Community Dent Oral Epidemiol 2007; 35: 118–129

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

Area deprivation and oral health in Scottish adults: a multilevel study

Elizabeth Bower[1], Martin Gulliford[2], Jimmy Steele[3] and Tim Newton[1]

[1]Department of Oral Health Services Research and Dental Public Health, King's College London Dental Institute, London, UK
[2]Division of Health and Social Care Research, King's College London, London, UK
[3]School of Dental Sciences, University of Newcastle upon Tyne, Newcastle, UK

Bower E, Gulliford M, Steele J, Newton T. Area deprivation and oral health in Scottish adults: a multilevel study. Community Dent Oral Epidemiol 2007; 35: 118–129. © Blackwell Munksgaard, 2007

Abstract – *Objectives:* To explore the association between area deprivation and adult oral health. *Methods:* Multilevel regression analysis of data taken from the 1998 Adult Dental Health Survey in the UK comprising 632 participants living in 346 households located in 31 postcode sectors in Scotland. Three oral health outcomes were investigated: number of sound (including restored) teeth; has one or more unsound teeth; has periodontal pocketing 4 mm or more in one or more teeth. *Results:* In the most deprived areas, individuals had a mean of 4.6 fewer sound teeth than those in the least deprived areas. The difference in normalised number of sound teeth between least and most deprived areas was −0.707 (95% CI −1.164, −0.250), $P = 0.024$. After adjusting for age, sex, qualification status, head of household social class and household income, the estimated difference was −0.238 (−0.591 to 0.115) ($P = 0.164$). Area deprivation was not associated with having one or more unsound teeth or periodontal pocketing 4 mm or more in one or more teeth. *Conclusions:* There is a univariate association of area deprivation with the number of sound teeth. This association is largely explained by household and individual level socioeconomic variables. A small area deprivation effect cannot be excluded in these data. The findings challenge current understanding of the relationship between area deprivation and oral health. Further multilevel research exploring the relationship between area deprivation and oral health is required using a larger sample and a prospective longitudinal design.

Key words: multilevel modelling; oral health; social context; social deprivation; social determinants of health

Elizabeth Bower, Department of Oral Health Services Research and Dental Public Health, King's College London Dental Institute, Caldecot Road, London SE5 9RW, UK
Tel: 0203 299 3481
Fax: 0203 299 3409
e-mail: elizabeth.bower@kcl.ac.uk

Submitted 31 October 2005;
accepted 14 April 2006

It has been recognised for many years that an individual's oral health may be influenced by his or her social context (1–3). Yet in the main, research into the social determinants of oral health has conceptualised and measured oral disease at the individual level, neglecting contextual effects on oral health (4). More recently, however, there have been suggestions that oral epidemiology should pay greater attention to the role of contextual factors in shaping oral health (5, 6). Area deprivation is one such factor. There are no commonly accepted definitions of area deprivation (7), but it is has been conceptualised as a multidimensional phenomenon reflecting the lack of access to material resources and social participation in a geographical area (7–9).

Most of the research exploring the relationship between area deprivation and oral health has been conducted in children. The studies fall into two broad groups: ecological and individual level studies. Findings from the ecological studies are contradictory. Most suggest a clear relationship between area deprivation and caries prevalence and severity in children (10–12). However, a study examining 6–12-year-old children living in Brazil failed to show a relationship between area deprivation and mean dmft scores (13). In the individual level studies, clear relationships were found between area deprivation and childhood dental caries (14–17). There is also some evidence for a relationship between area deprivation and traumatic dental injuries in children (18). Research on the

relationship between dental erosion in children and area deprivation is contradictory. Some studies suggested a positive relationship (19, 20), one study found a negative relationship (21), and a further study found a weak and inconsistent relationship (22). School deprivation status was not associated with the gingival health of children examined in the 2003 Children's Dental Health Survey in the UK (22).

There is some evidence for a relationship between oral health and area deprivation in adults. This comes from individual-level studies. Adults living in deprived areas had more oro-facial pain than those living in affluent areas in a postal questionnaire-based study conducted in the north-west of England (23). Area deprivation was associated with self-reported oral health status in two studies based in Canada (24, 25). However, in an English study looking at the relationship between area deprivation and oral health using clinical indices and an oral health-related quality of life measure, no differences in clinical outcomes were observed according to deprivation score, and only three out of the eight quality of life measures showed any differences (26). No studies examining the relationship between periodontal disease and area deprivation were found. There is some evidence that area deprivation is a risk factor for oral cancer (27, 28).

Thus, there are clear variations in oral health outcome according to area deprivation, particularly in children. What is not clear is whether the area deprivation effect is valid. It is possible that the unfavourable oral health outcomes found in deprived communities reflect differences in the socioeconomic and behavioural characteristics of individuals who live in such communities (compositional effect) rather than differences in the physical and social features of the neighbourhood (contextual effect) (29). The effect of area deprivation may be exaggerated by the selection bias of unhealthy individuals being left behind in less privileged social groups while more healthy/dynamic individuals move on to other areas (30).

The potential bias of uncontrolled socioeconomic differences at the individual/household level is found in many of the studies reviewed above. Only one study investigating dental caries in children (17) and two studies exploring self-reported oral health in adults (24, 25) included both individual level socio-economic factors and area deprivation scores in the regression analyses. In all three studies, neighbourhood deprivation had a significant effect on the oral health outcome after adjusting for individual/household socioeconomic factors. However, the studies in adults did not include clinical data and the findings only pertained to participants aged 50 years or over. Thus, the evidence for an area deprivation effect on oral health over and above individual/household level socioeconomic characteristics is relatively weak.

The rapidly expanding literature on the effects of area deprivation on general health suggests that area deprivation has a significant impact on health outcomes over and above individual or family level characteristics (31–34). However, area deprivation may be less important than individual and family level characteristics in influencing health outcomes (31). Current research is moving beyond the simple quantification of area deprivation effects and is attempting to examine how neighbourhood level and individual level factors are interrelated (35). For example, what are the processes by which area deprivation impacts on the health of individuals? Are the same processes applicable to all social groups? Are certain types of individuals protected from the impact of area deprivation and what individual level characteristics provide such protection? (33, 36–37).

It is clear that further research into the impact of area deprivation on oral health is required. If oral health is the outcome of an interaction between individual and area level factors, it may be necessary to target features of the environment in order to reduce oral health inequalities (7). Until recently, such research has been hampered by the limitations of standard regression analysis. Research into contextual effects usually results in clustered data. The assumption of independence of observations is then violated, resulting in an underestimation of the SE of regression coefficients and a greater chance of type 1 errors (38). Thus, an area deprivation effect may be exaggerated. Even if the observations are truly independent, the disaggregation of group level data to the individual level and application of standard regression analysis methods to the data rests on the possibly erroneous assumption that contextual factors operate in the same way for all social groups (39). For example, the impact of area deprivation on oral health may be greater for people from the lower social classes rather than those from professional and managerial backgrounds. An ecological approach overcomes the problem of clustering, but the aggregation of data may result in a loss of statistical power. The role of individual level variables in shaping health

outcomes is also ignored (35). Where there are a small number of groups, defining separate regression coefficients for each group works well. However, this method is not practical where there is a large number of groups, or small numbers of participants in each group (35).

Multilevel modelling overcomes these difficulties by allowing the simultaneous examination of the effects of contextual and individual level predictors. Variance is partitioned into contextual and individual levels. This provides a helpful estimate of the magnitude of contextual effects as well as reducing the likelihood of type 1 statistical errors. Interactions between contextual and individual level predictors can also be explored (40). Whilst multilevel modelling is now used regularly in periodontal research (41, 42), it has had little application in research exploring the social determinants of oral health other than a study exploring the association between school environment and childhood traumatic dental injury (43). This study uses multilevel modelling to explore the association between area deprivation and oral health outcomes in adults.

Method

Data

The data were taken from the 1998 Adult Dental Health Survey in the UK (44). This is the only dataset available in the UK, which has both individual/household level socioeconomic indices and area level deprivation scores available and provides clinical oral health data on adults. The survey was undertaken by the Office for National Statistics in collaboration with the dental schools of Birmingham, Dundee, Newcastle-upon-Tyne and Wales. At the first stage 76 postcode sectors in England, 32 postcode sectors in Scotland and 16 postcode sectors in Wales were selected from a list stratified by region (Government Office Regions), socioeconomic group and car ownership. Forty addresses within each sector were then selected. This gave a total of 4960 sampled addresses. Interviewers were sent to each address to seek interviews with all adults aged 16 or over living there. Eleven per cent of these addresses did not contain an eligible household. Of the remaining eligible addresses, 21% refused to take part and 5% could not be contacted; 3666 households responded. A total of 6764 adults were found in the remaining addresses. Of these, 6204 (92%) agreed to be interviewed about dental issues. A total of 5281 adults had one or more natural teeth. Of these dentate adults, 3817 (72%) had a dental examination in addition to being interviewed about their dental health. Further details regarding the conduct of the study, calibration of examiners, etc. are detailed elsewhere (44).

The data subset analysed in this study consisted of 632 dentate participants living in 346 households located in 31 postcode sectors in Scotland who had a dental examination. The Scottish data subset was selected from the whole as this was the only data in the survey to have area deprivation scores available, which corresponded to the postcode sectors. Data from one postcode sector in Scotland were not included in the analysis as the area deprivation scores were mixed within the sector.

Oral health outcomes

Three outcome measures were chosen:

- number of sound teeth (including restored sound teeth);
- one or more unsound teeth;
- periodontal pocketing 4 mm or greater on one or more teeth.

The number of sound teeth (including restored sound teeth) corresponds to the 'number of functioning teeth' (FS-T), a composite indicator of dental health (45). FS-T is more sensitive than the sum of decayed, missing and filled teeth (DMFT) in identifying social and behavioural risk factors significantly related to oral health (45).

The variables 'one or more unsound teeth' and 'periodontal pocketing 4 mm or greater on one or more teeth' represent the presence of unrestored dental caries and periodontal disease history, respectively. Continuous data on the number of unsound teeth and the number of teeth with pocketing 4 mm or greater did not transform to a normal distribution using a variety of different transformations. One solution is to transform the data into an ordinal scale and undertake multilevel modelling for ordered categorical responses (40). However, as there were very small numbers of participants in categories representing high levels of caries or severe periodontal disease, the models did not converge. Thus, the number of unsound teeth and the number of teeth with pocketing 4 mm or greater were re-coded into the dichotomous variables 'one or more unsound teeth' and 'periodontal pocketing 4 mm or greater on one or more teeth', respectively. The thresholds for dichotomising the continuous data on caries and periodontal

disease corresponded to those in the 1998 Adult Dental Health Survey (44).

Missing data

There were missing data relating to head of household social class (7.9%), weekly household income (7.6%) and periodontal pocketing (7.4%). A missing data analysis was undertaken. Forty-eight per cent of missing social class data was due to the head of the household having never worked. There were missing social class data in all the age groups but participants in the 16–24 age group had the largest proportion of missing data (20.7%). There were no observable patterns with regard to missing income data. Missing periodontal data were due to a medical history problem, which prevented the periodontal examination being conducted. Participants with missing periodontal data had a mean age of 52.4 years compared with the general mean of 42.8 years. The area deprivation profile of participants with missing data and those with complete data differed. There was a loss of participants from the most affluent areas; 57% participants with missing socioeconomic data lived in Depcat areas 1–3, whereas 49% participants with complete data lived in those areas. Participants with missing socioeconomic data had slightly more sound teeth (mean 23.2 teeth) than those with complete data (mean 22.3 teeth). They were much less likely to have periodontal pocketing 4 mm or more (34.1%) then those with complete data (50.7%), and much less likely to have one or more unsound teeth (38%) than those with complete data (47.3%). Only complete data were analysed. The net effect of the missing data was a loss of participants with better oral health, and a loss of participants from the most affluent areas.

Statistical methods

A three level random intercepts model (individual, household and area) was fitted for each oral health outcome (Null model). Households were included as a separate level in the model because of evidence of a significant degree of clustering at the household level in similar surveys (46). The variable 'number of sound teeth' was treated as a continuous variable. A normal scores transformation was used to achieve normal distribution of the residuals (40). Normal probability plots, in which the ranked residuals are plotted against corresponding points on a normal distribution curve, were used to verify the assumption of normality of the residuals at each level (38). Logistic multilevel regression modelling was used for the binary outcomes.

Carstairs and Morris area deprivation scores based on 1991 census data were added to the Null model for each oral health outcome in order to assess the association with area deprivation without other covariates (Model 1). The deprivation index is based on four factors in the postcode sector: level of overcrowding in households; male unemployment; proportion of social classes IV and V; and the proportion of persons in private households with no car. The index consists of seven deprivation categories (Depcat 1 = least deprived, Depcat 7 = most deprived) (47). Because of the low numbers of participants in Depcat areas 1,6 and 7, the area deprivation score was re-categorised into five groups with Depcat 1–2 and Depcat 6–7 areas combined.

Individual and household level explanatory variables were then added to the null model for each oral health outcome (Model 2). Individual level explanatory variables included age, sex and level of educational qualification [no qualifications, below degree level, and degree level and above]. The relationship between age and the number of sound teeth (normal scores transformation) was found to be linear. Household level explanatory variables were head of household social class [Registrar General classification, grouped into I-IIINM, IIIM, IV-V] and weekly household income. The relationship between weekly household income and the number of sound teeth (normal scores transformation) was not linear and so the continuous income variable was grouped into quintiles.

In order to assess if area deprivation contributed to any of the area level variance in oral health outcome in Model 2, the five-category area deprivation scores were added to Model 2 for each oral health outcome (Model 3).

There were no *a priori* expectations of cross level interaction effects and it was assumed that the only variation between households and between areas was in their intercepts. Thus, random slopes models were not fitted.

Multicollinearity analyses included calculation of the variance inflation factor (VIF) for each explanatory variable (48). The highest VIF score was 1.212, which is satisfactory (49). The stability of model estimates for differing subsets of covariates was also observed (48). There was no reversal of the relationship between any

independent variable and outcome variable when other covariates were added to the models, which again suggests that assumptions about multicollinearity were met (48).

Regression estimates were calculated by means of the reweighted iterative generalised least square algorithm using MLwiN 2.02 (50). In the multilevel logistic regression models, second order PQL estimation was used (40). The statistical significance of individual parameters was calculated using the Wald test (38). The statistical significance of area deprivation was calculated using the likelihood ratio test for the outcome 'number of sound teeth'. For the binary outcomes, the significance of area deprivation was assessed using the Wald test, which is appropriate for testing two or more estimates simultaneously (33, 40).

Results

Participants had an average of 22.3 sound teeth (SD = 6.86). Adults from the most affluent areas (Depcat 1) had an average of 23.2 teeth compared with those from the most deprived areas (Depcat 7) who had an average of 17.3 teeth (Table 1). The relationship between area deprivation and the number of sound teeth was significant ($P = 0.024$) when other covariates were not considered (Model 1, Table 2). However, the reduction in area variance from 0.062 in the Null model to 0.020 in Model 2 (Table 2) suggests that some of the area variation in outcome was associated with the clustering of individual and household sociodemographic characteristics. Increasing age, membership of social classes IV-V, having a low household income and achieving no qualifications was significantly associated with having fewer sound teeth in Model 2 (Table 2). Area deprivation did not significantly contribute to a reduction in area level variance in Model 3 (Table 2) ($P = 0.164$). Thus, the apparent relationship between area deprivation and the number of sound teeth did not remain when the clustering of individual and household characteristics was taken into account.

Two hundred and ninety-one participants (46.0%) had one or more unsound teeth. The numbers of participants with one or more unsound teeth living in each deprivation category are shown in Table 1. In contrast to the outcome 'number of sound teeth', the odds of having one or more unsound teeth did not significantly increase ($P = 0.405$) when area deprivation was the only predictor in the model (Model 1, Table 3). A low household income significantly increased the odds of having one or more unsound teeth in Model 2 (Table 3), but no other individual/household variables were significant. Area deprivation did not significantly contribute to a reduction in area level variance in Model 3 (Table 3) ($P = 0.773$).

Two hundred and eighty-six participants (48.9%) had periodontal pocketing 4 mm or more in one or more teeth. The numbers of participants with periodontal pocketing 4 mm or more living in each deprivation category are shown in Table 1. As with the outcome 'one or more unsound teeth', the odds of having periodontal pocketing 4 mm or more did not significantly increase ($P = 0.409$) when area deprivation was the only predictor in the model (Model 1, Table 4). Age was the only individual/household level factor to significantly increase the odds of having periodontal pocketing of 4 mm of more (Model 2, Table 4). There was little change in the substantial area variance when area deprivation was added in Model 3 (Table 4) ($P = 0.581$).

Table 1. The relationship between area deprivation and oral health outcome

Area deprivation (number of participants)	Mean number of sound teeth (SD)	Number of participants with one or more unsound teeth (%)	Number of participants with periodontal pocketing 4 mm or more in one or more teeth (%)
Depcat 1 (55) (least deprived)	23.2 (7.99)	23 (41.8)	12 (23.5)
Depcat 2 (93)	24.2 (6.33)	32 (34.4)	37 (44.6)
Depcat 3 (168)	22.5 (6.52)	78 (46.4)	93 (59.2)
Depcat 4 (101)	23.3 (5.98)	45 (44.6)	31 (33.3)
Depcat 5 (166)	21.3 (7.15)	85 (51.2)	83 (54.2)
Depcat 6 (27)	20.8 (6.18)	15 (55.6)	21 (77.8)
Depcat 7 (22) (most deprived)	17.3 (7.52)	13 (59.1)	9 (42.9)
Significance[1]	$P = 0.024$*	$P = 0.405$	$P = 0.409$

*Significant at the $P < 0.05$ level.
[1]P values represent the effect of area deprivation in the multilevel model for each outcome (Model 1).

Table 2. Random intercepts model for the outcome *number of sound teeth* (normalised) showing the Null Model (no explanatory variables), Model 1 (with area deprivation), Model 2 (with individual/household variables) and Model 3 (with individual/household variables and area deprivation)

	Null model ($n = 541$)		Model 1 ($n = 541$)		Model 2 ($n = 541$)		Model 3 ($n = 541$)	
Fixed effects	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Intercept	−0.046	−0.173 to 0.081	0.197	−0.048 to 0.442	1.498	1.226 to 1.770	1.591	1.285 to 1.897
Age					−0.028***	−0.032 to −0.024	−0.029***	−0.033 to −0.025
Female[a]					0.096	−0.039 to 0.231	0.091	−0.044 to 0.226
Social class IIIM[b]					−0.143	−0.317 to 0.031	−0.132	−0.306 to 0.042
Social class IV-V[b]					−0.309**	−0.509 to 0.109	−0.303**	−0.503 to −0.103
Income 25–149[c]					−0.534***	−0.779 to −0.289	−0.509***	−0.749 to −0.269
Income 150–284[c]					−0.455***	−0.682 to −0.228	−0.448***	−0.675 to −0.221
Income 285–434[c]					−0.277*	−0.495 to −0.059	−0.287*	−0.503 to −0.071
Income 435–604[c]					−0.175	−0.395 to 0.045	−0.199	−0.417 to 0.019
No qualifications[d]					−0.237*	−0.439 to −0.035	−0.330*	−0.532 to −0.128
Qualifications below degree level[d]					0.333***	0.143 to 0.523	0.318**	0.128 to 0.508
Depcat 3[e]			−0.179	−0.500 to 0.142			0.046	−0.183 to 0.275
Depcat 4[e]			−0.125	−0.482 to 0.232			−0.071	−0.326 to 0.184
Depcat 5[e]			−0.406*	−0.725 to −0.087			−0.205	−0.440 to 0.030
Depcat 6–7 (most deprived)[e]			−0.707**	−1.164 to −0.250			−0.238	−0.591 to 0.115
Random effects	Variance	SE	Variance	SE	Variance	SE	Variance	SE
Area level variance	0.062	0.032	0.030	0.023	0.020	0.014	0.010	0.012
Household level variance	0.190	0.070	0.168	0.069	0.011	0.044	0.004	0.044
Individual level variance	0.754	0.074	0.768	0.074	0.603	0.056	0.609	0.056

[a]Reference category male.
[b]Reference category social class I-IIINM.
[c]Reference category income over £605 per week.
[d]Reference category qualifications above degree level.
[e]Reference category Depcat 1–2 (least deprived).
*Significant at the $P < 0.05$ level.
**Significant at the $P < 0.01$ level.
***Significant at the $P < 0.001$ level.

Table 3. Random intercepts model for the outcome *one or more unsound teeth* showing the Null Model (no explanatory variables), Model 1 (with area deprivation), Model 2 (with individual/household variables) and Model 3 (with individual/household variables and area deprivation)

	Null model ($n = 541$)		Model 1 ($n = 541$)		Model 2 ($n = 541$)		Model 3 ($n = 541$)	
Fixed effects	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Intercept	−0.083	−0.491 to 0.325	−0.702	−1.586 to 0.182	−0.530	−1.426 to 0.366	−0.924	−2.096 to 0.248
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Age[a]					0.946	0.826 to 1.082	0.947	0.828 to 1.085
Female[b]					0.766	0.514 to 1.143	0.765	0.512 to 1.143
Social class IIIM[c]					1.096	0.647 to 1.858	1.069	0.627 to 1.822
Social class IV-V[c]					1.137	0.625 to 2.066	1.103	0.603 to 2.017
Income 25–149[d]					4.623***	2.144 to 9.967	4.669***	2.140 to 10.187
Income 150–284[d]					4.486***	2.198 to 9.156	4.545***	2.214 to 9.331
Income 285–434[d]					2.411*	1.224 to 4.750	2.462**	1.242 to 4.879
Income 435–604[d]					1.859	0.927 to 3.728	1.891	0.937 to 3.814
No qualifications[e]					0.651	0.358 to 1.180	0.641	0.351 to 1.170
Qualifications below degree level[e]					0.689	0.380 to 1.247	0.721	0.391 to 1.297
Depcat 3[f]			1.611	0.490 to 5.295			1.318	0.415 to 4.189
Depcat 4[f]			1.682	0.469 to 6.037			1.409	0.407 to 4.882
Depcat 5[f]			2.924	0.922 to 9.276			2.113	0.681 to 6.559
Depcat 6–7 (most deprived)[f]			2.918	0.646 to 13.174			1.542	0.343 to 6.933
Random effects	Variance	SE	Variance	SE	Variance	SE	Variance	SE
Area level variance	0.949	0.329	0.848	0.305	0.785	0.292	0.757	0.285
Household level variance	0.177	0.247	0.202	0.252	0.213	0.265	0.227	0.267

[a]Odds ratios based on 10 year change.
[b]Reference category male.
[c]Reference category social class I-IIINM.
[d]Reference category income over £605 per week.
[e]Reference category qualifications above degree level.
[f]Reference category Depcat 1–2 (least deprived).
*Significant at the $P < 0.05$ level.
**Significant at the $P < 0.01$ level.
***Significant at the $P < 0.001$ level.

Table 4. Random intercepts model for the outcome *periodontal pocketing of 4 mm or more in one or more teeth*, showing the Null Model (no explanatory variables), Model 1 (with area deprivation), Model 2 (with individual/household variables) and Model 3 (with individual/household variables and area deprivation)

	Null model ($n = 503$)		Model 1 ($n = 503$)		Model 2 ($n = 503$)		Model 3 ($n = 503$)	
Fixed effects	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
Intercept	0.130	−0.527 to 0.787	−0.709	−2.210 to 0.792	−0.703	−1.820 to 0.414	−1.581	−3.439 to 0.277
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Age[a]					1.283*	1.092 to 1.506	1.306*	1.103 to 1.546
Female[b]					0.901	0.570 to 1.426	0.905	0.565 to 1.448
Social class IIIM[c]					1.462	0.806 to 2.653	1.459	0.782 to 2.722
Social class IV-V[c]					1.095	0.566 to 2.120	1.100	0.556 to 2.175
Income 25–149[d]					0.885	0.383 to 2.048	0.830	0.346 to 1.990
Income 150–284[d]					0.847	0.394 to 1.823	0.813	0.366 to 1.805
Income 285–434[d]					0.867	0.421 to 1.783	0.856	0.404 to 1.814
Income 435–604[d]					0.610	0.285 to 1.304	0.593	0.267 to 1.316
No qualifications[e]					0.826	0.414 to 1.650	0.791	0.385 to 1.625
Qualifications below degree level[e]					0.731	0.383 to 1.392	0.738	0.380 to 1.434
Depcat 3[f]			3.397	0.467 to 24.741			3.193	0.376 to 27.095
Depcat 4[f]			1.143	0.132 to 9.933			1.306	0.127 to 13.429
Depcat 5[f]			2.855	0.412 to 19.796			2.826	0.350 to 22.836
Depcat 6–7 (most deprived)[f]			8.499	0.668 to 108.211			7.622	0.487 to 119.209
Random effects	Variance	SE	Variance	SE	Variance	SE	Variance	SE
Area level variance	2.759	0.852	2.598	0.840	3.012	0.929	3.017	0.966
Household level variance	0.000	0.000	0.097	0.312	0.000	0.000	0.132	0.331

[a]Odds ratios based on 10 year change.
[b]Reference category male.
[c]Reference category social class I-IIINM.
[d]Reference category income over £605 per week.
[e]Reference category qualifications above degree level.
[f]Reference category Depcat 1–2 (least deprived).
*Significant at the $P < 0.01$ level.

Discussion

This study does not demonstrate a significant association between area deprivation and the oral health of adults after controlling for individual/household sociodemographic characteristics. The findings differ to those of similar studies, where a significant relationship between oral health and area deprivation is shown (17, 24, 25). However, in contrast to the studies by Locker and Ford (24, 25), the current study reports clinical outcomes rather than self-reported oral health, and researches participants from a wider age group. Moreover, the current study investigates oral health outcomes in adults rather than children.

The finding that individual/household sociodemographic factors are better predictors of oral health outcomes than area deprivation is shared by the wider health literature (31). However, the significant area deprivation effect on the general health of adults found in the wider health literature (31–33), including a study from Scotland (34), contrasts with the findings of this study. This could be a reflection of the different aetiology of oral disease. For example, the evidence of an association between individual level socioeconomic status and periodontal health is equivocal (51), and it has been argued that periodontitis has a predominantly biological rather than a social aetiology (52). Furthermore, there is better access to NHS dental services in most of the areas of high deprivation in Scotland compared with the less deprived areas, which may be ameliorating the effects of area deprivation (53).

Conversely, it is possible that there is an association between area deprivation and oral health which was not shown in this study. Demonstrating a causal relationship between neighbourhood context and health outcome is challenging (54). Population migration, environmental change, a time lag in manifestation of health-related contextual effects, and the differential impact of environmental factors on people of different ages and for different types of disease, are just some of the difficulties to be overcome (55–57). Moreover, individuals are both shaped by, and shape their neighbourhoods. For example, an individual's social class, based on his or her occupation, may be constrained by the local labour market (58).

Furthermore, it can be difficult to disentangle the effects of individual/household socioeconomic factors and neighbourhood deprivation in statistical models (59). It is possible that the area deprivation score acts as a socioeconomic descriptor of the individual/household rather than an indicator of a genuine contextual effect (7, 34).

It is also very difficult to capture the essence of 'deprivation' in one score (7, 60). The use of the 1991 Carstairs and Morris area deprivation indicator could be criticised in this respect. The indicator favours material rather than social deprivation. Newer indices such as The Scottish Index of Multiple Deprivation 2004 have better construct validity. The index is based on 31 indicators in the six domains of income, employment, housing, health, education, skills and training and geographic access to services and telecommunications (61).

Another possible reason for an apparent lack of association relates to the use of temporally mismatched deprivation data, which may introduce errors into the analysis (62). This is a common practice in studies examining the impact of area deprivation on general health because of the lack of contemporaneous deprivation data (34, 63). Considerable efforts were made to de-code the postcode sectors in the data set in order to be able to use more contemporaneous deprivation data obtained from measures with better construct validity. However, confidentiality clauses regarding the release of information about postcode sectors meant that the use of existing data was unavoidable.

The small sample size and missing data are other potential sources of bias. The sample size is rather small for multilevel modelling (64). Power for estimates at each level depends on the number of units at each level, although the number of higher level units has more effect on statistical power than the number of individual observations (64). It is possible that a significant relationship between area deprivation and oral health was not observed because of a small number of geographical areas in the dataset leading to a type 2 error. Small numbers of higher level units can also lead to an underestimation of the SE of the higher level variances (65). The few participants with severe periodontal disease and/or multiple unsound teeth and the lack of participants in some deprivation categories were consequent of the small sample size. The resultant dichotomisation of variables and the combination of deprivation categories are a potential source of bias in the study through loss of information and statistical power.

The area level variance in the outcome 'periodontal pocketing 4 mm or more' is surprisingly

large. It is very likely that some of the area level variance in periodontal status is due to poor inter-rater reliability. Before the survey was undertaken, training for the examiners was provided and a calibration exercise undertaken to measure variation between dentists. However, calibration data were only calculated for the condition of tooth and root surfaces, tooth wear, contacts and spacing. The nature of the clinical data and the number of different variables that were measured in the survey meant that no calibration data were calculated for periodontal condition. There was also no re-calibration during the period of data collection (44). Moreover, the dataset did not include some individual level variables often included in periodontal studies such as stress or smoking status. It is therefore possible that the high area level variance is also due to the clustering of individuals in geographical areas with these unmeasured individual level characteristics (29).

The study demonstrates the importance of considering the clustering of individual and household sociodemographic characteristics when exploring the association between area deprivation and oral health. Multilevel modelling is a useful statistical tool for analysing contextual effects on oral health because of its ability to account for both compositional and contextual factors in explaining individual health outcomes and is superior to analyses conducted at the individual level (40). However, limitations of multilevel modelling include the need for larger datasets with the associated cost considerations (64), and the increased complexity of multilevel analysis in comparison with single level regression analysis. In this study, separate models were specified for each oral health outcome. Multivariate multilevel modelling, where different outcomes are modelled simultaneously, may be useful in future research. Although the modelling is more complex, the relative influence of predictor variables can be assessed simultaneously for each outcome, and the covariation between oral health outcomes at individual, household and geographical levels can be explored (66). Moreover, multivariate multilevel modelling confers some advantages for handling missing data, and increasing statistical power (40).

In conclusion, this study significantly contributes to the debate surrounding the relationship between area deprivation on oral health and disease, because of the lack of similarly conducted studies in adults using clinical indices of oral health. Whilst there are clearly reasons why there may be a type 2 error in this study, and contextual effects may be being missed, the fact remains that no clear relationship was found between area level deprivation and adult oral health. These findings question current understanding of the role of area deprivation in shaping oral health. Further research is therefore required using a prospective longitudinal design, a much larger number of participants and geographical areas and contemporaneous deprivation indices with better construct validity. Furthermore, the relative effects of area deprivation on different social groups should be investigated. In addition, it would also be interesting to explore the relative impact of other contextual factors on oral health such as income inequality, social capital, rurality, access to services, features of the working environment, etc. in relation to area deprivation, taking into account individual/household characteristics.

References

1. Carmichael C. Inner city Britain: a challenge for the dental profession. A review of dental and related deprivation in inner city Newcastle upon Tyne. Br Dent J 1985;159:24–7.
2. Schamschula R, Sugart E, Agus H, Un P, Toth K. The fluoride content of human tooth enamel in relation to environmental exposure to fluoride. Aust Dent J 1982;27:243–7.
3. Centre for Reviews and Dissemination. A systematic review of public water fluoridation. York: Centre for Reviews and Dissemination, University of York; 2000.
4. Newton JT, Bower E. The social determinants of oral health: new approaches to conceptualizing and researching complex causal networks. Commun Dent Oral Epidemiol 2005;33:25–34.
5. Holst D, Schuller A, Aleksejuniene J, Eriksen H. Caries in populations – a theoretical, causal approach. Eur J Oral Sci 2001;109:143–8.
6. Baelum V, Lopez R. Periodontal epidemiology: towards social science or molecular biology? Commun Dent Oral Epidemiol 2004;32:239–49.
7. Locker D. Deprivation and oral health: a review. Commun Dent Oral Epidemiol 2000;28:161–9.
8. Townsend P. Deprivation. J Soc Policy 1987;16:125–146.
9. Bailey N, Flint J, Goodlad R, Shucksmith N, Fitzpatrick S, Pryce G. Measuring deprivation in Scotland: developing a long-term strategy Final report. [WWW document] URL http://www.scotland.gov.uk/library5/social/mdis-00.asp [accessed on 1 October 2005].
10. Antunes J, Frazao P, Narvai P, Bispo C, Pegoretti T. Spacial analysis to identify differentials in dental needs by area-based measures. Commun Dent Oral Epidemiol 2002;30:133–42.
11. Antunes J, Narvai P, Nugent Z. Measuring inequalities in the distribution of dental caries. Commun Dent Oral Epidemiol 2004;32:41–8.

12. Muirhead V, Marcenes W. An ecological study of caries experience, school performance and material deprivation in 5-year-old state primary school children. Commun Dent Oral Epidemiol 2004;32:265–70.
13. Pattussi M, Marcenes W, Croucher R, Sheiham A. Social deprivation, income inequality, social cohesion and dental caries in Brazilian school children. Soc Sci Med 2001;53:915–25.
14. Sweeney P, Gelbier S. The dental health of pre-school children in a deprived urban community in Glasgow. Commun Dent Health 1999;16:22–5.
15. Steele J, Lader D. Social factors and oral health in children. Children's dental health in the United Kingdom 2003. London: Office for National Statistics; 2003.
16. Tickle M, Moulding G, Milsom K, Blinkhorn A. Dental caries, contact with dental services and deprivation in young children: their relationship at a small area level. Br Dent J 2000;189:376–9.
17. Willems S, Vanobbergen J, Martens L, de Maeseneer J. The independent impact of household- and neighbourhood-based social determinants on early childhood caries. Fam Commun Health 2005;28:168–75.
18. Marcenes W, Murray S. Changes in prevalence and treatment need for traumatic dental injuries among 14-year-old children in Newham, London: a deprived area. Commun Dent Health 2002;19:104–8.
19. Dugmore C, Rock W. The progression of tooth erosion in a cohort of adolescents of mixed ethnicity. Int J Paediatr Dent 2003;13:295–303.
20. Al-Dlaigan Y, Shaw L, Smith A. Dental erosion in a group of British 14-year-old school children. Part I: prevalence and influence of differing socioeconomic backgrounds. Br Dent J 2001;190:145–9.
21. Bardsley P, Taylor S, Milosevic A. Epidemiological studies of tooth wear and dental erosion in 14-year-old children in North West England. Part 1: the relationship with water fluoridation and social deprivation. Br Dent J 2004;197:413–6.
22. Steele J, Lader D. Social factors and oral health in children. Children's dental health in the United Kingdom 2003. London: Office for National Statistics; 2004.
23. Aggarwal V, Macfarlane T, Macfarlane G. Why is pain more common amongst people living in areas of low socio-economic status? A population-based cross-sectional study. Br Dent J 2003;194:383–7.
24. Locker D, Ford J. Evaluation of an area-based measure as an indicator of inequalities in oral health. Commun Dent Oral Epidemiol 1994;22:80–5.
25. Locker D, Ford J. Using area-based measures of socio-economic status in dental health services research. J Public Health Dent 1996;56:69–75.
26. Richards W. Oral ill-health and deprivation among patients of a general dental practice in South Wales. Prim Dent Care 2002;9:105–12.
27. Greenwood M, Thomson P, Lowry R, Steen I. Oral cancer: material deprivation, unemployment and risk factor behaviour – an initial study. Int J Oral Maxillofac Surg 2003;32:74–7.
28. Thorne P, Etherington D, Birchall M. Head and neck cancer in the South-West of England: influence of socio-economic status on incidence and second primary tumours. Eur J Surg Oncol 1997;23:503–8.
29. Sloggett A, Joshi H. Higher mortality in deprived areas: community or personal disadvantage? Br Med J 1994;309:1470–4.
30. Macintyre S, Ellaway A. Neighborhoods and health. An overview. In: Kawachi I, Berkman L, editors. Neighborhoods and health. New York: Oxford University Press; 2003:20–42.
31. Pickett K, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. J Epidemiol Commun Health 2001;55:111–22.
32. Curtis S, Rees-Jones I. Is there a place for geography in the analysis of health inequality? Sociol Health Illn 1998;20:645–72.
33. Stafford M, Cummins S, Macintyre S, Ellaway A, Marmot M. Gender differences in the associations between health and neighbourhood environment. Soc Sci Med 2005;60:1681–92.
34. Leyland A. Socioeconomic gradients in the prevalence of cardiovascular disease in Scotland: the roles of composition and context. J Epidemiol Commun Health 2005;59:799–803.
35. Diez-Roux A. Multilevel analysis in public health research. Annu Rev Public Health 2000;21:171–92.
36. Hou F, Myles J. Neighbourhood inequality, neighbourhood affluence and population health. Soc Sci Med 2005;60:1557–69.
37. Jaffe D, Eisenbach Z, Neumark Y, Manor O. Individual, household and neighbourhood socioeconomic status and mortality: a study of absolute and relative deprivation. Soc Sci Med 2005;60:989–97.
38. Rasbash J, Steele F, Browne W, Prosser B. A user's guide to MlwiN. Version 2.0. London: Centre for Multilevel Modelling, Institute of Education, University of London; 2004.
39. Duncan C, Jones K, Moon G. Context, composition and heterogeneity: using multilevel models in health research. Soc Sci Med 1998;46:97–117.
40. Goldstein H. Multilevel statistical models. 3rd edn. London: Hodder Arnold; 2003.
41. D'Aiuto F, Ready D, Parkar M, Tonetti M. Relative contribution of patient-, tooth-, and site-associated variability on the clinical outcomes of subgingival debridement. I. Probing depths. J Periodontol 2005;76:398–405.
42. Tu Y, Gilthorpe M, Griffiths G, Maddick I, Eaton K, Johnson N. The application of multilevel modeling in the analysis of longitudinal periodontal data. Part II: changes in disease levels over time. J Periodontol 2004;75:137–45.
43. Malikaew P, Watt R, Sheiham A. Associations between school environments and childhood traumatic dental injuries. Oral Health Prev Dent 2003;1:255–66.
44. Kelly M, Steele J, Nuttall N, Bradnock G, Morris J, Nunn J et al. Adult dental health survey. Oral health in the United Kingdom 1998. London: Office for National Statistics; 2000.
45. Marcenes W, Sheiham A. Composite indicators of dental health: functioning teeth and the number of sound-equivalent teeth (T-Health). Commun Dent Oral Epidemiol 1993;21:374–8.
46. Gulliford M, Ukoumunne O, Chinn S. Components of variance and intraclass correlations for the design

of community-based surveys and intervention studies. Am J Epidemiol 1999;149:876–83.
47. Carstairs V, Morris R. Deprivation and health in Scotland. Aberdeen: Aberdeen University Press; 1991.
48. Tu Y-K, Kellett M, Clerehugh V, Gilthorpe M. Problems of correlations between explanatory variables in multiple regression analyses in the dental literature. Br Dent J 2005;199:457–61.
49. Garson D. PA 765 Statsnotes: An online textbook [WWW document] URL http://www2.chass.ncsu.edu/garson/pa765/statnote.htm [accessed on 28 February 2004].
50. Rasbash J, Browne W, Healy M, Cameron B, Charlton C. MLwiN Version 2.02. Multilevel models project. London: Institute of Education, University of London; 2005.
51. Klinge B, Norlund A. A socio-economic perspective on periodontal diseases – a systematic review. J Clin Periodontol 2005;32(Suppl. 6):314–25.
52. Unell L, Söderfeldt B, Halling A, Birkhed D. Explanatory models for indicators of periodontal disease in an adult population. J Clin Periodontol 2000;27:22–9.
53. Newton JT, Williams A, Bower E. Access to dental health services in Scotland. Edinburgh: Scottish Parliament; 2005.
54. Oakes J. The (mis)estimation of neighbourhood effects; causal inference for a practicable social epidemiology. Soc Sci Med 2004;58:1929–52.
55. Boyle P, Norman P, Ress P. Changing places. Do changes in the relative deprivation of areas influence limiting long-term illness and mortality among non-migrant people living in non-deprived households? Soc Sci Med 2004;58:2459–71.
56. Curtis L, Dooley M, Phipps S. Child well-being and neighbourhood quality: evidence from the Canadian National Longitudinal Survey of Children and Youth. Soc Sci Med 2004;58:1917–27.
57. Curtis S, Southall H, Congdon P, Dodgeon B. Area effects on health variation over the life-course: analysis of the longitudinal study sample in England using new data on area of residence in childhood. Soc Sci Med 2004;58:57–74.
58. Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise and measure them? Soc Sci Med 2002;55:125–39.
59. Greenland S. Ecologic versus individual-level sources of bias in ecologic estimates of contextual health effects. Int J Epidmiol 2001;30:1343–50.
60. Carr-Hill R, Sheldon T, Thunhurst C. The politics of deprivation indices and health. In: Spencer N, Janes H, editors. Uses and abuses of deprivation indices. Proceedings of the Deprivation Indices Conference. University of Warwick, Coventry, UK; 1992;1–76.
61. Scottish Executive. Scottish index of multiple deprivation 2004. [WWW document] URL http://www.scotland.gov.uk/library5/society/siomd-02.asp [accessed on 27 September 2005].
62. Buzzelli M, Su J. Multi-level modelling in health research: a caution and rejoinder on temporally mismatched data. Soc Sci Med 2006;62:1215–8.
63. Veugelers P, Yip A, Kephart G. Proximate and contextual socioeconomic determinants of mortality: multilevel approaches in a setting with universal health care coverage. Am J Epidemiol 2001;154:725–32.
64. Kreft I. Are multilevel techniques necessary? An overview, including simulation studies. Los Angeles: California State University; 1996.
65. Maas C, Hox J. Sample sizes for multilevel modelling. In: Blasius J, Hox J, de Leeuw E, Schmidt P, editors. Social science methodology in the new millenium. Proceedings of the fifth international conference on logic and methodology. 2nd edn. Opladen, RG: Leske & Budrich Verlag; 2002.
66. Twigg L, Moon G, Duncan C, Jones K. Consumed with worry: 'unsafe' alcohol consumption and self-reported problem drinking in England. Health Edu Res 2000;15:569–80.