Changing Inequalities in the Distribution of Caries Associated with Improving Child Oral Health in Australia

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Abstract

Objectives: *This study aimed to document the changing distribution of and inequalities in dental caries in Australian children across the 25-year period from 1977 to 2002.* ***Methods:*** *Oral health data were obtained from Australia's national Child Dental Health Survey. Measures of caries distribution included the Significant Caries Index and the proportions of children with high caries experience [decayed, missing and filled teeth (DMFT) ≥4], while inequality was assessed by using Gini coefficients calculated from Lorenz curves. Changes in caries distribution were compared with changes in child dmft/DMFT.* ***Results:*** *While appreciable reductions occurred in child caries experience, in terms of both mean dmft/DMFT and for those children with the poorest oral health, inequalities in the distribution of caries experience increased across the 25-year period. Inequalities in the distribution of decayed and filled teeth differed for the deciduous and permanent dentition and, in the permanent dentition, became increasingly similar in the 1990s.* ***Conclusions:*** *Increasing inequalities in child dental caries in Australia must be interpreted in the context of declines in both mean caries experience and in the caries experience of those children with the poorest oral health. The Gini coefficient documents that the majority of the caries experience is increasingly being confined to a smaller percentage of the child population; however, this is a consequence of population-wide child oral health improvements.*

Key Words: dental caries, inequalities, public health dentistry, children, Gini coefficient, Australia

Introduction

Reducing health inequalities is generally regarded as a worthy and vital public health goal. While inequalities can relate to differences in health outcomes between subpopulations as defined by socioeconomic, ethnic, or geographic groups, inequalities in the distribution of diseases across an entire population are also worth investigating. Indeed, studying health inequalities across individuals has been recommended as a starting point for research because studies of social group health differences tend to prejudge causality, which discourages scientific investigation into other key determinants of health inequalities (1). Consistent with this argument, the World Health Organization (WHO) has now given health inequality a central place in the WHO framework for assessing health system performance (2). Inequality in the distribution of disease indicates an increased susceptibility for a given section of the population and may point to the need for greater targeting of preventive or treatment services to those people at greater risk.

One of the most common chronic diseases affecting Western countries is dental disease, and, in Australia, dental problems comprise one of the most commonly reported medical conditions among children aged 0-14 years (3). The societal cost of dental disease is often considerable. In Australia, it was estimated that the direct costs of dental disease to the health-care system in 2005-06 totaled over \$5.3 billion (4), equivalent to about 1/15th of all spending on health care across that period. These costs do not include indirect costs to individuals (5).

Despite child caries experience having decreased appreciably in Australia since recordings commenced in the post-World War II period (6), it remains the case that a small percentage of children account for a large amount of the disease experience. For example, Armfield found that 20 percent of 6-year-olds accounted for 90 percent of the decayed, missing, and filled deciduous teeth (dmft) of the entire 6-year-old age group, while 35 percent of 12-year-olds accounted for 90 percent of the decayed, missing, and filled permanent teeth (DMFT) in that age group (7). The Significant Caries Index (SiC), a measure of the caries experience of the one-third of a population with the most caries (8), reveals that there is a segment of the child population with appreciably more caries experience than indicated by population means (9).

While examining the distribution of caries experience allows for an insight into the inequalities in dental disease within a population, it is important that these inequalities be quantitated. One way to examine inequality in the distribution of caries is to plot a Lorenz curve of the continuous distribution frequency of disease experience. This allows the calculation of the Gini coefficient,

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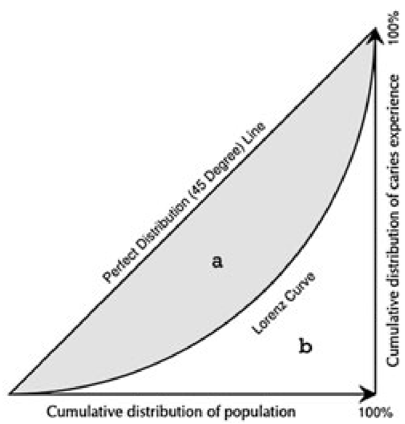
Figure 1
Lorenz curve for calculating Gini coefficient



which is a ratio derived from areas under and over the Lorenz curve compared with a uniform distribution line, which effectively represents no inequality (Figure 1). The greater the distance of the Lorenz curve from the diagonal uniform distribution line, the greater the inequality. While the Gini coefficient was first described in the 1920s (10) and has frequently been used to characterize a nation's income inequality, the first study using the Gini coefficient to investigate oral health did not occur until the mid-1990s (11). Since that time, however, an increasing number of studies have reported on Lorenz curves and the Gini statistic as they apply to caries distributions (12-20). For example, Weyent *et al.* used Lorenz curves to compare caries inequalities of 1st- and 11th-grade children (19), while other studies have compared Gini coefficients across fluoridated and nonfluoridated areas (13,20).

Inequality as determined by the Gini coefficient should be viewed as separate from the level of disease in a population because the Gini coefficient reflects inequality to the extent that dental disease is not uniformly distributed. A coefficient of 0, or perfect equality, would occur if every person had exactly the same level of disease, whether this is a DMFT of 0, or a DMFT of 20. Maximum inequality, indicated by a Gini value of 1, would occur if all diseases are in one individual with DMFT >0.

Although work has been produced documenting long-term declines in caries experience in a number of countries, much less attention has been paid to changes in childhood caries inequalities over time. The only research on changing inequalities in the distribution of disease comes from Brazil. Antunes and colleagues, for example, found that, while 12-year-old DMFT declined between 1998 and 2002, inequalities as measured using the Gini coefficient actually increased (12). They attributed this to improved preventive treatments, greater access to fluoridated water, and new dental education initiatives not being distributed homogeneously through the population. They also argued that greater understanding of the skewed distribution of caries experience demands the monitoring of inequalities in the distribution of caries. It is the case that improvements in oral health for a child population may not be shared equally by all children within that population. Therefore, although child caries has been declining in Australia, it is of value to examine whether these improvements have been accompanied by either an increase or a decrease in caries inequality.

This study explored inequalities in the distribution of child dental caries in Australia across the period from 1977 to 2002. Caries distribution was examined by using both the proportion of children with high caries experience and the SiC. Inequalities in the caries distribution were measured by using the Gini coefficient.

Methods

The study involved a secondary analysis of data collected as part of the evaluation component of the Australian School Dental Scheme (ASDS) and the Child Dental Health Survey. The ASDS evaluation data covered the period from 1977 to 1988 and were collected by the then Australian Commonwealth Department of Health (CDH). The ASDS entailed a national dental program for school-age children, providing free preventive and treatment services. In 1989, child oral health data collected from children attending the school dental services of Australia's states and territories came under the responsibility of the Australian Institute of Health and Welfare (AIHW) Dental Statistics and Research Unit, which has provided yearly reports on child oral health since that time. Unit data obtained from the CDH were extracted from magnetic tapes. However, unit-record data could not be retrieved for all of Australia for the years 1978, 1980, 1986, and 1987 because of the degraded state of the tapes. All oral health data were collected by the staff of the school dental services (SDS) from each state and territory and provided under agreement to either the CDH or the AIHW for use. At times, and in some jurisdiction, additional sociodemographic information has been collected alongside oral health information; however, the lack of consistent available data precludes the use of such variables in examining some factors that might underlie the long-term trends in caries inequalities. Sample sizes by individual year of age and year of available data are provided in Table 1. Unless stated otherwise, data for each year were available for each of Australia's eight states and territories. The number of 4- to 14-year-old children participating in the survey ranged from 45,765 in 1994 to 954,727 in 1985.

Since the school dental services were established, target populations and coverage have varied across the states and territories. In particular, while most school dental services cover the primary-school-age children population, there are appreciable differences in the coverage of high-school- or secondary-school-age children. It should be recognized that, while children examined within the SDS in any Australian state or territory in any year are generally representative of children enrolled in the SDS in that jurisdiction, they may not be representative of all children residing in the state or territory.

Table 1
Number of Children by 2-Year Age Groups for Each Year of Data Included in the Study

	Age					
Year	5-6 years old	7-8 years old	9-10 years old	11-12 years old	13-14 years old	Total
1977	62,986	70,403	60,296	47,464	5,716	246,865
1979*	45,052	56,366	53,263	33,272	1,838	189,791
1981	182,909	219,885	228,163	165,017	16,717	812,691
1982	191,896	229,020	241,523	182,387	16,713	861,539
1983	215,116	245,880	249,344	195,884	20,046	926,270
1984	206,469	232,239	228,697	177,073	21,663	866,141
1985	231,373	244,413	244,463	183,625	25,132	929,006
1988	98,214	95,053	91,138	67,810	15,038	367,253
1989	18,683	18,746	18,282	18,618	16,698	91,027
1990	18,339	19,015	18,720	19,237	17,579	92,890
1991	28,378	31,373	29,597	22,929	7,533	119,810
1992	13,102	12,956	12,587	12,726	11,527	62,898
1993	13,142	12,996	12,625	12,765	11,563	63,091
1994†	8,641	8,543	8,302	8,399	7,574	41,459
1995	8,838	8,740	8,490	8,584	7,775	42,427
1996	13,938	13,585	13,621	13,728	13,753	68,625
1997	14,521	14,497	14,231	14,418	14,530	72,197
1998	13,799	14,936	14,951	14,243	14,521	72,450
1999	60,724	68,302	69,166	63,138	69,066	330,396
2000	26,448	56,381	57,323	52,550	59,407	252,109
2001‡	17,202	23,628	21,142	18,843	21,429	102,244
2002‡	20,274	25,047	25,817	23,638	26,427	121,203

* Data not available from South Australia, Western Australia, Tasmania, or the Northern Territory.
† Data not available from Tasmania.
‡ Data not available from New South Wales.

However, the extent of this variation cannot be determined as no parallel population-level child oral health data collections are undertaken. Differences in recall intervals are also apparent across Australia's states and territories. Nonetheless, all school dental services provide diagnostic, preventive, and treatment services to enrolled children where necessary.

The dental outcomes for the study were a) the number of decayed, missing, and filled teeth in both the deciduous (dmft) and permanent dentition (DMFT); b) the percentage of children with high caries experience (dmft ≥4 or DMFT ≥4); c) the SiC; and d) the Gini coefficient for the caries distribution. Counts of the number of decayed, missing, and filled teeth were provided by dentists or dental therapists as part of a child's scheduled dental examination. Epidemiological guidelines were made available to examiners and were based on WHO international standards in effect at the time of the examination (21-23).

The SiC is calculated as the mean dmft or DMFT of the one-third of children with the most caries experience and was developed by Bratthall as a way of bringing attention to those people with the worst oral health within a population (8). The SiC was calculated by using a Microsoft Excel (Microsoft Corporation, Seattle, WA, USA) spreadsheet available from the WHO Collaborating Centre in Malmo University, Sweden, downloadable at (http://www.whocollab.od.mah.se/expl/siccalculation.xls). The Gini coefficient was calculated after first plotting the Lorenz curve representing the cumulative frequency of deciduous dmft for 5- to 6-year-olds and permanent DMFT for 11- to 12-year-olds. The Gini coefficient was calculated by dividing the area between the 45° diagonal and the Lorenz curve by the area under the 45° diagonal [$a/(a+b)$ in Figure 1], with scores ranging from 0 to 1, with 0 representing perfect equality and scores closer to 1 representing greater inequality. An SPSS (Chicago, IL, USA) syntax file was created to calculate the Gini coefficient, and values were cross-checked by using an Excel spreadsheet for computing Gini coefficients made available online by José Antunes from the University of Sao Paulo in Brazil (http://www.fo.usp.br/arquivos/Gini_calculation_for_caries_distribution.zip).

An example of the data setup for calculation of a Gini coefficient is given in Table 2. The example data are based on the distribution of 11- to 12-year-old DMFT in 1977. After sorting DMFT scores from lowest to highest, the cumulative percentage of total DMFT and the cumulative percentage of the total population could be calculated. The data points from the example can be plotted to obtain the Lorenz curve.

Results

Table 3 shows deciduous caries experience indices for children aged 5-6 years, 7-8 years, and 9-10 years. For 5- to 6-year-olds and 7- to 8-year-olds mean dmft decreased across the

Table 2
Example Data Used for Deriving a Lorenz Curve of the Cumulative % of DMFT against Cumulative % of the Sample

DMFT	*n*	Cumulative *n*	Cumulative DMFT	Cumulative % sample	Cumulative % DMFT
0	5,441	5,441	0	0.13	0.00
1	2,972	8,413	2,972	0.20	0.02
2	3,924	12,337	10,819	0.29	0.06
3	4,548	16,885	24,462	0.39	0.13
4	10,731	27,616	67,388	0.65	0.37
5	4,182	31,798	88,298	0.74	0.49
6	3,201	34,999	107,504	0.82	0.59
7	2,139	37,138	122,477	0.87	0.67
8	1,809	38,947	136,948	0.91	0.75
9	1,033	39,980	146,246	0.93	0.80
10	808	40,788	154,331	0.95	0.85
11	485	41,273	159,668	0.96	0.88
12	418	41,691	164,688	0.97	0.91
13	344	42,035	169,157	0.98	0.93
14	208	42,243	172,068	0.99	0.95
15	117	42,360	173,825	0.99	0.96
16	133	42,493	175,949	0.99	0.97
17	71	42,564	177,160	0.99	0.97
18	92	42,656	178,818	1.00	0.98
19	56	42,712	179,874	1.00	0.99
20	27	42,739	180,407	1.00	0.99
21	20	42,759	180,824	1.00	0.99
22	8	42,767	180,991	1.00	1.00
23	14	42,781	181,314	1.00	1.00
24	9	42,790	181,541	1.00	1.00
25	9	42,799	181,771	1.00	1.00
26	1	42,800	181,806	1.00	1.00
27	1	42,801	181,843	1.00	1.00
28	1	42,802	181,873	1.00	1.00

Note: Data used are 11- to 12-year-old DMFT for 1977.
DMFT, decayed, missing, and filled permanent teeth.

period from 1977 to 1996. However, a series of increases followed in 2002. For 9- to 10-year-olds, a similar pattern was observed, except that the lowest mean dmft was seen in 2000. For both the SiC and percent dmft ≥4, the lowest levels of caries experience occurred in the same year as the lowest mean dmft, with increases again seen in the years following. Decreases in mean dmft between 1977 and those years with the least recorded caries experience were 55.2, 49.7, and 44.6 percent for 5- to 6-year-olds, 7- to 8-year-olds, and 9- to 10-year-olds, respectively. These exceeded reductions in the SiC across the same period, which were 43.9, 32.8, and 29.1 percent for the corresponding age groups. The percentage of children with dmft ≥4 decreased by more than half for all age groups, from 37.4 to 14.9 percent and from 44.6 to 19.7 percent for 5- to 6-year-olds and 7- to 8-year-olds, respectively, between 1977 and 1996, and from 34.9 to 16.7 percent for 9- to 10-year-olds between 1977 and 2000. The increase in mean dmft for 5- to 6-year-olds and 7- to 8-year-olds between 1996 and 2002, back to the levels of caries experience seen in the early 1990s, was almost identical to the trend seen for both SiC and percent dmft ≥4. For 9- to 10-year-olds, mean dmft, SiC, and percent dmft ≥4 all increased between 2000 and 2002 to approximately those levels of disease seen in 1995.

Similar levels of concordance are also evident between DMFT, SiC, and percent DMFT ≥4 in the permanent dentition for all three age groups (Table 4). The lowest levels of caries for each measure occurred for the same year within each age group. In addition, the subsequent increase in caries experience in 2002 brought each index to a similar level as seen in 1992 for 9- to 10-year-olds and 1995/96 for both 11- to 12-year-olds and 13- to 14-year-olds. Reductions in SiC and percent DMFT ≥4 were substantially larger in the permanent dentition than was shown in the deciduous dentition. The SiC decreased by 74.2, 71.6, and 69.7 percent for the three consecutive age groups between 1977 and the year with the least disease experience (1996 for 9- to 10-year-olds and 1998 for both 11- to 12-year-olds and 13- to 14-year-olds). The percentage of children with percent DMFT ≥4 showed remarkable reductions across the same periods, reducing

Table 3
Deciduous Caries Experience Indices, 1977-2002

	5- to 6-year-olds			7- to 8-year-olds			9- to 10-year-olds		
Year	dmft	SiC	% dmft ≥4	dmft	SiC	% dmft ≥4	dmft	SiC	% dmft ≥4
1977	3.06	7.13	37.4	3.36	6.90	44.6	2.67	5.70	34.9
1979	2.95	7.18	35.3	2.99	6.48	39.1	2.43	5.37	30.8
1981	2.60	6.57	31.1	2.97	6.54	39.1	2.43	5.42	31.0
1982	2.51	6.41	29.9	2.93	6.53	38.4	2.48	5.55	32.0
1983	2.29	6.02	26.9	2.78	6.33	36.2	2.45	5.55	31.6
1984	2.19	5.79	25.7	2.62	6.16	33.6	2.37	5.47	30.4
1985	2.04	5.49	23.7	2.51	5.98	32.0	2.32	5.42	29.6
1988	1.84	5.10	20.9	2.13	5.41	26.1	2.00	4.96	24.7
1989	2.10	5.72	23.3	2.34	5.85	29.1	2.08	5.17	25.2
1990	1.98	5.43	22.2	2.26	5.70	26.9	2.04	5.09	24.6
1991	1.89	5.23	21.2	2.25	5.67	27.4	2.05	5.11	25.0
1992	1.86	5.21	20.7	2.06	5.34	25.3	1.90	4.76	23.0
1993	1.83	5.14	20.5	2.08	5.38	25.0	1.93	4.86	23.1
1994	1.74	4.89	19.1	2.09	5.37	25.0	1.89	4.83	22.5
1995	1.63	4.62	17.9	1.97	5.15	23.7	1.80	4.64	21.5
1996	**1.37**	**4.00**	**14.9**	**1.69**	**4.64**	**19.7**	1.61	4.34	19.2
1997	1.40	4.10	**14.9**	1.72	4.65	19.8	1.62	4.33	19.1
1998	1.44	4.17	15.7	1.72	4.67	20.3	1.55	4.16	17.9
1999	1.53	4.38	16.7	1.75	4.72	20.3	1.50	4.09	17.1
2000	1.56	4.44	17.2	1.80	4.85	21.5	**1.48**	**4.04**	**16.7**
2001	1.85	5.13	20.6	2.25	5.69	27.3	1.77	4.57	21.3
2002	1.89	5.27	21.4	2.27	5.77	27.6	1.79	4.62	21.0

Note: Each number in bold text indicates the lowest value for an index between 1977 and 2002.
DMFT, decayed, missing, and filled permanent teeth dmft, decayed, missing, and filled deciduous teeth SiC, Significant Caries Index.

Table 4
Permanent Caries Experience Indices, 1977-2002

	9- to 10-year-olds			11- to 12-year-olds			13- to 14-year-olds		
Year	DMFT	SiC	% DMFT ≥4	DMFT	SiC	% DMFT ≥4	DMFT	SiC	% DMFT ≥4
1977	2.83	5.08	43.8	4.25	7.70	60.6	5.97	10.82	71.2
1979	2.34	4.78	34.6	3.52	6.60	50.5	4.80	9.33	60.3
1981	1.80	4.03	23.9	2.81	5.39	40.7	4.18	7.91	56.1
1982	1.64	3.82	20.9	2.58	5.12	36.7	3.82	7.36	51.7
1983	1.40	3.44	16.3	2.22	4.72	29.8	3.47	6.90	46.5
1984	1.15	3.04	11.6	1.90	4.34	23.8	3.05	6.28	39.9
1985	1.07	2.86	10.4	1.79	4.17	21.6	2.69	5.80	34.8
1988	0.81	2.34	6.7	1.32	3.43	13.7	2.20	5.10	26.9
1989	0.74	2.17	5.6	1.46	3.68	16.6	2.51	5.80	33.4
1990	0.72	2.16	5.3	1.50	3.85	13.9	3.06	6.87	38.8
1991	0.63	1.88	4.0	1.08	2.88	9.5	1.85	4.43	19.6
1992	0.61	1.83	3.9	1.18	3.19	12.1	2.01	4.89	22.7
1993	0.58	1.75	3.6	1.05	2.86	9.4	1.67	4.37	18.1
1994	0.56	1.69	3.4	1.01	2.78	8.7	1.88	4.42	19.2
1995	0.51	1.55	3.1	0.90	2.55	7.7	1.67	4.14	19.5
1996	**0.44**	**1.31**	**2.3**	0.79	2.30	5.9	1.31	3.57	**11.4**
1997	0.47	1.40	2.6	0.76	2.24	5.8	1.38	3.69	13.1
1998	0.49	1.48	2.8	**0.74**	**2.19**	**5.5**	**1.21**	**3.28**	11.9
1999	0.47	1.42	2.9	0.76	2.24	5.9	1.30	3.55	12.0
2000	0.45	1.36	2.7	**0.74**	2.22	5.9	1.24	3.39	12.3
2001	0.57	1.71	3.8	0.84	2.40	6.7	1.57	4.09	16.0
2002	0.60	1.80	4.0	0.87	2.47	6.9	1.55	4.05	15.5

Note: Each number in bold text indicates the lowest value for an index between 1977 and 2002.
DMFT, decayed, missing, and filled permanent teeth dmft, decayed, missing, and filled deciduous teeth SiC, Significant Caries Index.

from 43.8 to 2.3 percent in 1996 for 9- to 10-year-olds, from 60.6 to 5.5 percent in 1998 for 11- to 12-year-olds, and from 71.2 to 11.4 percent in 1996 for 13- to 14-year-olds. However, declines in mean DMFT were also substantial, being 84.5, 82.6, and 79.7 percent between 1977 and 1996 for 9- to 10-year-olds and 11- to 12-year-olds, and between 1977 and 1998 for 13- to 14-year-olds.

Despite significant reductions between 1977 and the mid- to late 1990s in caries experience in both the deciduous and permanent dentitions, the inequality in disease experience as measured by the Gini Index has increased. In the deciduous dentition of 5- to 6-year-olds, the Gini coefficient increased from just under 0.6 in 1977 to just under 0.8 in 1997 before declining to 0.73 in 2002 (Figure 2). Comparison of the Gini coefficient with the mean dmft indicates that inequalities initially increased as decay experience decreased, with inequalities only starting to reduce when caries experience started increasing in the mid 1990s. In the permanent dentition, the more even distribution of disease experience in 1977 (Gini coefficient = 0.4) becomes more unequal over time, reaching 0.78 in 2000 (Figure 3). Again, the Gini coefficient mirrors the mean DMFT, increasing across the 25-year period as caries experience declined.

Breaking the dmft index into decayed and filled components revealed greater inequality in the distribution of filled teeth than of decayed teeth (Figure 4). The Gini coefficient for the distribution of decayed deciduous teeth for 5- to 6-year-olds increased from 0.68 in 1977 to 0.82 in 1996 and 1997, but, across the period 1985 to 2002, there was very little variation. Similarly, although the Gini coefficient for the mean number of filled deciduous teeth ranged from 0.81 in 1982 to 0.91 between 1996 and 2000, in contrast to results for deciduous dmft, there was relatively little variation between 1988 and 2002.

Figure 2
Gini coefficients and mean decayed, missing, and filled permanent teeth (DMFT) of 11- to 12-year-old children, 1977-2002

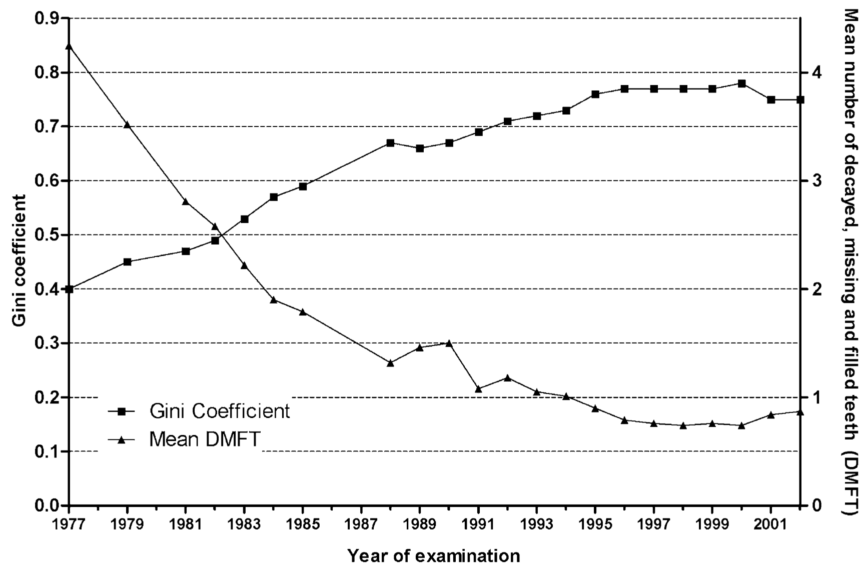


Figure 3
Gini coefficients and mean decayed, missing, and filled deciduous teeth (dmft) of 5- to 6-year-old children, 1977-2002

In the permanent dentition of 11- to 12-year-olds, greater inequalities were evident in the distribution of decayed than filled teeth (Figure 5). A large difference between the Gini coefficients computed for decayed and for filled teeth was evident during the 1970s and 1980s. However, this gap narrowed during the 1990s so that, by 1998, the Gini coefficients for both components of the DMFT index were equal. Increases in the Gini coefficient for both the mean numbers of decayed and filled teeth were considerable across the 25-year period and ranged from 0.65 (in 1977) to 0.88 (in 1996) for the decayed component, and from 0.59 (in 1977) to 0.86 (from 1998 to 2001) for the filled component.

Figure 4
Gini coefficients for mean number of decayed and filled deciduous teeth of 5- to 6-year-old children, 1977-2002

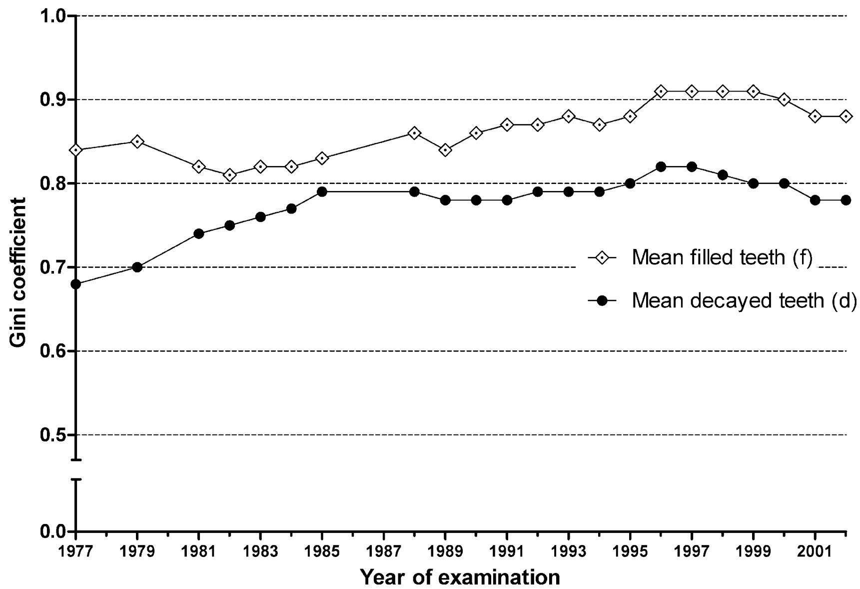


Figure 5
Gini coefficients for mean number of decayed and filled permanent teeth of 11- to 12-year-old children, 1977-2002

Discussion

This study found substantial changes in the distribution of dental caries in Australian children over time as well as changes in inequality across the period from 1977 to 2002. Despite the substantial decline in both deciduous and permanent caries experience across the 25-year period and reductions in disease experience among those children with the most caries, inequalities have shown corresponding increases.

Differences were found between the Gini coefficients for decayed compared to filled teeth over time. In the deciduous dentition of 5- to 6-year-olds, greater inequalities were evident for filled teeth than for decayed teeth, and this probably reflects the higher experience of decayed teeth than filled teeth. For example, in the primary dentition of 5- to 6-year-olds in Australia in 2002, approximately 65 percent of caries experience was recorded as decay (9). However, in the permanent dentition of 11- to 12-year-olds, greater inequalities were apparent in the distribution of decayed teeth than filled teeth. In contrast to the deciduous dentition, filled teeth comprise a greater percentage of the total caries experience in the permanent dentition, and this becomes more so across increasingly older age groups (9). That the temporal trends in Gini coefficients for decayed and filled deciduous teeth parallel one another indicates that changes in the distributions of decayed and restored deciduous teeth have been similar across the 25-year period covered by the data. However, in the permanent dentition, while reductions in untreated decay occurred relatively rapidly after the introduction of the School Dental Services, reductions in the number of filled teeth took much longer to occur. This may reflect the capacity of treatment and utilization decisions to significantly reduce the decayed component of the DMFT index in contrast to the cumulative nature of the count of filled permanent teeth.

While understanding oral health equalities and inequalities cannot be reasonably divorced from an understanding of the oral health of the entire population, it is also the case that measures of average disease experience are no longer considered a sufficient indicator of a nation's health performance (24). Health inequalities are increasingly seen as a distinct dimension relevant to the performance of health systems (25). In Australia, the desirability of public health initiatives to simultaneously address inequalities is becoming increasingly emphasized.

There is a tendency to assume, when looking at inequality in disease, that equality is a worthwhile and desirable outcome whereas inequality is an undesirable outcome. However, it should be noted that equality in disease outcome does not necessarily represent a beneficial outcome in and of itself. If, for example, an entire child population had very high numbers of decayed, missing, and filled teeth, the disease distribution could be said to be very equitable, yet it would also be the case that overall child oral health was very poor. In a similar vein, there would be perfect equality of disease experience whether all children had no carious teeth or whether all children had maximum caries experience, yet the difference in population child oral health could not possibly be greater. Indeed, inequality perhaps only becomes a real issue once there has been a substantial improvement in oral health – it is only when enough of the population have good oral health that we need to start considering those who have not benefited as part of the general improvements. In any event, when using statistical tools to measure inequality, it is worth remembering that inequality is not the same as inequity and that inferences about the "fairness" or otherwise of distributions without reference to contextualizing data are inappropriate (26).

Inequalities in this article were measured by using the Gini coefficient. While this has been the main measure of inequality in caries distribution presented in the literature to date, it has not been universally accepted. For example, Nugent *et al.* have developed the Dental Health Inequality Index (DHII) which compares the area under the Lorenz curve to a Poisson distribution of disease experience rather than to straight-line equivalence (16). The authors' argue that the Poisson distribution is theoretically "fair," in contrast to the idea of an equitable distribution of disease used for calculation of the Gini coefficient. Comparisons of the Gini coefficient and the DHII using children from Michigan in the United States show that the DHII is lower than the Gini coefficient and that these differences increase as the caries prevalence decreases (27). However, Antunes *et al.* found a very high correlation ($r = 0.95$) between the Gini coefficient and the DHII, concluding that these tools could be used interchangeably for assessing inequality in the distribution of dental disease (13). It seems then that, although the DHII may move the standard for equality in the distribution of disease, it differs little from the Gini Index when used to make comparisons across time.

Despite its increasing use in the literature, there are several issues to take into account when using the Gini coefficient as a measure of equality and inequality. First, it must be remembered that the Gini coefficient focuses on equality rather than on general oral health outcomes – all people having the maximum amount of disease and all people having no disease are both taken to indicate perfect equality. Inequality is not wholly meaningful if removed from the context of other disease measures. Second, the coefficient weights the results away from equality at the low caries end and toward inequality at the highest end of the caries distribution. This can be appreciated in the following hypothetical example. Say, 99.9 percent of children have no caries experience with 1 in 1,000 having a DMFT of 1. The Gini coefficient would indicate almost perfect inequality with a coefficient of 0.999. However, if 99.9 percent of children had a DMFT of 1 and only 1 in 1,000 children had a DMFT of 0, the Gini coefficient becomes 0.001, indicating almost perfect equality. This is despite the fact that 99.9 percent of the children have the same DMFT in each of the scenarios. Equality of disease trumps equality of health because the coefficient is measuring the percentage of children with a certain percentage of disease. Third, and as hinted by the example just given, almost any improvement in oral health results in a more inequitable distribution when using the Gini coefficient. As higher percentages of children attain a cavity-free dentition, the Gini coefficient necessarily increases. It becomes almost impossible to reduce caries in the population while, at the same time, reducing inequalities.

The use of the Gini coefficient to quantitate the inequality in the distribution of dental disease is at odds with its use in the medical literature where it has been advanced as a way of measuring the association between exposure to a risk factor and disease prevalence (28,29). According to this approach, a larger Gini coefficient would mean that the risk of disease is more variable in the population, while a smaller coefficient, resulting from a "flatter" Lorenz curve, indicates a more uniform distribution in disease risk (28). It has been argued that using the Lorenz curve and Gini Index overcomes some of the shortcomings of measures such as relative and attributable risk. This approach clearly deviates from that used by dental researchers, and followed here, where the Lorenz curve represents the association between the distribution of disease and that of people with the disease. However, and despite the problems with using the Gini coefficient as a measure of caries inequality, it does provide a useful disease burden description and adds statistical credibility to statements about cumulative disease burdens (27). There is considerable policy value in understanding the extent to which disease experience is concentrated in a relatively small percentage of children and in quantitating the extent to which this occurs.

Knowledge of inequalities in the distribution of child caries must inevitably invite the question as to the causes of this phenomenon. Certainly, access to dental services cannot be the answer, as all the children included in this study had access to and were receiving examinations within the SDS. While some children may have also been seeing private dentists, there is no available information to determine any differences in private dentist visiting patterns between children with better or poorer oral health. Similarly, information on socioeconomic status is not available to examine its possible role in explaining dental caries inequalities. While some school dental services collect information on whether children qualify for means-tested health-care cards, a possible proxy for household income, this is in only a small number of jurisdictions and only collected by SDSs that have recently commenced moving away from universal free coverage.

Ultimately, inequalities in child oral health will always exist as long as children experience caries. In all societies, some children will suffer varying extents of dental decay, while others will be decay free. There is an expansive body of literature reporting risk factors for caries experience. For example, child-rearing practices, including transmission of oral bacteria and amount and timing of exposure to cariogenic foodstuffs and drinks, are associated with variable levels of risk. In contrast, differences in the amount and timing of exposure to fluoridated toothpaste, water fluoridation, and other fluoride vehicles will confer variable preventive benefits. Visiting the dentist is also known to be beneficial, with dentists and therapists able to provide several effective preventive services, whether fissure sealants, topical fluoride or other applications, or appropriate oral health advice and instruction.

Several changes are likely to have occurred over the time period covered by this study. Across the 25-year period from 1977 to 2002, lifetime exposure to water fluoridation and fluoride from toothpaste increased for successively older cohorts of children. In addition, there has been a generational change with parents desiring their children to have better oral health than they themselves had as children, leading perhaps to increased diligence in child toothbrushing supervision. These changes have moved the entire child caries distribution "to the left," with increasingly large percentages of children being caries free across the entirety of their childhood. This population-level improvement in child oral health has, as a by-product, led to greater inequality in the caries distribution. And it is inevitable that, if child dental health continues to improve, the remaining caries experience will, of necessity, become increasingly concentrated in smaller and smaller percentages of the child population. Indeed, even if caries could be eliminated in those children with the poorest oral health, inequalities as measured by the Gini coefficient would either change little or increase slightly because of the resultant population caries experience being concentrated in a smaller percentage of the child population. It is for this reason that equality in the caries distribution should not be seen as a desirable end point in and of itself (unless that means the total eradication of caries) but as a useful statistic that measures the concentration of caries in a population. Measures such as the Gini coefficient require interpreting within the context of the overall state of child oral health.

This study has several limitations. First, because of the very large number of dentists and dental therapists employed in the school dental services around Australia, it is not feasible to bring these people together for clinical standardization and calibration. As a result, inter-examiner reliability cannot be determined. However, as there are generally similar training and examination conditions across and within Australia's states and territories, variation between examiners would be expected to be minimal with any variation unlikely to be a source of bias. Second, available information on the sociodemographic, geographic, or socioeconomic circumstances of the children, as well as dental utilization behavior outside of the school dental services, is not consistently available and cannot therefore further inform the analyses carried out here.

In conclusion, although this study found decreases in the caries experience of those Australian children with the worst caries experience over a 25-year period, these reductions were exceeded by the decreases in the mean number of decayed, missing, and filled teeth for all children across the same period. Inequality in the distribution of dental caries in Australia between 1977 and 2002 has increased although the use of measures such as the Gini coefficient should be interpreted in the context of other measures of disease, which shows tremendous child oral health improvements across the 25-year period being examined. Although there has been a decline in caries experience from levels seen in 1977, more still need to be carried out to help the minority of children who bear the majority of the burden of dental disease in Australia.

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