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ABSTRACT

This study aimed to (1) describe social gradients in dental caries in a population-level survey and (2) examine whether inequalities are greater in disease experience or in its treatment. Using data from Australia's National Survey of Adult Oral Health 2004-2006, we examined absolute and relative income inequalities for DMFT and its separate components (DT, MT, FT) using adjusted proportions, means, and health disparity indices [Slope Index of Inequality (SII) and Relative Index of Inequality (RII)]. Approximately 90% of Australian adults had experienced caries, with prevalence ranging from 89.7% in the highest to 96.6% in the lowest income group. Social gradients in caries were evident across all components of DMFT, but particularly notable in Missing (SII = -15.5, RII = -0.3) and untreated Decay (SII = -23.7, RII = -0.9). Analysis of age- and gender-adjusted data indicated less variation in levels of disease experienced (DMFT) than in the health outcomes of its management (missing teeth). The findings indicate that social gradients for dental caries have a greater effect on how the disease was treated than on lifetime disease experience.

KEY WORDS: social differentials, dental caries, Absolute Concentration Index, Slope Index of Inequality, Relative Concentration Index, Relative Index of Inequality.

Greater Inequalities in Dental Treatment than in Disease Experience

BACKGROUND

Social inequalities in a wide range of oral health parameters, both clinical and self-reported, have been documented. For example, Borrell and Crawford (2008) reported differences in periodontal disease prevalence by income, education, and race/ethnicity in the United States, while Sabbah and colleagues (2007) found poorer self-rated oral health reported by individuals with low income and low education. Wamala and colleagues (2006) reported that increased levels of socio-economic disadvantage were associated with decreased use of dental services and poorer oral health among Swedish adults. Previous research in Australia demonstrated income inequalities with regard to edentulism (Sanders and Spencer, 2004), while in the United Kingdom, social gradients with respect to untreated dental disease in both children and adults have been reported (Watt and Sheiham, 1999).

The use of standard inequality measures allows for assessment of the scale of inequalities within populations and comparison of inequalities between and among population groups, as well as monitoring of inequality trends and better communication of the extent of social inequalities (Harper and Lynch, 2005). The utility of these measures also rests on their use of the SES distribution for total population while accounting for the size of the respective SES groups (Keppel *et al.*, 2005). Standard guidelines for reporting health disparities recommend using several indices, since each measure emphasizes different dimensions of disparity; it is also recommended that absolute and relative measures be examined simultaneously, because different conclusions could be drawn from the same data depending on the scale of measurement used (Keppel *et al.*, 2005; Harper *et al.*, 2008).

An absolute summary measure of inequality is the Slope Index of Inequality (SII), with its relative counterpart being the Relative Index of Inequality (RII). The SII and RII are regression-based measures, thus assuming that the relationship between social grouping and health outcome is linear (Harper and Lynch, 2005; Keppel *et al.*, 2005). Health disparity indices take into account the size of each category and are sensitive to changes in the distribution of population groups. Because the indices depend on strict ordering of the social groups, they are sensitive to the direction of the health gradient, with a negative score indicating the outcome decreases as deprivation decreases, that is, if a hypothetical individual were to move from the bottom to the top of the social group distribution, also stated as an upward gradient in health (Harper and Lynch, 2005).

In a study of oral health inequalities, the chronic nature of disease and its measurement also needs to be considered. The pathological process of dental diseases, such as caries, cumulatively affects oral structures; their repeated recurrence (and repeated need for dental care) is common at a population level. The lifelong effects of the disease and its management can be directly observed and measured. The most commonly used measure of dental caries

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(DMF index – a count of decayed, missing, or filled teeth/surfaces) reflects actual disease experience (past and present) and, through its components, the management of that disease.

Our ability to address social inequalities in oral health depends on our understanding of whether such inequalities are due to the experience of disease *per se* or depend on the treatment of disease. Whereas social inequalities in disease experience point toward differential rates of disease, differences in the management of disease point toward social inequalities in health care.

The aim of this study was to describe social differentials in dental caries in adult Australians and to explore whether oral health inequalities are greater in disease experience or in its treatment.

METHODS

Data were from 15+-year-olds in Australia's National Survey of Adult Oral Health (NSAOH) 2004-2006, the methods of which have been described previously (Slade *et al.*, 2007). Participation rates varied by location, socio-economic levels, and between and among survey components (Mejia *et al.*, 2007). A thorough evaluation of potential biases due to non-participation revealed that the degree of bias present in most estimates was of low magnitude and provided sufficient evidence of the validity of estimates with NSAOH data (Mejia *et al.*, 2007).

NSAOH utilized a three-stage, stratified clustered sampling design. Dentate individuals aged 15 years or more who completed the computer-assisted telephone interview were invited to undergo a standardized oral examination. Examining dentists ($n = 30$) followed a standardized clinical protocol (Slade *et al.*, 2007). Weights were calculated to reflect probabilities of selection and to adjust for different participation rates across postcodes, and among age and gender categories.

Ethical approval was received from the University of Adelaide's Human Research Ethics Committee. Participants provided verbal consent prior to answering questions in the initial telephone interview but provided positive informed consent and medical history information prior to the oral epidemiological examination.

Income

The main explanatory variable was household income, which was obtained during the telephone interview and assessed by the question, "Could you please indicate the category of your total household income?," with response options categorized into "Less than \$20,000," "\$20,000 to less than \$40,000," "\$40,000 to less than \$60,000," "\$60,000 to less than \$80,000," and "\$80,000 or more."

Dental Caries

The DMFT (sum of decayed, missing, and filled teeth in the permanent dentition) index was used to assess dental caries disease experience (mean DMFT and percent DMFT > 0). Treatment of caries experience was measured as mean untreated decay (DT), mean missing teeth (MT), mean filled teeth (FT), percentage DT > 0, percentage MT > 0, and percentage FT > 0.

Dental Care

Access to dental care was assessed by the question from the telephone interview: "How long ago did you last see a dental professional about your teeth, dentures or gums?" ("less than 12 months ago" or "more than 12 months").

Statistical Analyses

Caries experience was first analyzed through cross-tabulations and adjusted for age and gender through regression analysis. The adjusted estimates and weighted population counts were used to calculate the disparity indices following data preparation guidelines by the US National Cancer Institute's (NCI, 2014) Surveillance Epidemiology and End Results (SEER) program. NCI's Health Disparities Calculator, version 1.1, was used to generate SII and RII estimates to quantify the direction and magnitude of inequalities. The SII and RII use ordered social groups, low- to high-income, and weigh the categories by their population share. The health outcome is plotted against the midpoint of the cumulative social group distribution, and a regression line is fitted to the data. The regression slope is the SII. The RII is obtained by dividing the SII by the mean level of health in the population (Harper and Lynch, 2005; Keppel *et al.*, 2005).

Household income was imputed to address the 6.5% of missing data. A sequential regression imputation procedure was done with IVEware, version 0.2, and used socio-demographic variables as well as clinical measures of dental disease (Raghunathan *et al.*, 2001). No statistical evidence of differences was found between complete case estimates and results from the imputation; hence only imputed results are presented. SAS callable SUDAAN, version 10.01, was used to account for the complex data structure.

RESULTS

In total, 5,505 Australians underwent the clinical examination. In weighted analyses, there were equal proportions of men and women. The population distribution by income level ranged from 14.5 in the lowest income category to 28.8 in the highest. Just under 60% reported having visited a dentist in the past year. Approximately 90% of the sample population had experience of dental disease (mean DMFT = 12.9), with one-quarter having untreated decay (mean DT = 0.6), 61% having missing teeth (mean MT = 4.6), and 83% having filled teeth (mean FT = 7.7). Fig. 1 presents dental outcomes in the total population by level of income. Fig. 2 stratifies the dental outcomes by age groups and level of income. Table 1 presents results adjusted by age and gender, including the SII and RII as measures of inequality. Table 2 presents the same but stratified by dental visiting.

Dental Caries Experience (DMFT)

Fig. 1 shows a clear income gradient when the total population is considered, yet, in Fig. 2, when stratified by age groups, the gradient becomes less obvious. The cumulative nature of dental caries experiences is clearly depicted with an increase in mean DMFT across older age groups (Fig. 2). In Table 1, the age- and

Figure 1. Total population dental outcomes by level of income.

Figure 2. Dental outcomes by age and level of income.

gender-adjusted DMFT proportion, mean, and related inequality indices indicate a shallow social gradient relative to cumulative caries experience by household income. The inequality indices indicated that an upward gradient (*i.e.*, moving from low to high income) was associated with a decline in the mean number of teeth with caries experience – the SII indicates an average of 1.5 fewer teeth with dental caries experience in higher income

groups. However, the RII indicates minimal social inequality, although the mean DMFT was slightly higher among lower income groups.

Table 2 shows that, among people who reported visiting the dentist in the previous year, the upward direction of the gradient was more apparent but remained modest, with the majority of the population experiencing caries at similarly high levels. The inequality indices were of low magnitude. With regard to those whose last dental visit was over 12 months earlier, the proportion experiencing disease is lower in the lower income groups (by 2.3 percentage points according to the SII), whereas the mean DMFT is higher in the lower-income groups (by 1.3 teeth on average according to the SII).

Treatment of Dental Caries

Untreated Decay

Figs. 1 and 2 show income gradients for untreated decay for the total population and across all population groups, despite wide confidence intervals. Table 1 indicates that the proportion of people with untreated decay varied across income levels, with the inequality indices suggesting a disproportionate concentration of untreated decay among low-income groups. Untreated decay presented large inequality estimates – for example, the SII indicated that the absolute difference in the prevalence of untreated decay was –23.4 percentage points across the income distribution, and the RII indicated a 92% decline in the prevalence of untreated decay when individuals moved upward in the income distribution. A similar upward pattern was observed (lower incomes having larger estimates than higher incomes) among mean numbers of teeth with untreated decay. Among people with a dental visit in the previous year (Table 2), an almost identical situation was observed, whereas among those visiting longer ago, the gradient, although present, is less pronounced.

The proportion of people with untreated dental decay is lower among more recent visitors compared with those visiting longer ago.

Missing Teeth

Figs. 1 and 2 demonstrate an income gradient across all ages yet more apparent in older groups, albeit with less precise estimates

Table 1. Population with Outcome (SE) by Level of Income, Age- and Gender-adjusted

		Income (SE)					Measures of Inequality (SE) [†]	
		< \$20,000 (n = 1,106)	\$20,000 - < \$40,000 (n = 1,300)	\$40,000 - < \$60,000 (n = 1,036)	\$60,000 - < \$80,000 (n = 817)	\$80,000 or more (n = 1,246)	SII	RII
DMFT	% > 0	81.8 (4.0)	82.3 (2.5)	77.8 (2.6)	79.9 (2.5)	79.7 (2.0)	-3.0 (4.4)	-0.0 (0.1)
	Mean	13.5 (0.3)	13.4 (0.3)	12.5 (0.4)	12.3 (0.4)	12.4 (0.3)	-1.5 (0.5)	-0.1 (0.0)
Decayed teeth	% > 0	38.8 (2.8)	28.6 (2.0)	28.5 (2.0)	22.4 (2.2)	17.5 (1.7)	-23.7 (3.4)	-0.9 (0.1)
	Mean	1.2 (0.2)	0.8 (0.1)	0.6 (0.1)	0.5 (0.1)	0.4 (0.1)	-0.9 (0.2)	-1.4 (0.2)
Missing teeth	% > 0	74.2 (2.8)	66.9 (2.2)	56.0 (2.0)	57.3 (2.1)	60.2 (2.0)	-15.5 (3.7)	-0.3 (0.1)
	Mean	6.0 (0.2)	5.0 (0.2)	4.0 (0.2)	3.6 (0.2)	3.5 (0.2)	-2.9 (0.3)	-0.7 (0.1)
Filled teeth	% > 0	76.8 (2.6)	84.8 (1.9)	82.6 (1.9)	85.1 (1.9)	84.1 (1.8)	5.6 (3.3)	0.1 (0.0)
	Mean	6.1 (0.2)	7.6 (0.2)	7.8 (0.3)	8.2 (0.3)	8.5 (0.3)	2.3 (0.4)	0.3 (0.1)

Unweighted sample size (n) presented in parentheses.

[†]SII, Slope Index of Inequality; RII, Relative Index of Inequality.**Table 2.** Caries Outcomes (SE) by Dental Visit and Level of Income, Age- and Gender-adjusted

		Income					Measures of Inequality [†]	
		< \$20,000	\$20,000 - < \$40,000	\$40,000 - < \$60,000	\$60,000 - < \$80,000	\$80,000 or more	SII	RII
Dental visit within the past 12 months (n = 3,349)								
DMFT	% > 0	86.7 (3.2)	84.6 (2.4)	77.9 (3.4)	80.3 (3.4)	78.5 (2.8)	-9.5 (4.8)	-0.1 (0.1)
	Mean	15.2 (0.4)	15.3 (0.4)	14.3 (0.4)	13.9 (0.5)	13.7 (0.4)	-2.2 (0.7)	-0.2 (0.1)
Decayed teeth	% > 0	34.5 (3.7)	25.8 (2.9)	22.1 (2.6)	18.0 (2.6)	13.9 (2.0)	-23.4 (4.3)	-1.1 (0.2)
	Mean	1.2 (0.2)	0.7 (0.1)	0.5 (0.1)	0.3 (0.1)	0.2 (0.0)	-1.0 (0.2)	-2.0 (0.3)
Missing teeth	% > 0	83.0 (3.3)	74.5 (2.5)	63.1 (2.5)	63.3 (2.6)	65.8 (2.3)	-18.8 (4.3)	-0.3 (0.1)
	Mean	6.4 (0.2)	5.6 (0.3)	4.6 (0.2)	4.0 (0.3)	3.7 (0.2)	-3.3 (0.4)	-0.7 (0.1)
Filled teeth	% > 0	88.8 (2.7)	90.8 (2.2)	87.4 (2.1)	90.3 (2.0)	88.4 (1.7)	-1.2 (3.4)	-0.0 (0.0)
	Mean	7.7 (0.3)	9.0 (0.3)	9.1 (0.3)	9.6 (0.4)	9.7 (0.3)	2.0 (0.5)	0.2 (0.1)
Dental visit over 12 months ago (n = 2,151)								
DMFT	% > 0	85.5 (4.7)	87.9 (2.9)	84.6 (3.1)	86.0 (3.2)	88.4 (2.2)	2.3 (5.1)	0.0 (0.1)
	Mean	11.3 (0.5)	11.0 (0.4)	10.1 (0.5)	9.9 (0.5)	10.3 (0.6)	-1.3 (0.9)	-0.1 (0.1)
Decayed teeth	% > 0	41.1 (3.8)	32.3 (3.0)	37.7 (3.6)	29.8 (4.0)	23.9 (3.3)	-18.7 (5.6)	-0.6 (0.2)
	Mean	1.1 (0.2)	0.9 (0.1)	0.8 (0.1)	0.8 (0.1)	0.6 (0.1)	-0.6 (0.2)	-0.8 (0.3)
Missing teeth	% > 0	62.8 (4.6)	57.7 (3.4)	46.7 (2.8)	48.3 (3.4)	51.5 (3.3)	-13.5 (6.0)	-0.3 (0.1)
	Mean	5.2 (0.3)	4.2 (0.3)	3.2 (0.3)	2.9 (0.3)	3.3 (0.3)	-2.3 (0.5)	-0.6 (0.1)
Filled teeth	% > 0	65.6 (4.3)	77.5 (3.2)	75.4 (3.3)	76.6 (3.6)	77.8 (3.0)	9.7 (5.6)	0.1 (0.1)
	Mean	4.5 (0.3)	5.9 (0.3)	5.9 (0.4)	5.9 (0.4)	6.3 (0.4)	1.7 (0.6)	0.3 (0.1)

Unweighted sample size presented in parentheses.

[†]SII, Slope Index of Inequality; RII, Relative Index of Inequality.

(Fig. 2). The age- and gender-adjusted estimates in Table 1 indicate that the more socially disadvantaged groups have a higher proportion of people with missing teeth and higher mean numbers of missing teeth. The magnitude of the disparity is significant, with the negative values of the inequality indices indicating that the disparity in missing teeth favors the more socially advantaged. Very similar results were observed when time since

last dental visit was stratified, particularly among those reporting a dental visit in the past year (Table 2).

Filled Teeth

Among the younger age groups, filled teeth present little income variability, but in older groups the variability increases, with those in the lower income groups exhibiting fewer filled teeth

(Fig. 2). In Table 1, the estimates for the proportion of people with filled teeth indicate that only the lowest household income group differs significantly from the others by having a lower proportion of individuals with filled teeth. The mean number of filled teeth increases with higher income, with the inequality indices confirming this gradient. The results in Table 2 indicate that, among those reporting a dental visit in the previous year, the lower proportion of filled teeth in the lower income group is no longer observed, with the inequality indices supporting the finding of non-significant differences between the groups. For those whose last dental visit was over a year ago, there was a lower proportion with filled teeth in the lower income group, but the gradient is not clear for other income groups. The mean number of filled teeth increases with higher income for those visiting in the last year and those visiting longer ago.

DISCUSSION

This study examined social differentials in dental caries in an Australian population survey, and the findings indicated that, in this population, oral health inequalities are more apparent in measures which reflected disease management as opposed to outcome measures of disease experience.

Social gradients in caries were evident across all treatment components of DMFT, but were particularly notable in the “missing” and “untreated decay” sub-categories. Lower social position did not necessarily translate into higher disease experience (*i.e.*, DMFT), but was associated with the nature of dental treatment reported to have been received in the past year.

The analysis reports one-point-in-time associations; however, the issues of access, use, and treatment are repeated over the life-course, leading to inequalities in oral health outcomes later in life. This study has not addressed patterns of attendance or type of dental visiting, and we are unable to determine whether different stages of disease detection, with the consequent different treatments, differ across socio-economic levels and throughout the life cycle (Nicolau *et al.*, 2007; Listl, 2012). Ideally, equivalized income would be used for adjustment for the numbers and ages of household members. Unfortunately, deriving the factor to calculate equivalized income was problematic because of some inaccuracies in the number of people reported in a particular age range for some households. Although it could be argued that our choice of measure may affect the gradient within each outcome, it should have little impact on the differences observed between outcomes, the main aim of this study. A further limitation was the interpretation of missing teeth as a reflection of treatment only, rather than as a consequence of disease experience. Clearly, more extensive disease experience and more advanced stages of oral disease imply other (more invasive) treatment approaches than less extensive disease experience or detection of oral diseases at an earlier stage. In the analysis, we used 4 categories of age, to coincide with previous reports that focused on Australia’s four “dental generations” (Slade *et al.*, 2007), who experienced different historical influences on their oral health. Our stratified results reflect these generational differences. The results of the analyses agree with previous reports in which there were large differences in

missing teeth by age, with much steeper social gradients in older age groups (Sanders and Spencer, 2004). Likewise, the differences by age groups with regard to DMFT were also large.

We found modest variation by household income in overall caries experience (*i.e.*, DMFT), but the results of this study point to obvious gradients in measures of caries treatment. Although, from a clinical perspective, the average size for some of the differences could be considered generally small, some of the differences between income groups are noteworthy, with lower income groups bearing a higher burden. This is particularly noticeable for missing teeth and when stratified by age. There was greater variation in whether and how the disease was treated, particularly regarding tooth extractions, with a greater proportion of individuals with missing teeth among lower income groups and receiving an extraction among those visiting in the past year. The reasons for these extractions are unclear and could be the result of extensive disease, treatment philosophies, or participants having agreed to the lowest cost option (Bedos *et al.*, 2009). The largest inequalities were found in untreated decay, where lower household income groups bore a disproportionate burden of untreated disease and need for dental treatment.

Dental visiting and the treatments received are based on self-reported data. This study did not examine the validity of self-reported utilization by socio-economic status, but self-reported healthcare measures have been shown to be valid proxies for medical claims and administrative data (Short *et al.*, 2009); moreover, a recent study pointed to the minor variation in the concordance between self-reported and registered utilization measures across socio-economic groups (Reijneveld and Stronks, 2001).

Dental visiting in the past year did not show marked differences compared with a longer time since the last visit, and in fact, inequalities seemed to be less when the last dental visit occurred over 12 months earlier (with the exception of filled teeth). The similarity of the estimates between the general population and those visiting within the previous 12 months could indicate that recent visits may not be linked to comprehensive care, with unmet or incomplete treatment need, or that the course of care had not yet been completed or had not been followed (Manski *et al.*, 2012). Another explanation could be emergency care being sought and, as is the nature with emergency care, not all treatment needs being met (Lee *et al.*, 2012).

At a global level, Australia is often considered to be “fair” with regard to universal health schemes, including access to health services (AIHW, 2012). However, socially disadvantaged Australian adults are limited in their options regarding public dental care, with these scarce services being rationed through a range of strategies including waiting lists, limited range of services, and co-payments (Spencer, 2001). These strategies have the cumulative effect of suppressing demand and encouraging a problem-oriented approach to dental care utilization, which generally translates into poor dental outcomes. The majority of adults with low income in this study were not eligible for public dental care, and many who were eligible sought private dental care. Private dental care is the predominant mode of dental service delivery in Australia. While wait lists do not exist in the

private sector, waiting times for an appointment can vary. However, expressed demand is associated with household income, and price rations services and choice among alternatives for those making a dental visit (Manski *et al.*, 2012).

The study findings indicate that oral health inequalities may reflect dental disease management as opposed to dental disease *per se* and that lower social position may not necessarily translate into higher disease experience, but instead influences the use and nature of dental services received. The “equality” in disease experience favors population oral health promotion strategies, because everyone’s risk needs to be lowered, shifting the distribution for the whole population. The inequality in access/treatment additionally favors policy that tackles barriers to comprehensive and appropriate care, which, based on these results, is disproportionately affecting lower income groups.

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