NSAOH 2004–06), while the prevalence with non-functional dentition was from 41 percent (NSAOH 2017–18 and NHANES 2011–16) to 61 percent (NHANES 2003–04). The mean number of missing teeth was from 11 (NSAOH 2017–18) to 18 (NHANES 2003–04).

When stratifying oral health outcomes by ethnicity status (Table 2), the oral health outcomes (prevalence of edentulism and non-functional dentition, and the mean number of missing teeth) were higher among older Australians identifying as White. The opposite results were observed among older Americans identifying as Non-White, even though all oral health outcomes were reduced from timepoint 1 to timepoint 2 across the two countries. The biggest difference was that there was more than 2.5 times higher prevalence of edentulism in White than in Non-White older Australians, and the smallest gap was that there was only 1.1 times higher the mean number of missing teeth in Non-White than in White older Americans in timepoint 1. The biggest drop was about 50% reduction in edentulism prevalence in White older Americans, while the smallest drop was only 1.6% decrease of non-functional dentition prevalence in Non-White older Americans from timepoint 1 to timepoint 2.

Multivariable regression models' results were presented in Tables S2-S5.

The decomposition model in Table 3 shows the ethnicity-based inequalities in edentulism prevalence. The largest explanatory variable was household income in NSAOH 2004–06, and educational attainment in NSAOH 2017–18 among Australians aged 65 + years, which contributed for more than 80% of observed differences. The largest explanatory variable was last dental visit, which accounted for more than 70% of the differences among US participants in both NHANES 2003–04 and 2011–16. Also, household income and educational attainment played a significant role, the former explaining 20% in NHANES 2003–04, and the latter explaining 13% in NHANES 2011–16, respectively. Other variables, such as age and gender, contributed a relatively small insignificant proportion of the differences.

The decomposition model in Table 4 shows that, for ethnicity-based inequalities in prevalence of non-functional dentition. For Australian older adults, the largest explanatory variable was educational attainment (80%), followed by last dental visit (18%) in NSAOH 2004–06; and was age group (68%) and followed by educational attainment (60%) in NSAOH 2017–18. For U.S. participants, a similar pattern was observed in both NHANES 2003–04 and 2011–16: the largest explanatory variable was last dental visit (54% vs 47%), followed by household income (36% vs 29%) and educational attainment (16% vs 28%). Gender explained a relatively small insignificant proportion of the differences across two countries and two timepoints.

The decomposition model in Table 5 shows that, for ethnicity-based inequalities in mean number of missing teeth. For Australian older adults, the largest explanatory variable was educational attainment (76%) in NSAOH 2004–06 and was age group (67%) in NSAOH 2017–18. Last dental visit (19%) in NSAOH 2004–06, as well as last dental visit (24%) and educational attainment (18%) in NSAOH 2017–18 played a significant role. For U.S. participants, a similar pattern was observed in both NHANES 2003–04 and 2011–16: the largest explanatory variable was last dental visit (61% vs 56%), followed by household income (28% vs 22%) and educational attainment (13% vs 25%). Again, gender contributed a relatively small insignificant proportion of the differences across two countries and two timepoints.

It is important to note that, across all models, a large proportion of the factors contributing to the inequalities

Table 2 Prevalence of poor oral health between Australians and Americans aged 65 + years across two time points stratified by ethnicity (weighted)

	Time Point 1				Time Point 2			
	Australia (2004–06)		United States (2003–04)		Australia (2017–18)		United States (2011–16)	
	White	Non-while	White	Non-while	White	Non-while	White	Non-while
% edentulous	28.9 (26.2–30.3)	11.0 (3.8–16.2)	25.9 (19.4–26.2)	29.6 (23.8–36.3)	15.8 (14.3–17.3)	7.4 (4.2–13.3)	11.7 (7.1–16.5)	18.4 (13.8–23.0)
% Non-functional dentition	49.7 (45.0–53.0)	31.2 (14.2–59.2)	58.6 (50.8–68.1)	69.2 (63.5–74.2)	38.7 (37.8–46.3)	30.7 (12.3–59.7)	34.8 (26.4–43.5)	58.9 (52.4–66.8)
Mean number missing teeth	13.2 (12.9–13.8)	9.5 (7.5–11.0)	17.5 (17.3–19.1)	19.5 (17.5–19.7)	11.3 (10.6–11.4)	9.3 (5.5–10.0)	12.4 (11.9–16.6)	16.5 (16.0–17.6)

Table 3 Decomposition of the change in edentulism prevalence among Australian and US adults aged 65 + years between two time points

	Time point 1			**Time point 2**		
	Australians aged 65 + years			**Australians aged 65 + years**		
Prevalence (%) of Edentulism (Non-White)	11.0 (4.2–17.9)			7.4 (2.8–11.7)		
Prevalence (%) of Edentulism (White)	28.9 (26.9–30.9)			15.8 (14.1–17.4)		
Due to endowments (E)	0.056 (0.045, 0.148)			0.010 (-0.045, 0.012)		
Due to coefficients (C)	0.076 (-0.036, 0.233)			0.075 (-0.134, 0.170)		
Due to interaction (CE)	0.047 (0.007–0.127)			0.000 (-0.032, 0.047)		
Explained %	31.6			11.5		
Unexplained %	68.4			88.5		
Explanatory variables	**E**	**95% CI**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	-0.006	-0.025, 0.003	-10.7	-0.000	-0.021, 0.002	0.0
Sex	-0.002	-0.001, 0.002	-3.5	-0.001	-0.004, 0.003	-10.0
Educational attainment	0.010	-0.060, 0.024	17.9	0.008	-0.021, 0.049	80.0
Household income	0.046	0.031, 0.066	***82.1**	0.004	-0.008, 0.005	40.0
Last dental visit	0.008	-0.047, 0.520	14.3	-0.002	-0.012, 0.034	-20.0
	Americans aged 65 + years			**Americans aged 65 + years**		
Prevalence (%) of Edentulism (Non-White)	29.6 (23.0, 36.2)			18.4 (14.8, 22.0)		
Prevalence (%) of Edentulism (White)	25.9 (22.6, 29.3)			11.7 (9.1, 14.2)		
Due to endowments (E)	0.076 (0.038, 0.121)			0.098 (0.065, 0.129)		
Due to coefficients (C)	-0.013 (-0.076, 0.048)			0.003 (-0.028, 0.045)		
Due to interaction (CE)	1.026 (-0.002, 1,122)			-0.034 (-0.067, -0.009)		
Explained %	61.7			68.9		
Unexplained %	38.3			31.1		
Explanatory variables	**E**	**95% CI**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	-0.002	-0.007, 0.004	-3.3	-0.001	-0.005, 0.002	-1.7
Sex	0.001	-0.002, 0.003	1.3	-0.000	-0.002, 0.001	-0.2
Educational attainment	0.008	-0.001, 0.030	10.4	0.013	0.010, 0.048	****13.1**
Household income	0.015	0.002, 0.029	*19.5	0.012	-0.007, 0.023	12.1
Last dental visit	0.055	0.020, 0.080	**71.4	0.075	0.036, 0.086	*****75.8**

*** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05

Table 4 Decomposition of the change in prevalence of non-functional dentition among Australian and US adults aged 65 + years between two time points

	Time point 1			**Time point 2**		
	Australians aged 65 + years			**Australians aged 65 + years**		
Prevalence (%) of Non-functional dentition (Non-White)	31.2 (15.7, 46.6)			30.7 (17.89–43.47)		
Prevalence (%) of Non-functional dentition (White)	49.7 (45.9, 53.5)			38.7 (34.89–42.56)		
Due to endowments (E)	0.102 (-0.025, 0.105)			0.016 (0.000, 0.046)		
Due to coefficients (C)	0.136 (-0.269, 0.160)			0.044 (-0.206, 0.077)		
Due to interaction (CE)	-0.052 (-0.231, 0.051)			0.020 (-0.074, 0.123)		
Explained %	54.8%			20.3%		
Unexplained %	45.2%			79.7%		
Explanatory variables	**E**	**95% CI**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	0.007	-0.028, 0.009	10.8	0.043	0.031, 0.048	***67.5**
Sex	-0.007	-0.009, 0.013	-1.9	-0.002	-0.014, 0.007	-5.1
Educational attainment	0.137	0.071, 0.229	***81.2**	0.009	-0.057, 0.010	60.7
Household income	-0.026	-0.053, 0.003	-26,7	-0.011	-0.019, 0.029	-8.0
Last dental visit	0.023	-0.019, 0.051	18.4	-0.022	-0.025, 0.028	-15.2
	Americans aged 65 + years			**Americans aged 65 + years**		
Prevalence (%) of Non-functional dentition (Non-White)	69.2 (63.3, 75.1)			58.9 (54.4, 63.5)		
Prevalence (%) of Non-functional dentition (White)	58.6 (54.9, 62.3)			34.8 (29.8, 39.8)		
Due to endowments (E)	0.092 (0.053, 0.130)			0.127 (0.083, 0.168)		
Due to coefficients (C)	0.075 (0.005, 0.147)			0.137 (0.068, 0.205)		
Due to interaction (CE)	-0.061 (-0.099, -0.023)			-0.023 (-0.062, 0.021)		
Explained %	87.0			52.8		
Unexplained %	13.0			47.2		
Explanatory variables	**E**	**95% CI**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	-0.004	-0.012, 0.002	-4.3	-0.002	-0.009, 0.004	-1.6
Sex	-0.001	-0.004, 0.002	-1.1	-0.002	-0.008, 0.004	-1.6
Educational attainment	0.015	0.001, 0.029	***16.1**	0.035	0.016, 0.066	****27.6**
Household income	0.033	0.015, 0.054	****35.5**	0.037	0.006, 0.063	****29.1**
Last dental visit	0.050	0.022, 0.074	****53.8**	0.059	0.027, 0.082	*****46.5**

*** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05

Table 5 Decomposition of the change in mean number of missing teeth among Australian and US adults aged 65 + years between two time points

	Time point 1			**Time point 2**		
	Australians aged 65 + years			**Australians aged 65 + years**		
Mean number of missing teeth (Non-White)	9.51 (7.31, 11.71)			9.27 (7.55, 10.99)		
Mean number of missing teeth (White)	13.23 (12.66, 13.81)			11.30 (10.75, 11.85)		
Due to endowments (E)	1.233 (0.039, 1.655)			0.450 (0.286, 1.081)		
Due to coefficients (C)	2.913 (0.029, 4.946)			1.634 (0.090, 3.254)		
Due to interaction (CE)	-0.426 (-1.979, 1.128)			-0.053 (-1.144, 1.040)		
Explained %	33.1			22.1		
Unexplained %	66.9			77.9		
Explanatory variables	**E**	**95% CI)**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	0.140	-0.516, 0.121	7.0	0.574	0.062, 0.784	***66.6**
Sex	0.087	-0.099, 0.142	4.3	0.072	-0.090, 0.189	8.4
Educational attainment	1.523	0.025, 1.654	***76.0**	0.151	-0.065, 0.699	17.5
Household income	-0.132	-0.711, 0.051	-6.6	-0.141	-0.272, 0.407	-16.4
Last dental visit	0.385	- 0.018, 0.442	19.2	0.206	0.050, 0.699	***23.9**
	Americans aged 65 + years			**Americans aged 65 + years**		
Mean number of missing teeth (Non-White)	19.49 (17.94, 21.04)			16.52 (15.57, 17.48)		
Mean number of missing teeth (White)	17.52 (16.67, 18.38)			12.44 (11.44, 13.44)		
Due to endowments (E)	2.372 (1.261, 3.483)			3.273 (2.271, 4.202)		
Due to coefficients (C)	1.030 (-0.542, 2.603)			1.684 (0.396, 2.972)		
Due to interaction (CE)	-1.439 (-2.347, -0.531)			-0.839 (-1.687, 0.009)		
Explained %	88.2			79.3		
Unexplained %	11.8			20.7		
Explanatory variables	**E**	**95% CI**	**Proportion explained (%)**	**E**	**95% CI**	**Proportion explained (%)**
Age group	-0.035	-0.143, 0.072	-1.5	-0.056	-0.208, 0.096	-1.7
Sex	-0.011	-0.064, 0.042	-0.5	-0.021	-0.091, 0.049	-0.6
Educational attainment	0. 311	0.007, 0.616	***13.1**	0.797	0.350, 1.243	****24.6**
Household income	0.664	0.242, 1.087	****28.0**	0.706	0.101, 1.311	****21.8**
Last dental visit	1.442	0.617, 2.267	****60.8**	1.810	1.072, 2.549	*****55.9**

*** *p*-value < 0.001; ** *p*-value < 0.01; * *p*-value < 0.05

observed remain unexplained. For prevalence of edentulism, the contribution of unexplained factors was 68.4% for NSAOH 2004–06, 88.5% for NSAOH 2017–18, 38.3% for NHANES 2003–04 and 31.1% for NHANES 2011–16. For prevalence of non-functional dentition, the contribution of unexplained factors was 45.2% for NSAOH 004–06, 79.7% for NSAOH 2017–18, 13.0% for NHANES 2003–04 and 47.2% for NHANES 2011–16. For mean

number of missing teeth, the contribution of unexplained factors was 66.9% for NSAOH 2004–06, 77.9% for NSAOH 2017–18, 11.8% for NHANES 2003–04 and 20.7% for NHANES 2011–16.

Discussion

The study aims were to assess the contribution of social inequalities in oral health among older populations in Australia and the United States by ethnicity status over time using decomposition analysis. Although risk factors that contributed the most to the gap in dental disease outcomes explained by ethnicity for both older adults in Australia and the United States were largely the same over time, different associations were also observed. For example, for older adults in Australia in 2004–06 and 2017–18, risk factors with the greatest impact on all oral health outcomes were educational attainment and household income. For older adults in the United States in 2003–04 and 2011–16, the most dominant risk factor for all oral health outcomes was last dental visit. The findings have important policy translation implications, as they indicate that social and structural systems in Australia and the United States operate differently in the context of oral health over time among older citizens. This is important for both targeting of effective oral health promotion initiatives and for policy implications in the allocation of scarce resources in the public dental health setting.

The findings demonstrate that, across both countries, older adults are retaining more of their natural teeth. The occurrence of all three oral health outcomes; edentulism, prevalence of non-functional dentition and mean number of missing teeth, decreased between surveys for both countries, irrespective of age-group, ethnicity status, educational attainment, household income and last visit to a dentist. This was especially stark with the prevalence of edentulism, essentially halving in both countries between time points. This decrease in tooth loss is supported by the literature [16], and likely reflects a societal shift towards increased oral health awareness resulting in lower rates of dental disease and tooth extraction, the introduction of fluoride in dentrifices and public water supplies, and success of public campaigns in tobacco smoking cessation [17]. Based on the availability of fluoride [14], survey participants in Time Point 2 of both countries would have received the benefits of fluoride as adolescents or young adults as compared to the Time Point 1 sample.

There were marked country-level differences between oral health outcomes across both time points when stratified by ethnic status. In Australia, poorer oral health was observed among the White group when compared with the non-White group, while in the United States, the opposite was observed. This may reflect, in part, the different ways in which ethnic status was defined in each country, with the White group representing 96% of the Australian population at Time Point 1 and 91% at Time Point 2, compared with the White group representing 83% of the United States population at Time Point 1 and 76% in Time Point 2. It may be that both current and historical migration policies focusing on high education attainment in Australia have led to the older non-White population being more able to access dental services (for instance, the National Oral Health Plan of Australia, 2015–2024 provided a 'priority access' for vulnerable groups which included refugees [18]) than the older non-White population in the United States (for instance, the non-White population was almost 3 times less likely to have a dental visit than the White population due to implementation of pro-equity policies [19]), with consequent impacts on oral health.

The oral health systems in Australia and the United States deserve mention, as these impact the service provision models available to older populations in both countries. In Australia, although older populations are recognized in the National Oral Health Plan [18] as being a priority population, only 14 percent of the population aged 65 + years are eligible for dental care through the public sector (which is means tested). Those ineligible need to access dental care through the private sector; either by purchasing health insurance which can mitigate some or all dental care costs not routinely covered by Australia's Medicare system, or by paying out-of-pocket. Service models for older Australians, especially those in residential care facilities, are recognized as being under-resourced, with the triple-edged sword being that more Australians are living for longer, more older Australians have retained their teeth, but often dental care that is required needs to be specialist due to medical comorbidities and fragilities in ability to brush, mobilise etc. [20]. In the United States, dental service provision is largely through the private sector through employee-based insurance schemes. A substantial proportion of the older US population who are no longer in paid employment need to pay for dental care through personal private insurance or directly out of pocket. There are some Medicaid schemes available for older, vulnerable populations, but these differ state by state [21].

Integration of oral health into general geriatric health care plans could help improve the oral health of vulnerable older adults in both Australia and the United States. Evidence in the United States has demonstrated that a range of healthcare and ancillary workers, with appropriate training and support systems, can both assess risk and screen for common oral conditions [22], provide preventive services including application of silver diamine

fluoride [23] and educate around how to best prevent oral diseases as comorbidities and other factors impacting mobility and agility (which may impact on ability to hold a toothbrush and brush teeth for a sustained period) increase[24–26].

Oral health challenges experienced by older populations with culturally diverse backgrounds were summarized by Marino into six salient points: (l) language and communication; (2) lack of information; (3) financial assistance and social support; (4) social isolation; (5) acculturation and (6) racism and prejudices [27]. Other factors include unfamiliarity of healthcare systems, lack of culturally tailored services, and different cultural behaviors and attitudes towards oral health [28–32]. As the goal of any country is to improve the health of all population groups, irrespective of cultural background, it is important that greater recognition be given to the different value and belief systems of multicultural groups. Systemic barriers that exist in terms of models of dental service provision for older populations identifying as non-White require far greater attention, both for economic and social equity reasons.

What cannot be ignored is that a significant portion of the disparities remained unexplained, suggesting that factors beyond those associated solely with ethnicity-based inequalities may also contribute. For instance, living in remote or very remote areas may affect access to and receipt of quality oral health care [33, 34] and socioeconomic status has a significant impact on dental insurance [35], without dental insurance, people may delay dental health care [36], resulting in poor oral health. Future studies should focus on the impact of these factors and their interactions to design targeted interventions.

Study limitations include a large proportion of the contribution of ethnicity-based inequalities (more than 90% in Australia and around 80% in United State were White ethnic group) in all three of the outcomes (% edentulism, % non-functional dentition and mean number of missing teeth) across both countries and time points, being from unexplained factors. This was particularly so for the Australian estimates. This emphasizes that, as much as the findings are an important contribution to the inequality literature in oral health, the full picture of what is driving these inequities remain unknown. Most likely they link to the commercial determinants of health and broader power structures (neoliberal policies that disadvantage vulnerable populations, for example), the impacts of which are difficult to measure in national oral health [37, 38]. This opens avenues for further research to examine the wider context within which oral health inequities at a global level play out and, more importantly, how best to advocate and inform policy change to overcome these [39, 40]. In addition, there were differences in data timelines across both countries and timepoints, which may contribute to confounding bias. Because all data were obtained by cross-sectional study designs, causal hypotheses could not be tested. In the future, longitudinal data should be used to establish temporal sequences or to account for dynamic changes over time.

Conclusion

Although the prevalence and severity of tooth loss decreased in all groups of older adults, social inequities persisted across time in both Australia and the United States. Factors that drove oral health inequities between White and Non-White ethnic groups in Australia were education and household income, while in the United States, the dominant factor impacting oral health inequities between White and Non-White populations was access to dental care. The findings support the need to increase older adults' access to culturally safe dental services, such as geriatric dentistry models of care, with a far greater safety net required than is currently available in both countries. Other potential solutions include increasing access to cost-effective and culturally safe interventions delivered by auxiliary dental teams (for example, silver diamine fluoride), integration of dental into general medical care plans, and increasing visibility to the unique needs of older populations who are culturally diverse. Our findings provide evidence for policy makers that make efforts to reduce both White and Non-White oral health inequalities in two countries, with such action needing to occur in the social, economic and political spheres. As reported by the World Health Organization [41], improving the oral health of older populations, especially those who are socially vulnerable, needs to be a public health priority at a global level.

Abbreviations

CAPI	Computer-assisted personal interviewing
CATI	Computer-assisted telephone interview
NHANES	National Health and Nutrition Examination Survey
NSAOH	National Survey of Adult Oral Health
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
US	United States

Supplementary Information

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Supplementary Material 1.

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had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Authors' contributions
L.J. and X.J. wrote the main manuscript text and X.J. prepared all tables. All authors reviewed the manuscript. LJ and XJ conceived and designed the study. GM, SC, and LL investigated the data. XJ did the statistical analyses, produced the Tables, interpreted the data, and contributed to writing manuscript drafts. LJ, BW, SC, LL, and GM are guarantors for this article. All authors contributed to data acquisition and interpretation, and critically reviewed and approved the manuscript.

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Data availability
Both NSAOH 2004-06 and NSAOH 2017-18 data is available upon request to the corresponding author. NHANES is available at: http://www.cdc.gov/nchs/nhanes.htm.

Declarations

Ethics approval and consent to participate
Both NSAOH 2004–06 and NSAOH 2017–18 were reviewed and approved by the University of Adelaide Human Research Ethics Committee. NHANES protocols were approved by the National Center for Health Statistics Ethics Review Board.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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