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Background: Previous research suggests there are significant differences between socio-economic groups in prevalence and amount of decayed missing and filled primary teeth (d3mft). The aim of this study was to describe the variation in obvious tooth decay experience amongst 5-year olds in Scotland and to look at the association between d3mft and deprivation in Scotland. Methods: Data derived from 1993 to 2003 National Dental Inspection Programme were modelled using Bayesian multilevel zero-inflated Negative Binomial models, adjusting for age, sex and the deprivation. Results: Deprivation is positively and significantly associated with having d3mft; the odds of a child in DepCat 7 (most deprived) having d3mft in 1993 were 7.49 (5.03–11.15) that of a child in DepCat 1 (most affluent). Inequalities in the prevalence of d3mft have reduced and in 2003 the odds of a child in DepCat 7 having d3mft were 4.60 (3.47–6.14) that of a child in DepCat 1. However, socio-economic inequalities in the amount of d3mft for those with d3mft have seen no reduction and have in fact increased between 1993 and 2003, with this increase approaching significance. Conclusion: While socio-economic inequalities in prevalence of children with d3mft have decreased in recent years, socio-economic inequalities in the amount of d3mft for those with d3mft persist. This suggests that improvements are only seen for those children with the potential for low d3mft. High d3mft persists among children from more deprived areas. The national target conceals this apparent inconsistency.

Keywords: oral health, dental caries, inequalities, multilevel modelling.

Introduction

The British Association for the Study of Community Dentistry (BASCD) in conjunction with the National Health Service (NHS) co-ordinates a series of annual epidemiological surveys of caries prevalence to monitor the dental health of children in the United Kingdom.1 Indices of d3mft (decayed into dentine, missing and filled primary teeth) and D3MFT (decayed into dentine, missing and filled permanent teeth) are recorded by region and comparisons can be drawn between geographies and over time.2,3

The measures principally reported by BASCD, recommended by the World Health Organization (WHO), are mean d3mft/D3MFT and d3mft/D3MFT prevalence, i.e. the percentage of those children who have d3mft/D3MFT > 0. Recent reports have shown that the last two decades have seen decreases in the prevalence and incidence of d3mft in 5-year-old children in Great Britain. More recently this decrease has levelled off. This is in line with findings of other countries in Western Europe where a decline in caries prevalence was observed in the latter half of the 20th century.4 The shape of the decline varied across countries but for most was seen to stabilise at a low average count of caries.

In Scotland, mean d3mft and the prevalence of d3mft amongst 5-year olds has historically been higher than in England and Wales. To combat this, a target was set by the Scottish Office in 1991 that 60% of children would have d3mft = 0 by the year 2000.5 This was not achieved and the target was re-set for the year 2010.6 Caries prevalence in Scotland remains relatively high compared with other parts of Great Britain; in 2004 the average number of d3mft for 5-year olds was 2.367 compared with 1.55 for England and Wales.7 Decline in d3mft though slow has persisted over time, however, as has the increase in the proportion of children without experience of caries into dentine (d3mft = 0). A change in the BASCD definition of dental caries occurred in 1992. Prior to this caries was recorded only once cavitation had occurred. After 1992, caries which had not yet cavituated, but which in the opinion of the examiner clearly extended into dentine was included as ‘visual caries’.8

Socio-economic inequalities in mortality and morbidity exist in Scotland for a range of conditions and have been rising for almost a quarter of a century.9,10 The health of those living in the most deprived areas is poor compared with those living in affluent areas. The most deprived areas of Scotland are concentrated for the most part in the central belt of Scotland, with 76% of postcode sectors and 75% of the population defined as most deprived found in Greater Glasgow NHS Board.11 Geographic variations in health are also thought to exist and are greater in Scotland than any other part of the UK.12 Socio-economic and geographic inequalities in dental health have been observed in the UK in previous cross-sectional studies.13–15 In Scotland in the 1980s the greatest improvement in dental health occurred among the most affluent.

This previous research suggests there are significant differences between deprivation categories in the prevalence and amount of d3mft. The aim of this study was to describe the variation in dental caries experience amongst 5-year olds in Scotland and to look at the variation within and across deprivation categories in Scotland.
Methods

The data used in this study were collected biennially by the Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) surveys conducted at four time points between 1993 and 1999 and from its successor, the National Dental Inspection Programme (NDIP), carried out in 2002/2003 and 2003/2004; six cross-sectional surveys in all. The surveys were conducted on random samples of primary school children aged ~5 years, using a two-stage sampling technique under SHBDEP guidelines and sampling of school classes under NDIP.

Scotland is divided into 895 postcode sectors with a population average of approximately 5500. Postcode sectors are nested within 15 NHS boards. The survey data were collected by examiners recruited within each NHS board. The Carstairs Indicator is a measure of deprivation, produced decennially using data collected by the UK Censuses on the basis of four components: car ownership, low social class, male unemployment and overcrowding. The 1991 and 2001 Carstairs Indicators, calculated from the 1991 and 2001 Censuses were both included in this analysis, in categorical form, ranging from most affluent (DepCat 1) to most deprived (DepCat 7).

Mean d3mft and the prevalence of d3mft, i.e. the percentage of those with d3mft > 0, were calculated for each of the six surveys of 5-year-old children between 1993 and 2003, and by deprivation category using the 1991 Carstairs Indicator for 1993 and 1995 surveys and the 2001 Carstairs Indicator for 1997–2003 surveys. As samples were drawn within each NHS board these were not proportionally represented within the dataset and analysis had to be weighted to ensure that the statistics produced were representative of the Scottish 5-year-old population. The distribution across deprivation categories was then compared over time to assess the change in inequalities.

Data were modelled using multilevel Binomial modelling in computer package MLwiN and multilevel Negative Binomial modelling using the Hurdle approach for zero-inflated counts in WinBUGS. The hurdle approach treats the dataset as two independent processes, modelling zeros and count data independently of one another, so that the first process is equivalent to a multilevel binary model with outcome variable d3mft = 0/d3mft > 0, and the second process is equivalent to zero-truncated Negative Binomial modelling. Both zero-inflated Negative Binomial modelling and multilevel modelling techniques to take account of the clustered nature of the data have been employed previously in the analysis of dental data, although to our knowledge there have been no previous attempts to model dental data using multilevel zero-inflated Negative Binomial models.

The data were first modelled separately by year and then together in an all-years model. For the most part models in this analysis had four levels: NHS Boards, examiner, school and child. In 1993 no examiner or school information was recorded, therefore only two levels were included for this time point. In the remaining five survey years the number of schools ranged from 241 to 327. Similarly, examiner information recorded in 2003 was sparse, therefore only three levels were included. The number of examiners included in the all-years model was greater than the number in reality, as examiners were assigned codes at each survey independently of previous years. Coding examiners as different over time may result in underestimation of variance attributed at the examiner level. However, examiners performance between surveys does vary between years. An extreme example could be where an examiner previously considered the 'gold standard' subsequently fails to calibrate in later exercises.

Results

Table 1 gives a breakdown of the samples surveyed at each of the six time points between 1993 and 2003. There was a clear downward trend in both mean d3mft and the proportion of children with obvious decay experience (d3mft > 0 for) all of Scotland over time, with just a slight increase between 1999 and 2002.

<table>
<thead>
<tr>
<th>Year</th>
<th>1993</th>
<th>1995</th>
<th>1997</th>
<th>1999</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sample</td>
<td>5656</td>
<td>6776</td>
<td>6551</td>
<td>6768</td>
<td>9858</td>
<td>8346</td>
</tr>
<tr>
<td>Number (Weighted%) with d3mft &gt; 0</td>
<td>3397 (61.8)</td>
<td>3992 (58.8)</td>
<td>3733 (56.8)</td>
<td>3652 (55.0)</td>
<td>5626 (55.3)</td>
<td>4119 (49.2)</td>
</tr>
<tr>
<td>Mean d3mft</td>
<td>3.21</td>
<td>2.93</td>
<td>2.70</td>
<td>2.56</td>
<td>2.36</td>
<td>2.36</td>
</tr>
<tr>
<td>Mean d3mft (and percentage with d3mft &gt; 0)</td>
<td>1.43 (35.1)</td>
<td>1.44 (37.4)</td>
<td>1.20 (35.1)</td>
<td>1.15 (33.9)</td>
<td>1.21 (36.0)</td>
<td>1.00 (30.3)</td>
</tr>
<tr>
<td>DepCat 1</td>
<td>1.73 (44.6)</td>
<td>1.95 (47.1)</td>
<td>1.57 (41.7)</td>
<td>1.53 (40.0)</td>
<td>1.73 (42.2)</td>
<td>1.43 (34.8)</td>
</tr>
<tr>
<td>DepCat 2</td>
<td>2.56 (58.5)</td>
<td>2.40 (52.3)</td>
<td>2.27 (51.3)</td>
<td>2.12 (49.5)</td>
<td>2.04 (45.0)</td>
<td>1.76 (40.7)</td>
</tr>
<tr>
<td>DepCat 3</td>
<td>2.30 (63.8)</td>
<td>3.09 (61.0)</td>
<td>2.61 (57.9)</td>
<td>2.57 (56.0)</td>
<td>2.87 (57.2)</td>
<td>2.63 (55.8)</td>
</tr>
<tr>
<td>DepCat 4</td>
<td>3.72 (68.8)</td>
<td>3.43 (65.8)</td>
<td>3.04 (61.7)</td>
<td>2.97 (64.2)</td>
<td>3.21 (62.5)</td>
<td>2.84 (55.4)</td>
</tr>
<tr>
<td>DepCat 5</td>
<td>3.85 (73.6)</td>
<td>3.67 (68.4)</td>
<td>3.49 (66.7)</td>
<td>3.63 (69.2)</td>
<td>3.61 (65.8)</td>
<td>3.21 (59.3)</td>
</tr>
<tr>
<td>DepCat 6</td>
<td>5.02 (81.1)</td>
<td>4.79 (79.8)</td>
<td>4.68 (78.1)</td>
<td>4.75 (79.0)</td>
<td>4.52 (77.6)</td>
<td>4.09 (69.6)</td>
</tr>
</tbody>
</table>
Table 1 shows that mean d₃mft and the prevalence of d₃mft decreased between 1993 and 2003 for all seven DepCats. The greatest absolute (1.12) and relative (39%) reductions in mean d₃mft were observed for DepCat 3. The absolute difference in mean d₃mft between DepCat 7 and DepCat 1 fell from 3.59 (5.02–1.43) in 1993 to 3.09 (4.09–1.00) in 2003. The absolute difference in prevalence of d₃mft between DepCat 7 and DepCat 1 fell from 46% (81–35%) in 1993 to 39% (70–30%) in 2003. The ratio of DepCat 7 to DepCat 1 which has been used in previous research as a measure of health inequalities in 1993 was 3.5 for mean d₃mft and 2.3 for prevalence of d₃mft. In 2003 these ratios were 4.1 and 2.3, respectively. This indicates no change in inequalities in the prevalence of d₃mft but an increase in inequalities in mean d₃mft.

This approach, however, using the ratio of DepCat 7 to DepCat 1 to measure socio-economic inequalities in health, does not consider data for middling categories, corresponding to 85.2% of postcode sectors and 87.1% of the population in 2001. Nor does it adjust for age and sex, which were significant in the models presented in table 2 and had a marked impact on the relationship between the outcome and year.

Table 2 presents ORs for the zero-inflated part of the hurdle models, equivalent to modelling binary outcome measure d₃mft = 0/d₃mft > 0. Adjusting for year as a continuous variable, the odds of d₃mft > 0 were 0.72 those of a decade previous (not shown), in line with the findings of table 1. This decrease is more apparent after adjusting for age, sex, reducing the odds of d₃mft > 0 to 0.64 those of a decade previous. Model 1 of table 2 included all the data and adjusted for age, sex and year of survey with year a categorical variable only, the odds of having d₃mft increased with age. In addition, it was found that the odds of having d₃mft were significantly lower for females. The odds of having d₃mft decreased over time and the year-on-year trend is apparent.

Models 2–7 shown in table 2 adjusted for Carstairs deprivation category. The odds of having d₃mft increased with deprivation category for all years (Models 2–7). The odds of having d₃mft for those in DepCat 1 in 1993 (Model 2) and fell to 4.60 those of DepCat 1 by 2003 (Model 7). An increase was seen, however, between 1995 and 1997. The results for the equivalent multilevel Binomial model (not shown) were similar to those seen in table 2.

The odds of having d₃mft for those in DepCat 7 relative to DepCat 1 seem to reduce over time (table 2). However, to investigate if these reductions are significant, all data must be modelled together and an interaction term between deprivation category and year included. An interaction term between year and deprivation category is a measure of the change over time in inequalities relative to DepCat 1. When this was modelled, significant reductions in inequalities were observed over time, for those in DepCat 7 relative to DepCat 1. This is shown in table 3 with year as a continuous variable. The OR can be interpreted as a year-on-year reduction in inequalities between DepCat 1 and DepCat 7 so that relative inequalities in d₃mft are 0.96 (0.66) those of the previous year (decade). When categorical year was used instead (too cumbersome to tabulate) a significant reduction in inequalities between 1993 and 2003 was also observed for DepCats 3 and 6 relative to DepCat 1. Socio-economic inequality in the prevalence of d₃mft has therefore decreased over time.

Table 4 presents Relative Risks (RRs) for the Negative Binomial part of the hurdle models, equivalent to outcome variable d₃mft for those with d₃mft > 0. In Model 1, the RR of

<table>
<thead>
<tr>
<th>Table 2 ORs for the zero-inflated part of the hurdle model, equivalent to outcome d₃mft = 0/d₃mft &gt; 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: 1.39 0.95 0.98 0.82 0.79 0.59 0.59</td>
</tr>
<tr>
<td>All years (1.31–1.48) (0.92–0.99) (0.83–1.18) (0.76–1.08) (0.69–0.98) (0.66–0.94) (0.49–0.71)</td>
</tr>
<tr>
<td>Model 2: 1.46 1.54 2.31 3.13 4.12 5.08 7.49</td>
</tr>
<tr>
<td>1993 (1.22–1.74) (0.83–1.03) (1.12–2.13) (1.70–3.18) (2.29–4.32) (2.98–5.72) (5.03–11.15)</td>
</tr>
<tr>
<td>Model 3: 1.30 1.46 1.84 2.69 3.11 3.40 5.69</td>
</tr>
<tr>
<td>1995 (1.10–1.54) (1.07–1.98) (1.37–2.47) (2.00–3.60) (2.25–4.30) (2.47–4.69) (3.99–8.17)</td>
</tr>
<tr>
<td>Model 4: 1.53 1.00 1.90 2.56 3.15 3.48 6.53</td>
</tr>
<tr>
<td>1997 (1.30–1.80) (0.90–1.11) (1.45–2.50) (1.95–3.40) (2.38–4.22) (2.58–4.72) (4.77–8.94)</td>
</tr>
<tr>
<td>Model 5: 1.43 1.33 1.94 2.54 3.49 4.53 6.25</td>
</tr>
<tr>
<td>1999 (1.21–1.69) (0.91–1.12) (1.46–2.56) (1.91–3.38) (2.57–4.76) (3.26–6.33) (4.32–9.12)</td>
</tr>
<tr>
<td>Model 6: 1.29 1.40 1.77 2.52 3.26 3.63 5.80</td>
</tr>
<tr>
<td>2002 (1.12–1.47) (1.01–1.92) (1.29–2.38) (1.86–3.41) (2.36–4.48) (2.59–5.04) (4.17–8.31)</td>
</tr>
<tr>
<td>Model 7: 1.54 1.16 1.58 2.86 3.05 3.30 4.60</td>
</tr>
<tr>
<td>2003 (1.34–1.78) (0.80–0.97) (0.90–1.50) (1.25–2.01) (2.26–3.66) (2.37–3.96) (2.53–4.34) (3.47–6.14)</td>
</tr>
</tbody>
</table>

a: Reference category is Male
b: Reference category is 1993
c: Reference category is DepCat 1

Table 3 ORs of all-data model interaction term Year:DepCat for the binary outcome d₃mft = 0/d₃mft > 0, equivalent to year-on-year change in inequalities relative to DepCat 1

<table>
<thead>
<tr>
<th>DepCat 2:Yeara</th>
<th>DepCat 3:Yeara</th>
<th>DepCat 4:Yeara</th>
<th>DepCat 5:Yeara</th>
<th>DepCat 6:Yeara</th>
<th>DepCat 7:Yeara</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.98 (0.95–1.01)</td>
<td>0.97 (0.94–1.00)</td>
<td>0.99 (0.96–1.02)</td>
<td>0.98 (0.95–1.01)</td>
<td>0.98 (0.94–1.01)</td>
<td>0.96 (0.93–0.99)</td>
</tr>
</tbody>
</table>

a: Reference category is DepCat 1: Year

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a proportional increase in $d_{3mft}$ fell over time; in 2003 it was 0.91 (0.86–0.96) that of 1993. The RR of an increase in $d_{3mft}$ increased with deprivation category for all years other than 1993 (Models 3–7). The RR of an additional $d_{3mft}$ for those in DepCat 7 was 1.53 that of DepCat 1 in 1993 (Model 2). This small rise in RR between 1993 and 2003 approached significance and was also observed for DepCats 4, 5 and 6 relative to DepCat 1. Inequalities in the amount of $d_{3mft}$ did not decrease over time, in fact the pattern is one suggesting an increase which could become significant over a longer time period.

### Discussion

Dental caries is an infectious and multifactorial disease whose risk factors such as age, sex, socio-economic status, oral hygiene, use of fluorides, frequency of toothbrushing and diet have been extensively studied. The number of children free of dentinal caries has increased, resulting in increased polarisation of the disease so that a large amount of the disease is now found in a small proportion of children, primarily of low socio-economic status in many countries worldwide. Area deprivation has also been shown to be associated with oral health outcomes among adults.

The data from 1993 to 2003 dental surveys of children in Scotland used in this study indicate that both the prevalence and amount of dental caries have increased with age. The risk of high levels of d3mft remain concentrated within the least affluent DepCats. It is likely that there is a complex interplay of determinants. The need for intensive strategies directed high-risk groups or individuals has been discussed previously with conflicting results. Burt suggests that a combination of population based measures and high-risk targeting is the best way forward. High-risk targeting has proved to be effective in bringing about dental health improvements in one particularly deprived area of Glasgow through the use of Oral Health Action Teams. This study suggests targeted high-risk strategies may be suitable in addressing existing inequalities which are currently masked by the prevalence measure used.

### Limitations

The first limitation is the suitability of using the 1991 and 2001 Carstairs Indicators to monitor changes over time. McLoone showed that there were some changes in areas’ level of deprivation between the 1991 and 2001 Censuses. He discussed the difficulty in using the Carstairs Indicator over time and recommended that it be used as a relative measure of

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**Table 4 RRs for the Negative Binomial part of the Hurdle model, equivalent to count outcome d3mft for those with d3mft > 0**

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>1995</th>
<th>1997</th>
<th>1999</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>1.06</td>
<td>0.94</td>
<td>0.96</td>
<td>0.92</td>
<td>0.90</td>
<td>0.91</td>
</tr>
<tr>
<td>All years</td>
<td>(1.03–1.09)</td>
<td>(0.93–0.96)</td>
<td>(0.91–1.01)</td>
<td>(0.87–0.97)</td>
<td>(0.85–0.95)</td>
<td>(0.89–0.99)</td>
</tr>
</tbody>
</table>

RRs (credible intervals in brackets) of an additional $d_{3mft}$ for those with $d_{3mft} > 0$ by year of survey adjusting for age–sex and deprivation category

<table>
<thead>
<tr>
<th>Age</th>
<th>Female</th>
<th>DepCat 2</th>
<th>DepCat 3</th>
<th>DepCat 4</th>
<th>DepCat 5</th>
<th>DepCat 6</th>
<th>DepCat 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>(0.99–1.15)</td>
<td>(0.92–1.01)</td>
<td>(0.81–1.16)</td>
<td>(1.09–1.52)</td>
<td>(1.06–1.49)</td>
<td>(1.12–1.57)</td>
<td>(1.08–1.54)</td>
</tr>
<tr>
<td>1995</td>
<td>(0.98–1.12)</td>
<td>(0.89–0.97)</td>
<td>(0.88–1.18)</td>
<td>(0.99–1.29)</td>
<td>(1.06–1.39)</td>
<td>(1.11–1.46)</td>
<td>(1.15–1.50)</td>
</tr>
<tr>
<td>1997</td>
<td>(1.06–1.22)</td>
<td>(0.90–0.99)</td>
<td>(0.93–1.25)</td>
<td>(1.11–1.45)</td>
<td>(1.16–1.52)</td>
<td>(1.24–1.64)</td>
<td>(1.30–1.72)</td>
</tr>
<tr>
<td>1999</td>
<td>(1.01–1.17)</td>
<td>(0.92–1.01)</td>
<td>(0.97–1.32)</td>
<td>(1.08–1.45)</td>
<td>(1.16–1.54)</td>
<td>(1.21–1.63)</td>
<td>(1.33–1.79)</td>
</tr>
<tr>
<td>2002</td>
<td>(0.98–1.10)</td>
<td>(0.89–0.95)</td>
<td>(0.99–1.37)</td>
<td>(1.07–1.45)</td>
<td>(1.20–1.62)</td>
<td>(1.24–1.68)</td>
<td>(1.33–1.81)</td>
</tr>
<tr>
<td>2003</td>
<td>(1.02–1.15)</td>
<td>(0.92–1.00)</td>
<td>(1.05–1.39)</td>
<td>(1.13–1.46)</td>
<td>(1.21–1.56)</td>
<td>(1.29–1.68)</td>
<td>(1.38–1.80)</td>
</tr>
</tbody>
</table>

**a:** Reference category is Male

**b:** Reference category is 1993

**c:** Reference category is DepCat 1
deprivation within each year as was carried out in this study to avoid spurious results arising from using an incorrect deprivation measure at any time point.

A second limitation was the lack of examiner and school level data for 1993 and examiner information for 2003. This was unavoidable as the data were not available for these years. The examiner level was not significant for most of the Binomial and Negative Binomial Hurdle models; however, it is difficult to know the impact of excluding the school information in 1993.

Conclusions

This study shows that a full picture of inequalities is only seen when not only child prevalence of d3mft, but amount of d3mft is examined. Having d3mft prevalence as a national target provides little incentive to reduce inequalities in amount of d3mft, and may indirectly cause inequalities in amount of d3mft to persist or even increase. The results from this study suggest that a high-risk approach, focusing on children with at least 1 d3mft, is necessary to achieve more equity in dental health. Further research is required to look into why some children may be more prone to disease within deprivation categories, as well as methodical issues around analysing dental data.

Acknowledgements

The author wishes to thank the schoolchildren who took part in the study, the dentists and scribes, all Scottish NHS Boards and The Dental Health Services Research Unit, University of Dundee.

Conflicts of interest: None declared.

Key points

- This study shows that although inequalities in the prevalence of d3mft have reduced with time, inequalities in the amount of d3mft for those with d3mft > 0 persist and may increase.
- This suggests that the measure and methodologies used worldwide to monitor population levels of d3mft may be inappropriate for measuring inequalities in dental caries experience.

References

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36 Hudson K, Stockard J, Ramberg Z. The impact of socio-economic status and those with at least one $d_{ijkl}$ ($d_{ijkl} = 0$) and those with at least one $d_{ijkl}$ ($d_{ijkl} = 1$). Thus

$$d_{ijkl} \sim \text{Bern}(\pi_{ijkl})$$

$$\logit(\pi_{ijkl}) = \beta_{0ijkl} + \beta_{1}X_{ijkl} + \ldots + \beta_{k}X_{kijkl}$$

$$\beta_{ijkl} = \beta_{0} + u_{ijkl} + v_{ijkl} + f_{ijkl}$$

The second stage is negative binomial with the same predictors and with truncated sampling (confined to values 1 and above). Thus

$$y_{ijkl} \sim \text{NB}(\mu_{ijkl}, \delta)(1,1)$$

$$\log(\mu_{ijkl}) = \gamma_{0ijkl} + \gamma_{1}X_{ijkl} + \ldots + \gamma_{k}X_{kijkl}$$

$$\gamma_{ijkl} = \gamma_{0} + u_{ijkl} + v_{ijkl} + f_{ijkl}$$

A vague gamma distributed prior is set on

$$\delta \sim \text{Ga}(0.01, 0.01)$$

Random effects are distributed normally as

$$u_{ijkl} \sim N(0, \tau_{u})$$

$$v_{ijkl} \sim N(0, \tau_{v})$$

$$f_{ijkl} \sim N(0, \tau_{f})$$

with gamma priors on the precisions of the variance components

$$\tau_{u}, \tau_{v}, \tau_{f} \sim \text{Ga}(0.001, 0.001)$$

A similar model was fitted to all of the data combined (model 1 in table 3) which included predictors for age, sex and year of survey (categorical).

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**Appendix 1**

**Dental Notation**

$d_{ijkl}$: The number of primary (or baby) teeth a child has that are decayed into the dentine, missing or filled.

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**Statistical Notation**

A Bayesian negative binomial hurdle model for excess zeros, as described by Congdon, was fitted to the data at each time point (Models 2–7 in table 3). The four level models include random effects for the $i$th child within the $j$th school under the $k$th examiner within the $l$th health board. A binary model with eight predictors ($X_1 = \text{Age}$, $X_2 = \text{Female}$, $X_3 = \text{DepCat2}$, $X_4 = \text{DepCat3}$, $X_5 = \text{DepCat4}$, $X_6 = \text{DepCat5}$, $X_7 = \text{DepCat6}$, $X_8 = \text{DepCat7}$) is used to model the first stage of the NB hurdle model, i.e. the distinction between no $d_{ijkl}$ ($d_{ijkl} = 0$) and those with at least one $d_{ijkl}$ ($d_{ijkl} = 1$). Thus

$$d_{ijkl} \sim \text{Bern}(\pi_{ijkl})$$

$$\logit(\pi_{ijkl}) = \beta_{0ijkl} + \beta_{1}X_{ijkl} + \ldots + \beta_{k}X_{kijkl}$$

$$\beta_{ijkl} = \beta_{0} + u_{ijkl} + v_{ijkl} + f_{ijkl}$$

The second stage is negative binomial with the same predictors and with truncated sampling (confined to values 1 and above). Thus

$$y_{ijkl} \sim \text{NB}(\mu_{ijkl}, \delta)(1,1)$$

$$\log(\mu_{ijkl}) = \gamma_{0ijkl} + \gamma_{1}X_{ijkl} + \ldots + \gamma_{k}X_{kijkl}$$

$$\gamma_{ijkl} = \gamma_{0} + u_{ijkl} + v_{ijkl} + f_{ijkl}$$

A vague gamma distributed prior is set on

$$\delta \sim \text{Ga}(0.01, 0.01)$$

Random effects are distributed normally as

$$u_{ijkl} \sim N(0, \tau_{u})$$

$$v_{ijkl} \sim N(0, \tau_{v})$$

$$f_{ijkl} \sim N(0, \tau_{f})$$

with gamma priors on the precisions of the variance components

$$\tau_{u}, \tau_{v}, \tau_{f} \sim \text{Ga}(0.001, 0.001)$$

A similar model was fitted to all of the data combined (model 1 in table 3) which included predictors for age, sex and year of survey (categorical).