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Inequalities in dental health: An ecological analysis of the interaction between the effects of water fluoridation and social deprivation on tooth decay in children living in England

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Oral health in England has improved considerably in recent years but continues to show a strong inequalities gradient. This study was aimed at investigating variations in dental decay and relation to social deprivation and local water fluoridation. An ecological analysis using the 2007 and 2008 National Dental Epidemiology Programme survey of 5 year old children in England. Postcode of residence was mapped to census lower super output area (LSOA). LSOAs were assigned a national deprivation quintile and a fluoridation category based upon therapeutic level of 1 mg/L. Multiple logistic regression was applied to determine independent influences on tooth decay. Analysis of covariance (ANCOVA) was used to investigate interactions between fluoridation and deprivation on the mean levels of dental caries. Analysis is based on 142,030 clinical dental examinations, representing 25% of estimated population of 5 year olds in England. Overall, 31% of children had at least one decayed missing or filled tooth (dmft). Multiple logistic regression showed that children living in the most deprived areas were three times more likely to experience tooth decay than those living in affluent areas; whereas children living in fluoridated areas were 1.5 times less likely to have dmft than those living in non-fluoridated areas. Therefore, although both are independently significant, living in the most deprived quintile of social deprivation doubled the impact on the likelihood of dental decay compared to non-fluoridation. ANCOVA showed a strong gradient of increasing mean dmft with increasing social deprivation in both water-fluoridated and non-fluoridated areas, with 3 times more dental decay in more deprived areas than in more affluent areas. In all deprivation quintiles, children living in fluoridated areas have significantly ($p < 0.001$) lower mean dmft than those living in equivalent deprivation with no water fluoridation. Fluoridated drinking water may moderate dental caries; however, socioeconomic deprivation has a stronger influence on dental decay than local fluoridation of water.

Key words: Fluoridation, tooth decay children, social deprivation, ecological epidemiology.

INTRODUCTION

Despite the considerable improvement in oral health experienced by most industrialised countries over the past 50 years, tooth decay remains the norm rather than the exception, globally (Beaglehole and Editions, 2009). The estimated impact on individual health and wellbeing

together with the economic burden of treating oraldisease is significant; as such oral health is an important public health issue (England, 2014; Patel, 2012).

The most common oral diseases are dental caries and periodontal disease both of which can eventually lead to loss of teeth; thus, the main global indicator of the dental health of populations is a measure of decayed, missing or filled teeth (dmft in children or DMFT in adults). Worldwide, 60 to 90% of school children have dental cavities (WHO, 2013a). In England, 27.9% of five-year-old children had experience of dental decay with over 30% of 12 year olds affected by tooth decay, with 6% of adults, but also increasing numbers of children living in the most socially deprived areas of the UK, such as Manchester, having few or no natural teeth (Davies et al., 2013). Despite improvements over time, there is considerable evidence that poor dental and oral health is associated with social deprivation (Costa et al., 2012; Moysés, 2012; Davies et al., 2013) ethnicity, old age, socio-economic status and living in a deprived area have all been linked to variations in dental health (NICE 2014; BDA, 2013; Petersen et al., 2005). Around a third of British 5-year olds suffer from tooth decay, missing teeth or fillings but in some parts of England, over 50% of children are affected (Pitts et al., 2005; Davies et al., 2013) illustrating inequalities in child dental health.

Efforts to reduce poor dental health commonly focus on changing oral health behaviours and have traditionally adopted a two-pronged approach incorporating both self-care since the 1940's/50's government intervention in the form of water fluoridation. Such universal utilitarianism (maximising benefits whilst minimising consequences) is contentious with much concern over the removal of individual choice. Arguably, successful precedents do exist, mass fortification of 'staple' foods with micronutrients for example have historically been used to prevent malnutrition (Gussow and Akabas, 1993). As relatively inexpensive forms of intervention, targeting whole populations, resulting in minor shifts in the normative curve (example, in health behaviour), is believed to be more effective than focused expensive intervention in high risk groups (Rose, 2008) (Rose, 2008). The UK has a fairly neo-liberal approach to health policy (Bambra et al., 2005) compared with the rest of the European Union, and is also described as having some of the most liberal approaches to fortification policies (European Directorate Safety of the food chain, 2006; Bonner et al., 1999). Although, fluoride is naturally occurring in water supplies, this is dependent on geography, and is not usually at adequate levels to protect (prevent dmft) dental health in young children. UK government has fortified natural water in geographic areas in areas of inadequate fluoride levels. Schemes to fluoridate water supplies in England have been in place for over 40 years with approximately 6 million people covered to-date (BFS 2012a).

Continuous improvement of oral health in the 21st century is one of the objectives of the World Health Organisation (WHO) Global Oral Health Programme, with the prevention of dental caries through the effective use of fluorides (not just water fluoridation) being a key aspect of the 'Health for All' programme (WHO, 2013b). Support for mass fortification is however equivocal. Water fluoridation is one of the most contentious public health issues debated globally with strong opposition on the one hand (Mcdonagh et al., 2000; Freeze and Lehr, 2009) and an assumption that it can level dental health inequalities on the other. The purpose of water fluoridation is to prevent tooth decay by adjusting the concentration of fluoride in public water supplies around one part of fluoride per million parts of water which is considered capable of providing protection against tooth decay(BFS 2012a). Allegedly, according to much of the oral health policy developed in England, water fluoridation overrides the effects of social deprivation on dental health as fluoridation is a 'great equaliser'. This belief stems from evidence gathered in the first evaluation of dental effects of fluoridation in 1962 (Bransby et al., 1963), followed by more recent attempts in the late 1990's (Yeung, 2008; Mcdonagh et al., 2000) and to the present day (Mcgrady et al., 2012). This most recent evaluation, comparing two socially deprived populations in England, concluded that water fluoridation appears to reduce the social class gradient in dental caries whilst increasing the risk of fluorosis. However, this study contend that the deprivation scale used to compare these social gradients were not comparing like-for-like (Tocque, 2013). Local quintiles of deprivation within the two cities did not account sufficiently for absolute variation in deprivation between the fluoridated and non-fluoridated populations. Despite the fact that national data has been recorded fairly consistently since the first survey in 1985/86, there has been no systematic analysis to determine the independent effects of fluoridation and deprivation on children's dental health.

Here, this study uses three national datasets with wide geographic coverage across all of England: survey data from the National Dental Epidemiology Programme for England; a national scale of deprivation; and geographic maps of reported drinking water fluoridation schemes. The aim of this study was to investigate variations in dental decay in children in relation to the social deprivation gradient in areas with and without local water fluoridation.

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MATERIALS AND METHODS

An ecological analysis was conducted on the most recently available data for the 2007/08 National Dental Epidemiology Programme survey of 5 year old children's dental health in England (TDO, 2009). Data were collected following the National Protocol developed for this survey which was a modified version of guidance on sampling for child dental health surveys (26). In 2007/08, the survey protocol was altered to include collection of the postcode of the child's residence so that ecological analyses could be improved and also in obtaining (positive) parental consent. A stratified sample of children attending mainstream schools aged 5 years at the time of the survey was conducted by each of the 302 English Local Authority's taking part. Details of the overall sample frame are published elsewhere (TDO, 2009). Data were collected by trained and calibrated examiners and involved visual-only detection of missing teeth, filled teeth and teeth with obvious dentinal decay.

The child postcode of residence was used to map to area based classifications using the Census Lower Super Output Area (LSOA) (ONS 2013). Each LSOA was then assigned a national deprivation quintile from the English Indices of deprivation (CLG, 2008). The 32,842 LSOAs were ranked and divided into 5 equal fifths of around 6,580 in each quintile. To investigate fluoridation, every LSOA was mapped to the most recently published zones of average fluoride levels in drinking water using geographic information systems (GIS) software. The static map for fluoride level zones in 2004 to 2008 (Appendix A; DWI, 2008) was imported into MapInfo 9.5 and overlaid with digital LSOA boundaries. Overlay analysis was used to allocate a fluoridation category to all 32,842 LSOAs. These comprised: 1, naturally below 0.5mg/l (or no water supplied); 2, naturally 0.5 to 0.99 mg/l; 3, naturally 1.0 to 1.5 mg/l; 4, Health Authority fluoridation scheme; and 5, LSOAs that were partially in a fluoridated area and partially not. Since recommended levels of fluoridation for public health benefit are 1mg/l, categories 1 and 2 were combined to 'non-fluoridated' and 3 and 4 to 'fluoridated'. The small proportion (0.3%) of LSOAs with a partial fluoridation category was assigned to 'non-fluoridated', following initial post hoc comparison tests (not presented).

Region of residence was retained in the analysis, because there are recognised regional differences in levels of water fluoridation (Law, 2013) and regional differences in the final sample frame (TDO, 2009). National Statistics Single Year of Age (SYOA) population estimates for 2007 were obtained for all LSOAs, and used to estimate the population base for the sample framework. The merged dataset was imported into statistical package for the social sciences (SPSS) v 15 for analysis. Multiple logistic regressions was used to determine the independent effects of region of residence, social deprivation and water fluoridation on the likelihood of experiencing tooth decay. Analysis of variance (ANOVA) was used to investigate interactions between fluoridation and deprivation on the mean levels of dental caries in children with some dental caries (dmft>0) and overall.

RESULTS

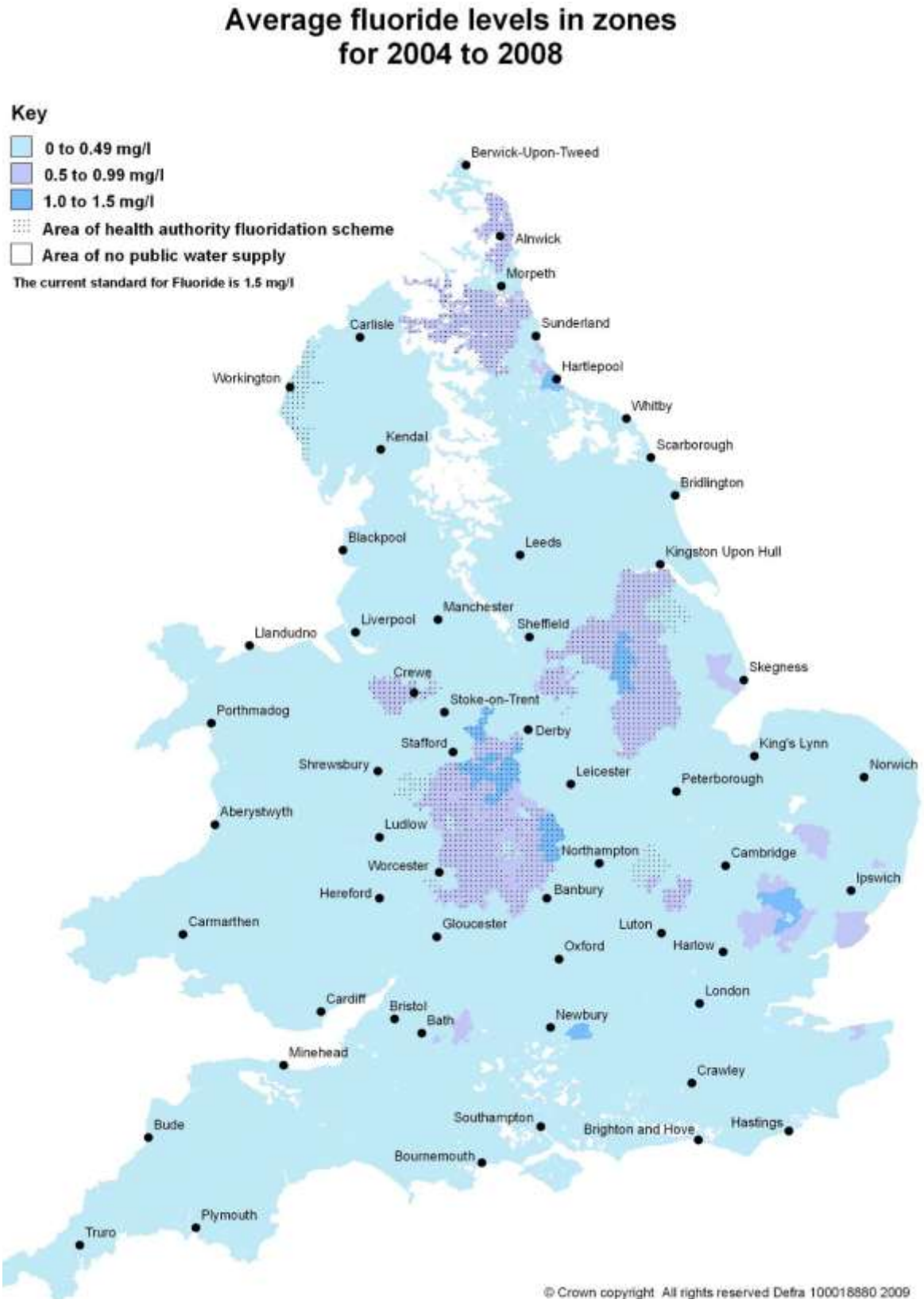
Analysis is based on 142,030 clinical examinations with a postcode of residence , allowing matching to Census Lower Super Output Areas (LSOA). National SYOA population estimates suggested that there were approximately 558,556 children aged 5 living in England in mid-2007. The overall sample of children included in this study represented 25% of estimated population base (Table 1).

Sampling

There was a large oversampling from the West Midlands region (28% of children measured compared to 11% of resident 5 year olds who lived in the West Midlands) and a slight oversampling from the North West region (20% of children measured compared to 13% of resident 5 year olds). Consequently, there was under-sampling from the other regions (Table 1). In addition, the population covered by water fluoridation schemes varied immensely between regions. West Midlands had 80% of its population covered, North East had 41% and East Midlands had 16%. All other regions had very small proportions or none of the population receiving fluoridated water supplies. Since the West Midlands is the most extensively fluoridated region and showed oversampling, across the whole of England nearly twice the proportion of children living in fluoridated areas were measured; 25.6% of children measured compared with 13% of resident 5 year olds lived in areas with fluoridated water supplies (Table 1). Therefore, data presentation and multivariate analysis use West Midlands as the benchmark. The proportion of the measured sample living in each of the five deprivation quintiles in England very nearly matched the distribution of the resident 5 year old population; almost a quarter of children live in the worst fifth of areas with slightly fewer than expected living in the middle 60% or areas.

Decay experience (prevalence)

Children with no obvious experience of tooth decay (dmft =0) accounted for 69% of the measured sample (Table 1). Thus, 31% of children aged 5 in England had at least one decayed missing or filled tooth (dmft>0) in 2007/08. There was a lower proportion of children that were decay-free in the more deprived northern regions 61 to 64% (North East, North West and Yorkshire and The Humber) than in more affluent southern regions 70-75% (East Midlands, East, and South East). West Midlands, typically a more deprived region had similar prevalence of decay-free children (72%) to more southerly regions. There was a very strong association between being decay-free and social deprivation, with 80% of children living in the most affluent areas being decay-free compared with only 56% of those living in the most deprived areas (Table 1). By contrast, there was only a small difference in being decay-free between fluoridated (73%) and non-fluoridated areas (68%). Multiple logistic regressions showed that, whilst controlling for social deprivation and fluoridation, the three deprived northern regions had significantly greater chance of experiencing tooth decay compared to West Midlands (Table 1). This is despite the fact that the North East has the second highest proportion of its population receiving fluoridated water.



Appendix A. Drinking water inspectorate map of average fluoride levels in zones which was published at the time of the 2007/08 dental survey was for 2004 to 2008. This map is no longer available online as it is regularly updated to current years. Source: http://dwi.defra.gov.uk/consumers/advice-leaflets/fluoride.pdf.

Table 1. The estimated population of 5 year olds, dental survey sample measured, proportion of the population fluoridated and survey results a) Government office regions; b) deprivation quintiles (CLG, 2008) ; and c) fluoridation water status.

Parameters	5 year old population		Measured sample		Fluoridated	Dental caries		
	n	%	n	%	%	% dmft-free	Mean dmft	Mean dmft>0
(a) Government region								
West Midlands	60.823	11	38.917	27	80	72	0.95	3.33
North East	25.997	5	2.940	2	41	61	1.44	3.63
North West	74.551	13	28.573	20	4	64	1.40	3.88
Yorkshire & The Humber	55.824	10	9.059	6	3	62	1.49	3.89
East Midlands	46.564	8	9.630	7	16	70	0.99	3.27
East of England	62.935	11	12.331	9	5	75	0.82	3.35
London	89.364	16	11.362	8	0	65	1.44	4.15
South East	90.952	16	20.488	14	0	74	0.89	3.41
South West	51.556	9	8.730	6	0	69	1.04	3.40
(b) Deprivation quintile (national)								
Least	112.118	20	28.874	20	10	80	0.57	2.78
Second	103.028	18	25.832	18	12	76	0.70	3.00
Third	101.302	18	25.392	18	12	71	0.96	3.33
Fourth	108.383	19	26.753	19	13	65	1.32	3.83
Most	133.735	24	35.179	25	19	56	1.81	4.15
(c) Fluoridation water status								
Fluoridated	75.059	13	36.361	26	100	73	1.97	3.22
No fuoridation scheme	483.507	87	105.669	74	0	68	2.41	3.72
Total sample								
-	558.566	-	142.030	-	13	69	1.11	3.42

Children living in East of England, London and South East had significantly less likelihood of experiencing decay than West Midlands. East Midlands and South West were not significantly different from West Midlands, despite the South East having no water fluoridation and East Midlands only 16% of the population receiving fluoridated water. There was an extremely strong independent influence of social deprivation on the likelihood of children experiencing tooth decay. Compared with the most affluent fifth of areas, children living in the most deprived fifth of areas were three times more likely to experience tooth decay. The relationship of decay experience with fluoridation was also significant: children living in fluoridated areas were 1.5 times less likely to have dmft than those living in non-fluoridated areas (Figure 1). Therefore, although both are independently significant, living in the most deprived quintile of social deprivation had twice the impact on the likelihood of dental decay compared to not having water fluoridation.The impact of water fluoridation was equivalent to the difference between the middle and the most affluent deprivation quintiles.

Mean dmft in children experiencing decay

Table 1 also shows that the mean dmft in children experiencing decay (dmft>0) is slightly higher (3.6-3.9 affected teeth) in the more northerly regions compared with southerly regions (3.3-3.4 affected teeth), with the exception of London. Children living in London who experienced decay had on average over 4 affected teeth. West Midlands was more similar to East of England and South West than other regions. The relationship between social deprivation and affected teeth was even stronger, with a mean of 2.8 affected teeth in the most affluent areas compared with 4.15 in the most deprived areas. The mean number of affected teeth was 3.2 in fluoridated areas compared with 3.7 in non-fluoridated areas.

Overall mean dmft

The overall population-level of tooth decay in children aged 5 is a combination of the prevalence of decay experience and the mean dmft in children with decay.

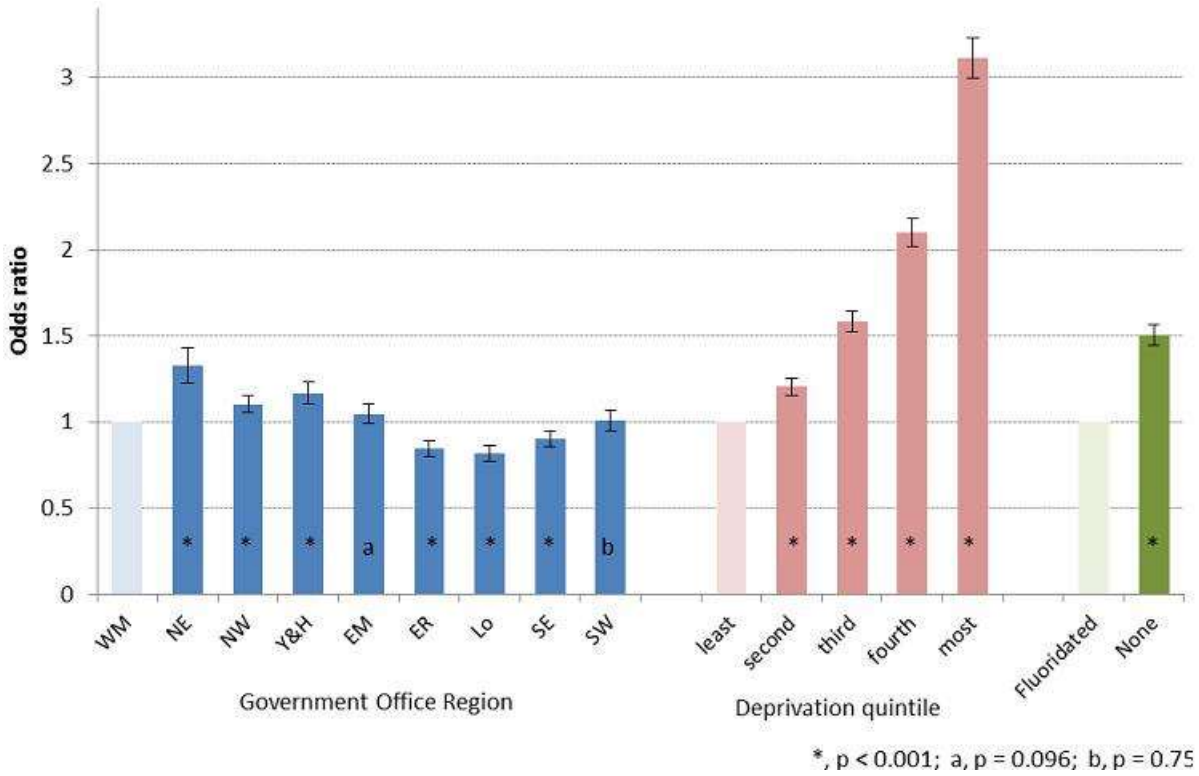


Figure 1. The likelihood (odds ratio determined by multiple logistic regression) of experiencing tooth decay compared with the base group by a) Government office regions; b) deprivation quintiles (CLG, 2008); and c) optimally fluoridated water supplies.

Both of these measures are independently related to both social deprivation and to the presence of drinking water fluoridation and both more strongly influenced by social deprivation. Appendix B shows that these measures vary little across the nine English regions. Region was retained in the analysis as a covariate to control for regional variations. ANCOVA shows the relationship between population level mean dmft and both factors (Figure 2). The strong gradient of increasing mean dmft with increasing social deprivation exists in both water-fluoridated and non-fluoridated areas, with 3 times more dental decay in more deprived areas than in more affluent areas. In all deprivation quintiles, children living in fluoridated areas have significantly ($p < 0.001$) lower mean dmft than those living in equivalent deprivation with no water fluoridation. There was a 33% reduction in mean dmft due to fluoridation which differs little across deprivation quintiles. In fact it is slightly lower in the most deprived and most affluent quintiles (30%) than in the middle quintiles (34 to 36%). However, there was overall 68% reduction in mean dmft by living in the most affluent areas compared to living in the most deprived areas, for both fluoridated and non-fluoridated populations (Figure 2). In fact, in non-fluoridated areas, each reduction in a deprivation quintile resulted in significantly lower mean dmft ($p < 0.001$) with a reduction by 20 to 27% at each step.

DISCUSSION

In 2007/08 a third (31%) of 5 year olds in England had at least one decayed missing or filled tooth (dmft>0), which is high in comparison to other European countries (XX Caries Res. 2009;43(2):155-62). This ecological study provides England-wide evidence that living in areas of high social deprivation has a greater detrimental influence on children's dental health than living in areas without water fluoridation. There is no doubt that water fluoridation results in an overall lower mean dmft in children but the independent effects of social deprivation are much greater than this benefit. There was a 68% reduction in mean dmft in more affluent areas for children living in both fluoridated and non-fluoridated areas. These differences are a combination of the greater influence of social deprivation than water fluoridation on both decay experience (prevalence of tooth decay) and on the mean number of affected teeth in children with decay. Despite statistically lower mean dmft in children living in the most deprived areas with fluoridated water compared to those

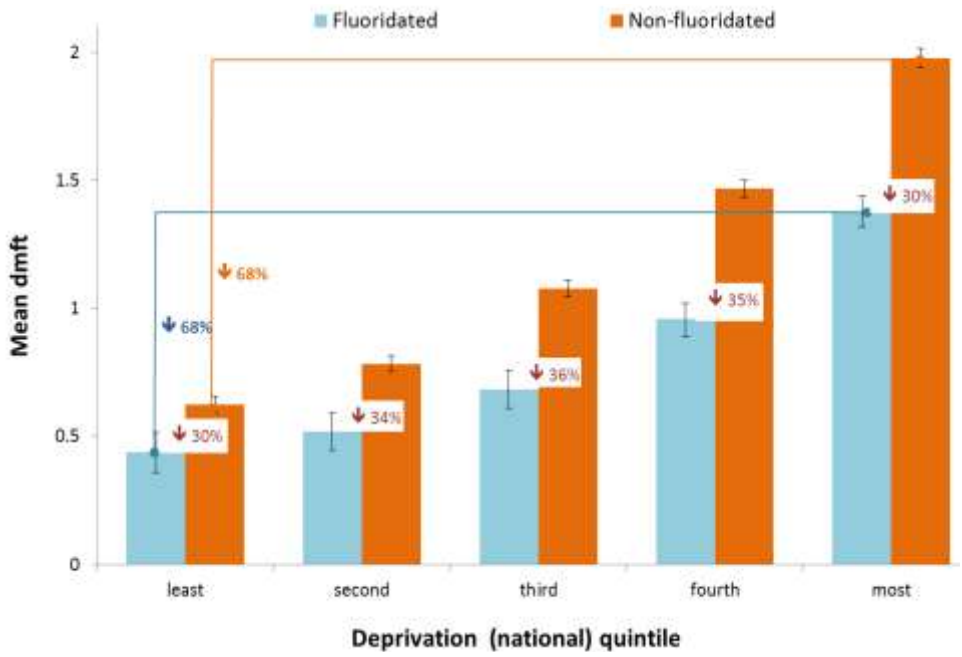
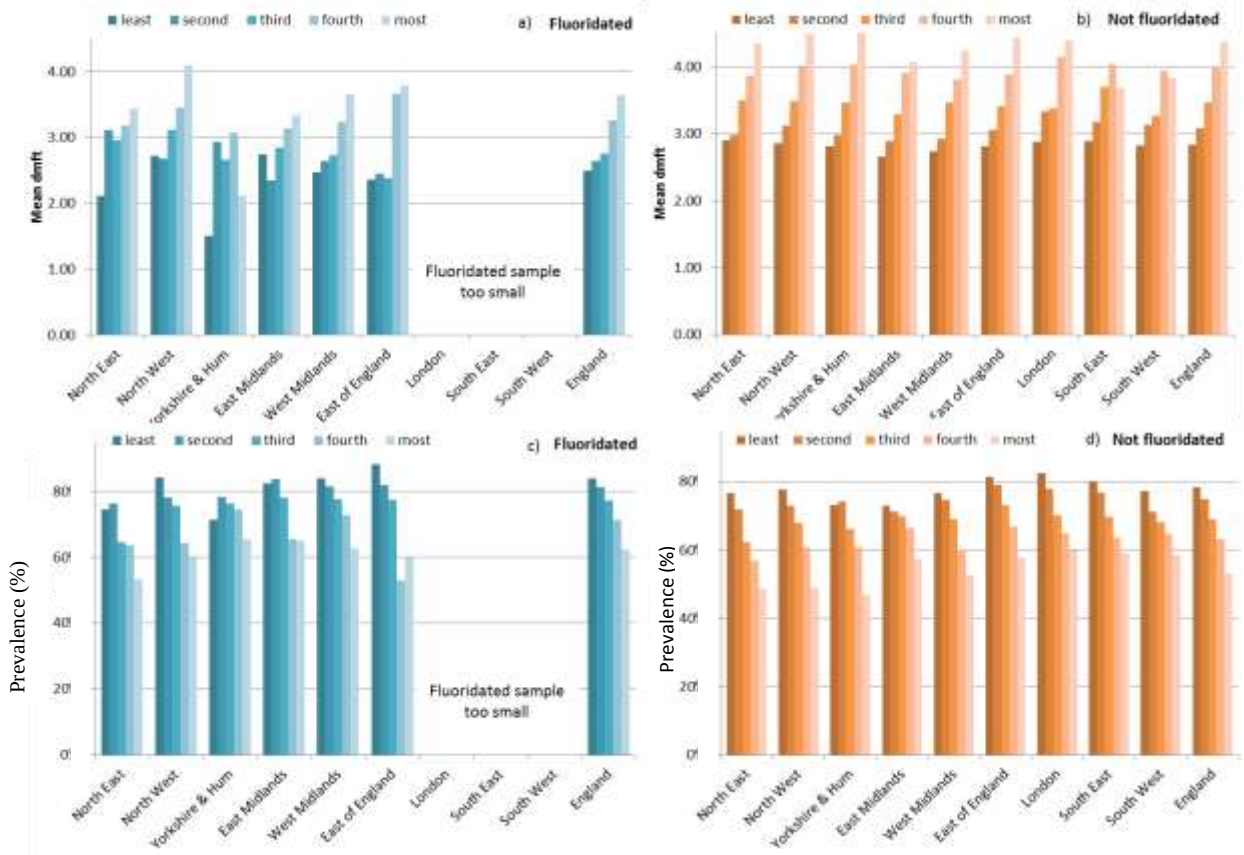


Figure 2. ANCOVA between deprivation quintiles (CLG, 2008) and fluoridated water status, with region as a covariate in the model.



Appendix B. Children's dental survey 2007/08 data showing mean dmft (where dmft>0) for a) fluoridated and b) non-fluoridated areas and prevalence of decay experience in c) fluoridated and d) non-fluoridated areas by English regions.

without fluoridation, there is no evidence that water fluoridation reduces inequalities in children's dental health; the social gradient remains the same whether children live in fluoridated areas or not. Each step down a deprivation quintile resulted in 20 to 28% lower mean dmft, resulting in an overall decrease of 68% in the most affluent areas; whereas the influence of fluoridation resulted in a 30% reduction overall. West Midlands (WM) is perceived to be the gold standard by health professionals who are pro water fluoridation (30) but even in this region, this study has shown that the detrimental effects of social deprivation outweigh any benefits of water fluoridation. The effects of deprivation are large and in all geographic areas, even fluoridated ones (WM). Therefore, other social, behavioural or nutritional aspects may help explain these variations in dental health. Although, fluoridation might not eliminate inequalities in oral health we recognise the beneficial role for fluoridation in helping to reduce treatment costs (through improved oral health) enabling this to resource prevention activities to help address inequalities in oral health.

Proximal determinants

It is widely acknowledged that many behavioural factors directly influence and/or interact to increase the dental decay experience of both adults and children living in deprived areas compared with those living in more affluent areas. Due to the ecological nature of the study design it was not possible to control for individual level confounding variable such as smoking, diet and dental hygiene practices, tap water consumption, water supply and access to and usage of dental care.

Dietary and oral hygiene practices

A systematic review of the risk factors for dental caries in children (Gibson and Williams, 1999) concludes that the aetiology of dental caries, particularly in children, is multi-factorial and complex. Furthermore, synthesis and interpretation of the evidence is hampered by the large number of different measures used to assess similar factors (for example tooth brushing frequency with various cut off points, supervision of tooth brushing, age tooth brushing started). They also concluded that children are more likely to develop caries if they have poor dental hygiene, including infrequent brushing (< once per day), use non-fluoride toothpaste, consume a cariogenic diet or more likely to adopt cariogenic dietary practices (bottle-fed, sugar-containing drinks etc.).

The significant contribution of sugars to cariogenic diet is widely recognised and much publicised in the media. To date, only one UK study has examined the relative significance of dietary sugars, tooth brushing frequency and social class as predictors of caries experience (caries vs. no caries). Gibson and Williams (1999) analysed data for 1,450 British pre–school children from the 1992 National Diet and Nutrition Survey (NDNS) and conclusions suggested that non-manual households tend to brush less, brush for shorter duration, use non-fluoride toothpastes and consume higher intakes of dietary sugars. The study found that children in non-manual groups were twice as likely to engage in tooth brushing and on two or more occasions, compared with children from manual households. The latter were also more likely to engage in cariogenic dietary practices (bottle feeds and high sugar). Based upon the strength of the association between social class and caries experience, the authors (ibid) concluded that regular brushing (twice a day) with a fluoride toothpaste may have greater impact on caries in young children than restricting sugary foods that is, dietary factors; the effect of social deprivation is important.

The main dietary factors involved in causing tooth decay, are sugar and in particular non-milk extrinsic sugars (NMES) such as sucrose (table sugar) sugar added to confectionary, drinks etc. Soft drinks (not diet), are the main source of non-milk extrinsic sugars (NMES) in the UK diet providing over 25% of intake; beverages (soft drinks) contribute 8% of total energy intakes; with 75% of this from soft drinks (not diet), both carbonated and not carbonated (NATCEN 2014). In the past decade, UK sales of soft drinks have been relatively stable, with consumption levelling off, with small increase in overall sales, from 225 to 235 litres per person p.a. Despite this, the most recent UK national dietary and nutritional survey (NDNS) outlines how children (aged 2 to 10 years) consume almost double the recommended level of NMES, 17% compared to 22% DRF of their total recommended food energy (NATCEN 2014). Consumption of non-diet soft drinks is greater in children in the Low Income Dietary and Nutritional Survey (LIDNS) than NDNS among the 4 to 18 year olds; most notably non-carbonated soft drinks (not diet) were consumed at almost twice the NDNS level (NATCEN 2014).

Clinical trials investigating the effectiveness of caries prevention programs in young children involving individual dietary counselling (see Community Dent Oral Epidemiol. 2010 Aug; 38(4):324-32), may reduce caries incidence by 22 % amongst low-income groups, but attrition is high (approximately one-third of subjects). Suggesting this type of preventive action is less effective and costly compared with population-wide interventions such as water fluoridation, even if directed at high risk patients only. The role of calcium in developing strong bones and teeth in childhood is widely recognised but the imperative role of Vitamin D in the regulation of calcium absorption is less known (NATCEN 2014). Nutritional

data from the LIDNS (NATCEN 2014) shows for boys and girls aged 2 to 3 years, mean daily intakes of vitamin D from food sources were only 22% of the recommended nutrient intake (RNI) whilst less than 0.5% of boys and 2% of girls had intakes that met or exceeded the RNI. The fact that intakes from food sources are so low in relation to the RNI does not necessarily imply a deficiency provided exposure to UV light is sufficient or dietary intakes are supplemented (NATCEN 2014). Recent government concern over social and geographic variations in Vitamin D, with consequences on bone and dental health, has been reported (Grimes, 2011). Hence, children from socially deprived households and those with reduced exposure to natural sunlight are at greatest risk of net loss of calcium from bones and teeth, resulting in increased likelihood of dental caries, due to Vitamin D deficiency.

Tap water trends

The Drinking Water Inspectorate (DWI), monitors tap water consumption in England and Wales; data for recent decades suggests an overall decline in tap water consumption from approximately 2.04 l/day in 1978 to 1.93 l/day 2008 (37); The 2012 report (DWI, 2012), shows on average boys drink more tap water than girls (591ml c.f. to 516ml), whilst children < 5 years consume the lowest (442ml/day), c.f to 6 to 10 yrs (560ml) and 11 to 15 yrs (659ml/day). No statistically significant differences are reported in tap water consumption across social groups; households living in the South West of England drank the highest levels of tap water, while children living in Greater London drink the least (645ml and 485ml respectively, compared to a total average for all children of 554ml) (DWI, 2012). In terms of consumption of bottled water, sales data suggests that consumption of bottled water by children is lower than tap water and has fallen slightly since 2005 (35.5 l p.p in 2005 compared with 33.6 litres bottled water in 2011), whether consumption is higher in professional occupational groups and regions in the south of the UK is unknown. Although, inherently difficult to monitor with precision, the data suggests that nationally fewer children are consuming tap water, fluoridated or not, regardless of geographic region or social class.

Access to dentistry

Other fluoride therapies, administered by dentists, have shown potential in preventing tooth decay and include toothpaste, mouth rinses, gels/foams and varnish however insufficient evidence exists on effectiveness of slow-release devices (Marinho, 2009) and although likely to be beneficial evidence is inconclusive for milk fluoridation (Marinho, 2009, Yeung et al., 2005). In the period of 2006 to 2013 the proportion of children living in England who had access to a dentist was consistent at around 70% (DHSSPS 2004). Trends on dental access for children are equivocal; as all under 18-year olds in the UK are entitled to free dental treatment. However, in Northern Ireland data suggest that people living deprived areas were 12% less likely to be registered with a dentist than people in the country as a whole (DHSSPS, 2004). Whereas, in Scotland, there is no association between registration with an NHS dentist and deprivation (all quintiles) with around 88% of all children registered (ISD, 2014). As stated, Marinho (2009) asserts that the benefits of topical fluorides are firmly established, based on a sizeable body of evidence from randomized controlled trials. The size of the reductions in caries increment in both the permanent and the primary dentitions emphasizes the importance of including topical fluoride delivered through toothpastes, rinses, gels or varnishes in any caries preventive program. A systematic review of the efficacy and safety of fluoridation (see 22) highlights that fluoridation of drinking water remains the most effective and socially equitable measure in caries prevention at present. This study however contends that a blanket approach is not sufficient to target and reduce inequalities in oral health.

Limitations

A number of limitations exist for this study. There may be issues around accuracy of fluoridation maps as some regions for example may operate a switch on and off system (example, North East), accuracy of LSOA mapping to fluoridation including its resolution and also the questions of mobility of people into and out of fluoridated areas. It is however plausible to assume that these movements would largely be to similar deprivation quintiles. Over sampling from fluoridated areas could explain the reduction in dmft observed in 2007/08 compared with 2005/06. This analysis is based on 2007/08 data but more recent data are now available (2012/13) since health inequalities have persisted and there is a strong correlation between local authority measures of dental decay in both years, there is no reason to assume that the analysis presented here would differ using more recent data.

CONCLUSION

This ecological study has shown that, on a national scale, local measures of socioeconomic deprivation have much greater influence on dental decay than local fluoridation of water supplies. Despite the fact that fluoridated drinking water can help moderate dental caries, in reality human behaviour such as beverage

consumption, dental hygiene, other nutritional factors and access to dental services are more likely to influence overall dental health. Thus, reducing the disparities in dental health might better be achieved by focusing resources on reducing the effects of socioeconomic deprivation on overall health and wellbeing; strategies tailored to the determinants and needs of each group along the social gradient (Northern Ireland Executive 2009).

This study contend that Government and Health Authorities would have a better chance of improving dental health in children and adults by tackling social determinants of health and influencing lifestyle choices of individuals, rather than mass fluoridation. Community water fluoridation is often branded as one of the most successful and ground-breaking contributions to public health in the 20th century. Perhaps this is because governments have continually failed across the board to solve the influences of social deprivation on poor health, which, if successfully addressed, would actually have a much greater achievement in improved overall health and wellbeing rather than trying to tackle one single disease at a time.

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Competing interests

The authors declare that they have no competing interests.

REFERENCES

Bambra C, Fox D, Scott-Samuel A (2005). Towards a politics of health. Health Promot. Int. 20:187-193.

Beaglehole R, Editions M (2009). The oral health atlas: mapping a neglected global health issue, FDI World Dental Federation.

Bonner G, Warwick H, Barnardo M, Commission F (1999). Fortification Examined: How Added Nutrients Can Undermine Good Nutrition; a Survey of 260 Food Products with Added Vitamins and Minerals, Food Commission. Available at: http://www.foodcomm.org.uk/pdfs/fortification.PDF

Bransby E, Forrest J, Mansbridge J (1963). Dental effects of fluoridation of water with particular reference to a study in the United Kingdom. Proc. Nutr. Soc. 22:84-91.

British Dental Association BDA (2013). Oral Health Inequalities Policy. British Dental Association. London.

British Fluoridation Society BFS (2012a). The extent of water fluoridation; One in a illion: the facts about water fluoridation. British Fluoridation Society. Avaliable at: www.bfsweb.org/onemillion/onemillion2012.html.

Costa SM, Martins CC, Bonfim MDLC, Zina LG, Paiva SM, Pordeus IA, Abreu MH (2012). A systematic review of socioeconomic indicators and dental caries in adults. Int. J. Environ. Res. Pub. Health 9:540-3574.

CLG (2008). Indices of deprivation 2007. Department for Communities and Local Government [Online]. Available: www.gov.uk/government/organisations/department-for-communities-and-local-government/series/english-indices-of-deprivation. [Accessed 20/11/14]

Davies G, Neville J, Rooney E, Robinson M, Jones A, Perkins C (2013). National Dental Epidemiology Programme for England: oral health survey of five-year-old children 2012: A report on the prevalence and severity of dental decay. Public Health England gateway reference: 2013-183. Available at: www.nwph.net/dentalhealth

Department For Communities And Local Government CLG (2008). CLG. Indices of deprivation 2007. Department for Communities and Local Government [Online]. Available at: www.gov.uk/government/organisations/department-for-communities-and-local-government/series/english-indices-of-deprivation.

Department Of Health, Social Services And Public Safety (DHSSPS) (2004). Equality and Inequalities in Health and Social Care: A Statistical Overview. Department of Health, Social Services and Public Safety, Northern Ireland. Available at: www.dhsspsni.gov.uk/dentalhealthdeprivation.pdf

Drinking Water Inspectorate DWI (2008). Fluoridation of drinking water. Drinking Water Inspectorate. [Online]. Available at: http://dwi.defra.gov.uk/consumers/advice-leaflets/fluoride.pdf

Drinking Water Inspectorate DWI (2012). A survey of tap water consumption patterns amongst children under 16 years of age. [Online]. Available at: http://dwi.defra.gov.uk/consumers/advice-leaflets/fluoride.pdf http://dwi.defra.gov.uk/consumers/advice-leaflets/

England NHS (2014). Public Health England. Water fluoridation - Health monitoring report for England 2014. March 2014.

European Directorate Safety of the food chain (2006). Discussion paper on the setting of maximum and minimum amounts for vitamins and minerals in foodstuffs. European Communities. Available at: http://ec.europa.eu/food/food/labellingnutrition/supplements/discus_paper_amount_vitamins.pdf.

Freeze RA, Lehr JH (2009). The Fluoride Wars: How a Modest Public Health Measure Became America's Longest Running Political Melodrama, John Wiley & Sons.

Gibson S, Williams S (1999). Dental Caries in Pre–School Children: Associations with Social Class, Toothbrushing Habit and Consumption of Sugars and Sugar–Containing Foods. Caries Res. 33:101-113.

Grimes DS (2011). Vitamin D and the social aspects of disease. QJM-Int. J. Med. 104:1065-1074.

Gussow JD, Akabas S (1993). Are we really fixing up the food supply? J. Am. Diet. Assoc. 93:1300-1304.

Information Services Division ISD (2014). Dental Statistics – NHS Registration and Participation. NHS Scotland. Available at: www.isdscotland.org/Health-Topics/Dental-Care/Publications/2014-06-24/2014-06-24-Dental-Summary.pdf?

Law P (2013). Fluoridation is key to improving nation's dental health, says expert. Wales Online, March 5th.

Marinho V (2009). Cochrane reviews of randomized trials of fluoride therapies for preventing dental caries. Eur. Arch. Paediatr. Dent. 10:183-191.

Mcdonagh MS, Whiting PF, Wilson PM, Sutton AJ, Chestnutt I, Cooper J, Misso K, Bradley M, Treasure E, Kleijnen J (2000). Systematic review of water fluoridation. BMJ 321:855.

Mcgrady MG, Ellwood RP, Maguire A, Goodwin M, Boothman N, Pretty IA (2012). The association between social deprivation and the prevalence and severity of dental caries and fluorosis in populations with and without water fluoridation. BMC Public Health 12:1122.

Moysés SJ (2012). Inequalities in oral health and oral health promotion. Braz. Oral Res. 26:86-93.

Natcen Social ResearcH, M. H. N. R. A. U. C. L. M. S. (2014). National

Diet and Nutrition Survey Years 1-4 2008/09-2011/12. 6th Edition, Colchester Essex UK.
National Institute For Health And Care Excellence (NICE) (2014). Oral health: approaches for local authorities and their partners to improve the oral health of their communities. Available at: http://www.nice.org.uk/guidance/ph55/resources/guidance-oral-health-approaches-for-local-authorities-and-their-partners-to-improve-the-oral-health-of-their-communities-pdf
Northern Ireland Executive (2009). A new trial aimed at reducing tooth decay in the under fives has been launched today by Health Minister Michael McGimpsey
Office For National Statistics ONS (2013). Census geography. Office for National Statistics. [Online]. Available at: www.ons.gov.uk/ons/guide-method/geography/beginner-s-guide/census/census.html.
Patel R (2012). The state of oral health in Europe. Report Commissioned by the Platform for Better Oral Health in Europe.Available at: http://www.mah.se/PageFiles/49503/Report%20-%20the%20State%20of%20Oral%20Health%20in%20Europe.pdf
Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C (2005). The global burden of oral diseases and risks to oral health. Bull. World Health Organ. 83:661-669.
Pitts NB, Nugent ZJ, Thomas N, Pine CM (2005). BASCD Survey Report: The dental caries experience of 5-year-old children in England and Wales (2003/4) and in Scotland (2002/3). Surveys co-ordinated by the British Association for the Study of Community Dentistry. Commun. Dent. Health 22:46-56.
Rose G (2008). Rose's strategy of preventive medicine, Oxford University Press.
The Dental Observatory TDO (2009). NHS Dental Epidemiology Programme for England Oral Health Survey of 5 year old Children 2007/2008. Public Health England. Available at: www.nwph.net/dentalhealth.
World Health Organization WHO (2013a). *Continuous improvement of oral health in the 21st century*. Available at: www.who.int/oral_health/en. [Accessed 2/11/14].
World Health Organization WHO (2013b). *Health Topics: Oral Health.* Available at: www.who.int/topics/oral_health/en.
Yeung C, Hitchings JL, Macfarlane TV, Threlfall A, Tickle M, Glenny AM (2005). Fluoridated milk for preventing dental caries. Cochrane Database Syst. Rev. Available at: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD003876.pub2/pdf
Yeung CA (2008). A systematic review of the efficacy and safety of fluoridation. Evid. Based Dent. 9:39-43.