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DDS thesis.

Ecological influences, observational caries epidemiological trends and associated socioeconomic and geographic dental health inequalities at five years of age in Scotland, 1993/94-2007/08

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1 Abstract: Ecological influences, observational caries epidemiological trends and associated socioeconomic and geographic dental health inequalities at five years of age in Scotland, 1993/94-2007/08

<u>Introduction</u>: In recent years many national Governments have called for health improvements at the population level and at the same time reductions in health inequalities. To date, dental epidemiology has concentrated mainly on tracking trends in dental health. Methodologies relating to dental health inequalities are, however, not well established.

Within Scotland, over the past decade, children's oral health improvement programmes have been established at national level. Preceding and concurrent with these developments, similar initiatives have been implemented within Greater Glasgow NHS Board. This is Scotland's largest NHS Board with the highest proportion of Scotland's socio-economic status (SES) deprived population.

Recent reports from the National Dental Inspection Programme (NDIP) for five-year-olds show improvements in dental health.

The above conditions provide the opportunity to explore dental trends in more detail at geographic level within Scotland and to investigate dental health inequality methodologies within the context of health improvement programmes and overall improvements in dental health.

<u>Aim</u>: To examine caries epidemiology data and apply and appraise a range of tests of health inequality to data from Primary 1 (P1) five-year-old children in Scotland during the period 1993/94-2007/08, against a background of health improvement programmes. Furthermore, to apply the selected inequalities tests to the caries data for a) Scotland as a whole and b) the geographic subgroups: 1] Glasgow (GGHB) and 2] the remainder of Scotland, outwith Glasgow (Not-Glasgow).

<u>Methods</u>: Secondary analyses were performed on eight successive cross-sectional NDIP five-year-olds' caries datasets, 1993/94 to 2007/08. These permitted both SES and geographic trends in mean $d_3$mft and % dmft=0 to be plotted for the areas: Scotland, GGHB and Not-Glasgow.

The metrics selected to model dental health inequalities were: the Significant Caries Index (SIC) and modified SIC^{10}, the Receiver Operator Curve (ROC), the Gini coefficient, the Concentration Curve (CC), Koolman and Doorslaer's transformed Concentration Index (CI), the Slope Index of Inequality (SII), the Relative Index of Inequality (RII) and the Population Attributable Risk (PAR). Odds Ratios and Meta-analyses using Generalised Linear Modelling assessed statistical-inference for dental health and inequality trends.

Results: Overall, usable data was retrieved for 68,398 five-year-old subjects (n=18,174 from GGHB; n=50,224 from Not-Glasgow).

In Scotland as a whole, marked SES gradients in caries prevalence and caries burden were related to the DepCat score of children's home postcode.

Between the start and endpoints of the study, the simple absolute SES inequality in mean $d_3$mft between the most affluent and most deprived groups decreased ($p<0.02$), whilst mean $d_3$mft reduced across the entire SES spectrum. Relative to the baseline year (1993), by 2007, the Odds Ratios for $d_3$mft>0 in Scotland decreased ($p<0.0001$) to 0.43 (95%CI, 0.40-0.46).

Although Scotland's simple absolute SES related dental health inequality (DHI) decreased for mean $d_3$mft ($p<0.02$), there were no improvements in simple relative SES DHIs over this time period.

Simple absolute and simple relative geographic inequalities in weighted %$d_3$mft=0 and mean $d_3$mft were seen when GGHB was compared with Not-Glasgow data. These geographic inequalities metrics tended to increase from 1993/94 until 1999/00. However, by 2007/08 reductions in simple absolute geographic inequality were observed, with marginal improvements in simple relative geographic inequality compared to baseline. Additionally, simple absolute and relative geographic inequality in SIC scores decreased overall against a background of SIC improvements in both GGHB & Not-Glasgow (Meta-analysis, $p<0.01$, respectively).

By 2007/08, relative to 1993/94, Odds Ratios for $d_3$mft>0 in the geographic subgroups GGHB and Not-Glasgow decreased, respectively ($p<0.0001$), to 0.31 (95%CI, 0.26-0.38) and 0.46 (95%CI, 0.43-0.50).

There was evidence of a 'Glasgow (dental health) Effect', whereby GGHB children's dental health was poorer than in Not-Glasgow during the period 1993 to 1999, after controlling for confounding factors ($p<0.01$). This 'Glasgow Effect' was no longer evident by 2007.

Modelling caries data using the complex inequality metrics has given further insights into different dimensions of geographic and SES-related dental health inequalities. For example, in each area from 1993/94-2007/08, the full SIC[10] distributions showed respective decreases in complex absolute DHI in affected individuals in population deciles (irrespective of SES). Simultaneously, Scotland's SII indicated that complex absolute SES inequalities decreased ($p<0.02$). Furthermore, in Glasgow the %PAR decreased by 24 percentage points, itself impacting on Scotland's decreased PAR.

However, the RII and transformed CI indicated that complex relative SES DHI increased in each area over the period of study.

The ROC, CC & RII plots were comparatively stable over time for Scotland, compared to trends in the GGHB subgroup.

There was evidence of some variation in DHI, and the Gini-coefficient (for individual DHI) was counter-intuitive.

Discussion:

Analysis and interpretation of simple and complex absolute and relative DHI outcomes are not straightforward against a background of population dental health improvements across the SES spectrum. If equivalent absolute dental health improvements are achieved in the best and poorest $d_3$mft groups, as %$d_3$mft>0 and mean $d_3$mft diminish in the denominator group it is increasingly difficult to achieve improvement in relative inequalities. Nonetheless, tests suggest that simple absolute geographic DHI in Scotland's P1's weighted %$d_3$mft=0 and mean $d_3$mft have improved, while simple relative geographic inequality has not deteriorated over the interval 1993-2007.

Further insights were obtained from examination of the cross-sectional distributions of SIC^{10}. These showed improvements in complex absolute individual inequality across all population deciles with $d_3$mft>0, over time, at each geographic level. Moreover, comparison of the geographic SIC^{10} scores for the worst affected deciles demonstrated reductions in simple absolute and relative geographic DHI in five-year-olds' $d_3$mft morbidity for those with the poorest dental health outcomes in 2007 *vs*. 1993.

Furthermore, Scotland's complex absolute SES-related DHI has decreased over time when assessed by SII. Improvements in complex absolute SES-related DHI have occurred more readily than improvements in complex relative SES-related DHI.

Conclusions:

For the first time, these multiple tests of inequality have been applied to Scotland's and Glasgow's child caries datasets. Generally, caries epidemiology trends occurred slowly and smoothly, however, DHI trends from this same data tended to fluctuate (especially in the geographic subgroups).

The apparent lack of consonance of the various inequalities metrics demonstrates that measurement, understanding and interpretation of population DHI trends are complicated and require knowledge of the underlying epidemiology trends. Nonetheless, with the exception of the Gini, all results provided useful information which aid understanding of DHI. The complex measures such as the SII and RII had the advantage of using all the available $d_3$mft information within the DepCat domains and weighting results for SES within the denominator populations. Furthermore, in Scotland as a whole, the SIC^{10} distribution, SII and RII appear to exhibit stable DHI trends, against the background populations' dental health improvements.

The results suggest that in addition to the simple measures, the SIC^{10} distribution, SII and RII appear the most useful tests when describing dental health inequality with caries epidemiology data of this type. Recommendations for future research include modelling other large caries databases and future Scottish P1 & P7 datasets with the selected DHI tests.

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Author's declaration

Parts of the research work included in this thesis have involved collaborations with others, including:

Chapter 1: in collaboration with Helen Marlborourgh, the development of permanent subject alerts for the Literature Review,

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Chapter 4 & Chapter 5: in collaboration with Zoann Nugent, pre-processing of SHBDEP and NDIP raw data outputs and appendment of DepCat 2001 scores to survey subjects' data. In collaboration with Alex McMahon, PC programming of inequalities analyses macros in SAS, testing of inequalities macros and the production of the epidemiological and inequalities statistical outputs and the later application of statistical tests in SAS.

I declare that the thesis is my own composition and has not been submitted in part or whole for any other degree.

Yvonne I Blair

Glasgow, August 2011.

List of Abbreviations

ABI	Area Based Indictor of socio-economic status
BASCD	British Association for the Study of Community Dentistry
BMI	Body Mass Index
c (value)	The predictive potential coefficient of exposure to a defined variable
CC	Concentration curve
CD	Community Development
CDC	US Department of Health and Human Services Centres for Disease Control
CDS	Community Dental Service
CHIs	Complex Health Interventions
CI	Concentration Index
CI(95%)	95% Confidence Interval
Con.	Conservative Party
CVD	Cardiovascular disease
DCPs	Dental Care Professionals
DepCat	Carstairs & Morris' Deprivation Category
DHE	Dental Health Education
DHI	Dental health inequalities
DHII	Dental Health Inequalities Index (Nugent *et al.*)
DHP	Dental Health Promotion
DOI	Diffusion of Innovation
DPH	Dental Public Health
erpho	Eastern Region Public Health Observatory
FVP	Fluoride Varnishing Programme
GB	Great Britain
GGHB	Greater Glasgow Health Board
GLM	Generalised Linear Model
GP	General Practitioner
HBM	Health Belief Model
HE	Health Education
HI	Health inequalities
HLOC	Health Locus of control
HP	Health Promotion
IAPD	International Association of Paediatric Dentistry
ICDAS	International Caries Detection and Assessment System
ID	Identification
IR	Irish Republic
ISD	Information & Statistics Division of National Health Services National Services
K&S	Knowledge and skill
Lab.	Labour Party
LE	Lay Epidemiology
LHCCs	Units of Primary Care administration in NHS Scotland 1997-2005
Max.	Maximum

MRC	Medical Research Council
NDIP	National Dental Inspection Programme
NHS	National Health Service
NHSGGC	National Health Services Greater Glasgow and Clyde
NS-SEC	National Statistics Socio Economic Classification
N/S	Not statistically significant at the $p<0.05$ level
OECD	Organisation of Economic Co-operation and Development
OHATs	Oral Health Action Teams in NHS Greater Glasgow and Clyde
OHI	Oral Health Improvement
OHP	Oral Health Promotion
ONS	Office of National Statistics
OR	Odds Ratio
PI	Performance indicator
PW	Partnership Working
QA	Quality Assurance
QI	Quality Improvement
RCT	Randomised Controlled Trial
RHI	Robin Hood Index
RII	Relative Index of Inequality
ROC	Receiver Operator Curve
SA	Simple absolute
SE	Scottish Executive
ScotPHO	Scottish Public Health Observatory
SD	Standard Deviation
SDECC	Scottish Dental Epidemiology Co-ordinating Committee
SES	Socio-economic Status
SHBDEP	Scottish Health Boards' Dental Epidemiological Programme
SIC	Significant Caries Index (Bratthall)
SIC^{10}	Modified Significant Caries Index (Morgan *et al.*)
SIGN	Scottish Intercollegiate Guidelines Network
SII	Slope Index of Inequality
SIMD	Scottish Index of Multiple Deprivation
SOC	Sense of coherence
SR	Simple relative
T	Time point
TBP	Theory of Planned Behaviour
TD	Trans-disciplinary (research)
TR	Translational Research
UK	United Kingdom
USA	United States of America
vs.	Versus
WB	World Bank
WCS	West-central Scotland
WHO	World Health Organisation

Introduction

Background

Health inequalities are the subject of an extensive literature. Increasingly, in association with policy implementation, policymakers, funding bodies and governments make demands for improvements in health and concurrent reductions in health inequalities. The literature suggests that making progress on both fronts, simultaneously, is extremely difficult to achieve. Furthermore, there does not appear to be consensus yet, as to how dental health inequalities and trends should be measured. In Scotland, to date, no comprehensive assessment of methodologies which may be appropriate for measuring/monitoring dental health inequalities has been published. It therefore seems appropriate that such a study is carried out.

A convenient starting point to begin exploration of the relationships between the above concepts would be to commence examination of two case-study Oral Health Promotion (OHP) programmes which have already demonstrated convincing dental health improvements at the epidemiological level. The author of this thesis has for over a decade had involvement in strategic oral health gain programmes in Glasgow and Scotland, which can provide a suitable platform for modelling inequalities in relation to the dental health outcomes of five-year-old Primary 1 (P1) school children. Baseline and follow-up data can therefore be modelled to assess dental health improvements and associated dental health inequalities, using a variety of selected tests of inequality. Following interpretation in the light of epidemiological changes, the inequalities measurement techniques can be assessed for future applicability in Scotland from a dental health inequalities perspective.

In Scotland, the first national OHP programme's pilot phase began in 2000 (i.e. the nursery toothbrushing and distribution of free F^- dentifrice and toothbrushes for home use). The OHP programme further developed using 'Theory-Based' research methods to build upon earlier OHP programmes which were piloted in Scotland (Shaw *et al.*, 2009; Macpherson *et al.*, 2010; Turner *et al.*, 2010) and further afield. The Scottish Government has since 2006 funded a National Demonstration OHP Programme which is now known as *"Childsmile"*. Detailed information on *Childsmile* and the earlier NHS Greater Glasgow '*Possilpark Project'*, will be provided in a later section (Chapter 3) of this thesis to give environmental context and to assist understanding of changes in dental health and any associated inequalities observations.

Although there have already been indications of dental health improvements in 5-year-olds temporally associated with the above OHP, there had, however, been no systematic consideration of the extent of, or trends in, dental health inequalities within the scope of these programmes. Furthermore, there has been uncertainty whether such health improvement programmes *per se* could reasonably be expected to effect increases or decreases in dental health inequalities in the age group. Macintyre (2008) considered that there may be conflict between the public health goals of health improvement for the whole population and at the same time those of decreasing health inequalities. Nevertheless, in spite of this, politicians and policy makers propound these twin aims. The field of health inequalities is one of evolving intervention and evaluation strategies. As yet, there is considerable uncertainty about the most effective ways to bring about improvement in dental health inequalities outcomes and also on the most effective ways to measure changes in dental health inequalities.

Chapter 1

1 Literature review

1.1 Introduction to a review of the literature on associated subjects

The OHP programmes' pilots in Scotland and Glasgow, commenced from 2000 and 1996, respectively, and both involved widespread establishment of nursery toothbrushing and supplies of free F^- dentifrice and toothbrushes to young children for home use. These form the starting point for an expectation that alongside the improvements in caries epidemiological outcomes for five-year-olds, there may also have been some changes in dental health inequalities. It must be pointed out at this stage that improvement in dental health outcomes do not necessarily translate into improved dental inequalities outcomes and overall improvement in dental health statistics could potentially conceal overall worsening dental inequalities or deterioration of inequality in sub-groups. As the nature of any inequalities outcomes will be determined by the HP interventions' design etc, it seems logical to begin this review by thoroughly examining the evolution of ideas about good practice with respect to generic Health Education and Health Promotion, as the above noted programmes form part of the back-drop to any changes in dental health inequalities which may be observed.

For the above reasons, in order to provide a historical developmental framework to this body of work, which seeks to test inequalities metrics by assessing caries inequality outcomes in Scotland and Glasgow, this review of the literature will begin by examining some of the prominent associated theories of behaviour change. The health and inequalities outcomes and the reported limitations of simple Health Education will be considered, as will the contemporary transition towards Health Promotion programmes, which by definition are more complex. These and further subject reviews related to the health inequalities agenda will follow a pattern of first considering issues related to general health and inequalities outcomes, before focusing on those related more specifically to dental health. This perspective will permit the reader to assess the extent to which the interventions frameworks described later, within Chapter 3, were rational within the ecological and inequalities contexts of their time, persons/populations and places. Consideration will also be given to the Scottish Government's policy agenda for child health and dental health improvement, with particular reference to socio-economic dental health inequalities of five-year-olds.

The universal nature of morbidity and mortality inequalities at national and international level will then be demonstrated to explain the extent to which the nature of inequalities is secular.

Thereafter, salient methodological issues relevant to caries epidemiology, geographic and socio-economic inequalities in dental health will be considered to provide a contemporary viewpoint to the epidemiological methodology applied later in this thesis (Methods 1). The review will proceed to investigate modern-day approaches aimed towards the measurement of health improvement outcomes, inequality outcomes and issues associated with evaluation of complex intervention programmes, such as the ones outlined later in this thesis. A history of the contemporary interest in inequalities will then be outlined. This will precede an exploration of methods published in the scientific literature for measuring general health inequalities, prior to a similar investigation of specific tests which have been used previously to quantify dental caries inequalities. Thus, a variety of inequalities tests will be selected from the potential tests of inequalities discovered.

1.2 Search strategies

1.2.1 Initial strategy

With the support of the Subject Librarian (Medical), University of Glasgow, an initial search strategy to gain a general impression of previous inequalities research was developed in Ovid using the subject search terms i) [inequalit$ or deprivation or deprived or disparit$ or under privileged or poverty or socio-economic$ or social class]; ii) [health or dental or oral]; iii) [i) and ii) combined]; iv) [index or indice$ or tool$ or scale$ or score] and v) [i) and iv) combined]. Access was *via* the Athens gateway and electronic abstracts were obtained for selected titles in the above yields. Assessment of the abstracts formed the basis of an initial selection of full text papers for reading and review. The author used a similar strategy to explore e.g. previous examples of Health Promotion programmes and their evaluation using terms [health promotion or health program$ or oral health program$ or oral health promotion or dental health program$ or dental Health Education] and [outcome$ or program$ evaluation]. Electronic searches were extended by use of further search tools and databases e.g. ISI Web of Knowledge, PubMed, Google Scholar and the NHS e-library to pursue specific subjects e.g. [deprivation index or deprivation indic$ or SIC or DHII or Jarman Underprivileged Area Score or SIMD index or SIMD score or Gini coefficient] and authors e.g. Antunes J.L., Watt R. or R.G. and Chestnutt I.G.. Whenever possible, full texts were accessed *via* electronic databases accessible to the author. However, when electronic access was not available, documents were sourced *via* the University of Glasgow James Ireland Memorial Library.

1.2.2 Grey-literature

Additionally, articles in Dental Public Health textbooks and ‘grey literature’ were extensively hand searched permitting further key research-terms, -authors and -papers in related fields to be pursued.

1.2.3 Permanent subject and author alerts

Permanent alerts were set up for all authors and subjects of interest to this thesis in Ovid AutoAlert; ISI Web of Knowledge search alerts and the MIMAS Zetoc Alert Service.

The literature appearing in the following review was obtained by the methods described above. As aforesaid, the main topic of the review will be related to health inequalities. However, to set the scene it will begin by describing the evolution of strategies with potential to impact on health inequalities, before reviewing a range of further topics pertinent to (dental) health inequalities measurement research.

1.3 General Health Education

1.3.1 Introduction

The World Health Organisation (WHO) defined Health Education (HE) as any educational activity aimed to achieve a health related goal. However, application of the term HE tends to be restricted to interventions aimed at increasing health knowledge and skills. Health education is not synonymous with Health Promotion (Steckler *et al.,* 1994; Tones, 1997; Whitehead, 2003a). McKeown (1976) was among the early authors to deplore emphasis on posters, advertisements and rhetoric, as he considered that HE should become the central concern of every practising doctor (dentist) who should instead attempt to stimulate delicate and multifaceted lifestyle modifications. The wane of HE has been described in the late 1970s (Draper *et al.,* 1980), as it was by then recognised that multiple simultaneous interventions are required (Amathila, 2000).

A selective review by Tones (1997) indicated that success was dependent on the HE meeting certain minimum design criteria. Wanless (2004) later acknowledged the continuing difficulties in identifying effective interventions. However, he continued to place the main responsibility for improving health on individuals.

1.4 Theories of behaviour change

The development of an extensive range of HE models and theories of change are documented (Ritchie, 1991; Towner, 1993; Sogaard, 1993; Daly *et al.,* 2002). Psychologists tend to base most theories of change at an individual level, omitting the wider social context. Psychoanalysts proposed that individuals' behaviour was motivated by deep-seated instincts (Rotter, 1993) to respond to stimuli (Bandura, 1977) and avoid punishment (Rosenstock *et al.,* 1988).

1.4.1 Health Belief Model (HBM)

The Health Belief Model (HBM), also known as Social Cognitive Theory (Bandura, 1977; Rosenstock *et al.,* 1988) sought to explain patterns of health behaviour by examining underlying beliefs. The model suggests that individual perceptions are related to: susceptibility; severity of the condition; the cost *versus* benefits of taking action (within the range of possibilities for the individual). However, its predictive/explanatory value has been considered to be inferior to that of other theories (Greene & Mercer, 2007) and Meta-analysis found only weak effect sizes and predictive values (Harrison *et al.,* 1992). Paradoxically, Blaxter (1995) found that those indulging in unhealthy behaviours were the most aware of the relationship between their behaviour and disease.

1.4.2 Social learning theory and Health Locus of Control (HLOC)

Health Locus of Control (HLOC) theory is derived from Social Learning Theory (Rotter, 1993) and considers the extent to which individuals perceive that they themselves influence their health, compared to other external factors. The multiple dimensions of control are self- or internal-HLOC, 'powerful-others'-HLOC and chance-HLOC (Daly *et al.,* 2002). However, the construct of HLOC is always multidimensional (Wallston, 1992).

1.4.3 Self-efficacy

The concept of self-efficacy (Bandura, 1977) is considered the principal mediator of behavioural change in a systematic review (Strecher *et al.,* 1986). Perceived self-reliance and self-confidence are major determinants of both willingness to invest effort and duration of perseverance and the 'expectation of self-efficacy' is a prerequisite to a successful outcome (Rosenstock *et al.*, 1988). Antonovsky (1996) related 'sense of coherence' (SOC) to self-efficacy. Strong SOC is a prerequisite in moving people along a continuum towards health (Antonovsky, 1996). Adolescents' SOC was the most important 'psychosocial' predictor of oral health outcomes (Baker e*t al.*, 2010; Bernabe & Hobdell, 2010).

1.4.4 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) suggests that the closest determinant of behaviour is the 'intention to act' (Ajzen & Fishbein, 1977; Ajzen, 1991). Intention is modified by attitudes, subjective/social norms and perceived controls on the behaviour. A review indicates that TPB accounted for an average of 41% and 34%, respectively, of intention and of health related behaviour (Godin & Kok, 1996).

1.4.5 Diffusion of innovation model

Rogers (1962; Rodgers & Shoemaker, 1971) described the theory of diffusion of innovation (DOI) in which groups of people are arranged across the different segments of and 'S' shaped curve plotting proportions of person' against uptake of a innovation. Moving along the x-axis from the intersection are the first group i.e. the 'i*nnovators*' who are described as those eager for new practices, on the basis of reasoned action. They are followed by the '*early adopters'* and the '*early majority*' *(*usually young and of high SES status). Later groups to change are described as the '*late majority*' (usually of lesser social status) who learn from peers/social networks and lastly are the '*laggards'* who are characterised as hard to reach often socially isolated population groups (Rogers, 2002).

1.4.6 Stages of change model

The Prochaska & DiClemente (1983) so called '*stages of change*' model is now widely used to facilitate e.g. diet, exercise and drug prevention (Daly *et al.,* 2002). However, there is scant evidence to support use of this model (Riemsma *et al.,* 2002). This model ranks people according to their intention to change their own behaviour commencing with a stage described as the *'pre-contemplation'* stage. At this stage a person may be aware of a health promotion message, but will not have considered applying this information to his/her own lifestyle.

1.5 Limitations of Health Education (HE)

Blaxter (1995) suggested there is often dissonance between health knowledge and actions. Many Health Promotion (HP) programmes are founded on the premise of '*reasoned-action'*, i.e. that HE is the initial step in a sequence by which new information changes attitudes, which then lead to modification of health-related behaviour. This model does not reliably bring about sustainable behaviour change or change in health outcomes (Ritchie, 1991; Sheiham, 2000), as stand-alone HE interventions are of doubtful effectiveness (Donaldson & Donaldson, 1993; Williams *et* *al.*, 1998). Fundamentally, individual behaviours have a relatively modest influence on population health outcomes when compared to wider environmental, economic and social influences (McKeown, 1976; Freudenberg, 1987). Nonetheless, there is evidence that general education is relevant to health (Pincus *et al.*, 1998: Weare 2002; Population Reference Bureau, 2005).

Coaching-type approaches are considered effective for both children and adults (Weare, 2002). The corollary, rebuke for the non-compliant gave rise to a backlash against '*victim blaming*' (Freudenberg, 1987). Victim blaming is said to occur when individuals or groups are held accountable for actions or consequences beyond their control. This ideology used to justify social injustices of many types (Wikipedia). Victim blaming and punishment are never justifiable (Kay & Locker, 1997; Link & Phelan, 2002). Ritchie (1991) holds that we must not adopt over-paternalist attitudes which render people passive recipients.

1.6 Outcomes of Health Education

Since the mid-1990s there has been widespread political interest in whether HE is a) effective and b) has the potential to bring about cost savings in health care (Tones, 1997). In Scotland, a recent *Health Education Population Survey 1996-2003* (Malam *et al.*, 2004) showed overall small improvements in knowledge and attitudes related to risk of disease for selected topics. However, this self-reported data must be treated with caution. A Medical Research Council (MRC) review has advocated incorporating behavioural-change (the so called psychological) approaches into HE (Hardeman *et al.*, 2000). It seems naive to expect discrete parts of lifestyle to change solely by HE, while general exposure to health risks remains involuntary (Blaxter, 1995).

In Scotland, an unintended (*and unpalatable*) consequence of population level HE was that improved health indices occurred faster in more affluent groups and geographic areas leading to increasing health inequalities over the eight year period 1995-2003 (Malam *et al.*, 2004).

1.7 Health Promotion (HP)

1.7.1 Introduction and evolution of Health Promotion

Since the 1980s, it has been recognised that, even in major industrialised countries, more knowledge and skills within a framework of improved social and environmental conditions were required to improve population health. The concept of multidimensional '*health fields*' (Lalonde, 1981) replaced the earlier narrower concept that health arose from the art and science of medicine (alone). The theory of health fields proposes that human biology, environment, lifestyle and healthcare organisation all exert influences on health outcomes.

1.7.2 The Ottawa Charter for Health Promotion

The World Health Organisation (WHO) *Ottawa Charter for Health Promotion* (1986) built on Lalonde's model, defining Health Promotion (HP) as:

> " ……...the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well being, an individual or group must be able to identify and to satisfy needs, and to change or cope with the environment." (World Health Organisation, 1986)

Tones and Tilford (1994) further defined the symbiotic and synergistic relationships which are characteristic of HP. Furthermore, empowerment, democracy, equity, autonomy and health competency remain central tenets of HP (Weare, 2002).

1.7.3 Development of contemporary 'key areas for action'

The original key areas for action articulated by WHO (1986) were advocacy, enabling, mediation, building healthy public policy, creation of supportive environments, strengthening community action, development of personal skills and reorientation of health services. Recently, the Bangkok Charter (World Health Organisation, 2005) acknowledged the changed global context for Health Promotion.

1.7.4 The Settings approach

'Health settings' are defined as the places or social contexts in which people engage in daily activities and where environmental, organisational and personal factors interact to effect health and well-being (Nutbeam, 1998a). A recent review highlighted the diversity of potential settings and HP models (Whitelaw *et al.*, 2001). The 'settings approach' refers to more than just places. It encompasses the possibilities for developing supportive environments, opportunities for empowerment and for developing the physical, social, spiritual, economic and political dimensions of Health Promotion (Andrien, 1994; Nutbeam, 1998a).

1.7.5 Health Literacy

Modern use of the concept of '*Health Literacy*' evolved from conventional notions of learnedness in health issues to encompass: empowerment, political 'nous' and confidence of people(s) to act (Nutbeam, 2000; Kickbusch, 2001). Its use is not uncontroversial (Tones, 2002). Daly *et al.* (2010) have recently investigated this construct in the evaluation of '*Sure Start*' programmes in England.

1.8 Factors influencing health outcomes from Health Promotion

The literature on tackling inequalities in health makes explicit the need for investment in sustainable policies, actions, infrastructures and in communities in order to address the determinants of health. Systematic review has found that addressing: identified/expressed needs of target populations, collaborative multidisciplinary approaches, combinations of interventions and the involvement of peers along with improved economic or social conditions could reduce health inequalities (Arblaster *et al.,* 1996). Underpinning HP programmes with a sound theoretical background increases the likelihood of success (Hardeman *et al.,* 2000; Hardeman *et al.,* 2002).

1.8.1 Structural factors

Many operational factors are crucial for successful strategy development and implementation (Ader *et al*., 2001). Devolution and democratic leadership are key determinants of successful community partnerships (Butterfoss, 2006). However, professionals' relationships also matter (Simmons *et al*., 2009). Furthermore, subtle contextual factors are determinants beyond study design (Petticrew, 2003; Butterfoss, 2006; Armstrong *et al*., 2008).

1.8.2 Lay Epidemiology (LE)

The term 'Lay Epidemiology' refers to individuals' own understanding of patterns of health, illness and the causes, informed by anecdotal evidence, their personal experience, and the interpretation of science by popular literature and the media (Shaw *et al.,* 2007).

Failures to understand LE adequately, explains the relatively limited impacts of health programmes on poorer SES groups, compared to the more affluent (Lawlor *et al.,* 2003). Furthermore, LE promotes engagement among the disenchanted and those distrusting of health professionals/authorities (Shaw *et al.,* 2007). These mistrusts may be manifest in some families targeted for enhanced dental health support (Holme *et al.,* 2009).

1.8.3 Competence of the HP workforce?

Cochrane collaborators acknowledge difficulties critically appraising HP (Jackson & Waters, 2005) and there have been calls for competency frameworks for all workers with a HP role (Speller *et al.,* 1997; Aro *et al.,* 2005; Allegrante *et al.,* 2009; Battel-Kirk *et al.,* 2009; Shilton, 2009a). Management consultants (Frontline Consultants, 2005) commenting on the implementation of the anticipatory care paradigm explicit in the Kerr Report (Scottish Executive, 2005), identified that investment would be needed in frontline staff, leaders' knowledge and skills (K&S) and motivation, if change is to happen. Nevertheless, the principle of 'exchange' holds future potential to motivate OHP practitioners, as accredited and professionally recognised training is an important incentive (Holme *et al.,* 2009). Furthermore, Shah *et al.* (2011) found that dental professionals have specific training needs related to nutrition advice.

1.8.4 Expertise needed for Health Promotion and reduction of inequalities

Ogilvie *et al.* (2005) maintain that '*experts*' i.e. individuals with accredited higher competency on Health Promotion and Public Health have unique ability to inform policymakers on HP. However, the international HP workforce had demonstrable K&S needs (Speller *et al.,* 1997; Allegrante *et al.,* 2001; Harris *et al.,* 2009). Interventions with expert capacity-building inputs produce the most beneficial impacts on children (Tennant *et al.,* 2005). The essential domains of K&S for HP have been described (Battel-Kirk *et al.,* 2009; Hyndman, 2009). The *Tackling Inequalities: 2007 Status Report on the Programme for Action* (Department of Health, 2007) specifically identify workforce capacity and K&S as major determinants of reductions in health inequalities. Thus, accreditation of higher competency in HP has been suggested (Morales *et al.*, 2009; Speller *et al.*, 2009).

1.8.5 The sustainability of collaborations and Transdisciplinary (TD) science

Expert dental input is essential when devising 'common-risk factor' strategies for communities (Stokes *et al.,* 2009). Nevertheless, the tensions and dilemmas facing innovators/'*change-agents*' have been outlined (Faubert, 2009). The concept of change agents arises in the literature related to Human Resources and Organisational Development (OD). In the context of this thesis the term is used to describe individuals who are those who are skilled in OD theory and techniques. Moreover, the development of *change agents* is said to be required if the *Kerr Report* (Scottish Executive, 2005) is to successfully implement a philosophy of anticipatory care in Scotland (Frontline Consultants, 2005). Furthermore, covering fire is needed from senior level champions to support each innovation (Frontline Consultants, 2005), as individuals who would bring about change are often unwelcomed.

Collaboration and collective action cross-fertilises interventions to address inequalities (Sheiham *et al.*, 2011), although the 'yardstick(s)' by which to assess the outcomes of inter-disciplinary '*Transdisciplinary*' (TD) science remain to be identified. The term TD science describes science projects in which all the knowledge of the contributing persons is distributed within in the project and becomes common knowledge i.e.

> "Ideas from each participant are so thoroughly interwoven that their specific contributions tend to be obscured by the joint product…." (Abrams, 2006).

Nevertheless, TD approaches remain a 'bold experiment' and 'revolutionary' with potential to cause conflicts between parent organisations (Abrams, 2006) and professional grouping.

1.8.6 Evaluation of Health Promotion

Evaluation must clearly be considered and funded from the earliest planning stage (Whitehead, 2001; Whitehead 2003; Welby, 2006). It has even been suggested that to omit HP evaluation negates the whole process (Tones, 2000a; Whitehead, 2003).

1.8.7 Quality indicators (QI) & performance indicators (PI) in HP

Reviews of 'quality indicators' (QIs) considered that Donabedian's (1986) structure, process and outcome framework could satisfy a number of theoretical preconditions indicative of success (Ader *et al.*, 2001; Abrams, 2006). However, the University of York, Centre for Health Economics and others have recognised the problems associated with lag-times from intervention to outcomes (Buck *et al.*, 1996; Howes *et al.*, 2004; Aro *et al.*, 2005; Ogilvie *et al.*, 2005). Nevertheless, it is possible to populate a matrix with performance indicators (PIs)/process milestones along the way (e.g. Nutbeam, 1998b; Watt *et al.*, 2001).

The WHO calls for inequality outcomes to be a PI for HP activity. Clearly, an ability to assess inequalities trends is a pre-requisite to inform society on its future direction. The Organisation for Economic Co-operation and Development (OECD) is explicit about their rationale for PIs e.g. to deliver potential efficiency gains. Furthermore, the OECD considers that international policymakers are looking for methods to measure and benchmark the performance of their health care systems (Marshall *et al.*, 2004).

Evaluation of Health Education, Health Promotion and complex interventions will be discussed in more detail later in this literature review.

1.9 'Targeting' and 'population approaches' to bring about health improvement and decreased inequality

1.9.1 Universal population interventions

The central tenet of *Sick Individuals and Sick Populations* (Rose, 1985 & 2001) and *The Strategy of Preventive Medicine* (Rose, 1992) is that a large number of people at small risk may give rise to more 'cases' than the small number at high risk (Rose, 2001).

This limits the population health-impact of approaches aimed at only 'high-risk' individuals. Modelling studies suggest that numerically, the maximum health-gain will arise from reductions in risk-factors for the bulk of the population currently at average risk (McMichael, 1989). Thus, small reductions in risk-factors across whole populations have the potential to have a greater effect across the whole distribution of a disease than is possible from larger effects on only small targeted subgroups at extreme risk (Kottke *et al.,* 1985). Ebrahim & Lau (2001) have summarised the prevention paradox as follows: i.e. *few will benefit but all have to take part*.

Nonetheless, while health improvement itself is a justifiable goal, there is a danger that overall health improvement will be at the expense of increased health inequalities. Prominent examples of well intentioned campaigns resulting in increased inequality relate to health and dental education programmes in Scotland (Schou & Wight, 1994; Walle *et al.,* 1999; Malam *et al.,* 2004). However, McLaren *et al.* (2010) suggest that the reasons such information-based campaigns failed to decrease inequalities was not because they were population strategies, but because they failed to impact on everyone equally. We are further cautioned that the inequalities agenda may need cost-effectiveness trade-offs (Shaw *et al.,* 2009). There are also issues as to what constitutes the evidence-base, however unpalatable this may seem. As:

> "….to achieve the same results in a disadvantaged group almost certainly costs more than that for affluent communities………In deprived settings, the use of so-called second-best interventions and evidence might be appropriate…." (Tugwell *et al.,* 2006).

McLaren *et al.* (2010) do not consider that all population strategies are the same. They differentiate primarily between intervention strategies which are structural (impacting on social institutions and norms which shape actions) and those which are behavioural (i.e. require agency on the part of individuals). The former type of intervention holds greater potential to decrease inequality (McLaren *et al.*, 2010). Advantages of universal interventions *versus* those targeted to particular individuals are that they may be rapidly implemented to achieve population coverage and saturation. Poorer children thereby potentially receive the same benefits as those with more resources at their disposal (Victora *et al.,* 2003). However, sustaining high levels of coverage may be beyond the resources of some health systems which can lose momentum prior to reaching the hardest to reach groups (Bryce *et al.,* 2003).

Hypothetical 'diffusion of innovation (DOI) curves' for wealthy, poor (without specific policies for poorer people) and poor people with appropriate additional interventions have been proposed (Victora *et al.,* 2003). Thus, while an initial rise in inequality may be inevitable (as the DOI theory considers that the first wave of change will be adopted by the better-off, due to their better access and knowledge), whether or not the gap closes later will depend on the appropriateness of special efforts to close the 'gap' (McLaren *et al.*, 2010) e.g. by effective targeting and/or strong universal coverage (Victora *et al.,* 2003) or as Marmot *et al.* (2010) strongly argue, the targeting of the whole SES gradient in combined universal and differentially targeted interventions.

Meanwhile, other authors consider that health inequalities are likely to persist between groups, even in the event that lifestyle factors are equalised, if the fundamental root causes of inequality which render people still vulnerable are not addressed (Macintyre, 2008; Gruer *et al.,* 2009). The most fundamental causes are international political and economic forces and forms of social stratification (McIntyre, 2008). All impact upon the basic social conditions which embody an array of resources which protect health e.g. money, knowledge, power, prestige and beneficial social connections (Link & Phelan,1995; Phelan *et al.,* 2004; Phelan & Link, 2005; Kreiger, 2008). Some persist that strengthening of national health systems should be the overall aim (Bryce *et al.,* 2003). Furthermore, it is considered that associated costs from universal interventions are borne by society as a whole and that there is none of the so-called 'double discrimination' associated with belonging to a high risk-group and consequently being identified (Sergerie & Farley, 2001).

1.9.2 Targeted interventions

On the other hand there are targeted interventions which may take several forms e.g. 'direct targeting' refers to identifying poor households in order to deliver specific interventions to them. An example of this is distribution of vouchers for free goods or services to poor families. Another form, namely, 'indirect targeting' is said to occur when interventions are a) directed to poorer geographic areas, b) to specific groups with increased needs and c) when an intervention is accessible mainly by poor SES people e.g. fortifying with micro nutrients foods mainly consumed by the disadvantaged (Victora *et al.,* 2003). Targeting is specifically recommended for use in 'richer' countries (Kottke *et al.,* 1985; Coady *et al.,* 2004).

When considering the WHO 'Millennium Development Goal' interventions, which were potentially available to only 50% of the infant populations in developing countries, Gakidou *et al.* (2007) held that child mortality would fall by > 1.5×10^6, if the poor were targeted first. This reduction would be 30%-70% greater if the 50% intervention coverage reached poorer rather than wealthier (nonetheless needy) households first. In another example described in an analysis for the World Bank, targeting has been better able to reach the majority of households in the lowest two SES quintiles in a population (achieving 75% coverage) compared to non-targeted interventions which reached just 30% of these most disadvantaged quintiles (Grosh, 1994). Furthermore, programmes to address the diseases of the poor likely benefit the poor primarily (The World Bank, 2005). Nevertheless, the drawbacks of targeted programmes are that they are: a) difficult to administer, b) stigmatising and c) inappropriate or unethical in some circumstances e.g. in immunisation programmes (Victora *et al.,* 2003; Froehlich & Potvin, 2010).

1.9.3 Combined approaches towards reducing inequalities

A consensus (European Atherosclerosis Society, 1987) has recommended combined complementary strategies: a) directed to whole populations and b) to individuals at particular risk. Macintyre (2008) holds that the following characteristics increase the likelihood of decreasing health inequalities: structural changes to the environment, legislative controls, fiscal policies, income support, reducing price barriers, improved accessibility of services, prioritisation for disadvantaged groups, provision of intensive support and lastly, starting young.

Directed population approaches are further recommended for HP strategies in densely populated deprived communities in developed countries (Kottke *et al.,* 1985). Nevertheless, improving population health whilst at the same time reducing inequalities is considered to be a complex task requiring careful consideration about the ways to bring about maximum health gains for the disadvantaged because of the 'dynamics of advantage' (Mechanic, 2002; Pickett *et al.,* 2005; Kempf *et al.,* 2006; Marmot *et al.,* 2010). Interventions which promise the greatest possible health gains for the SES deprived may nevertheless bring about increases in inequality (Kempf *et al.,* 2006; Froehlich & Potvin 2010). Thus, is will always be important to continue to monitor for unintended effects on inequality (Starfield, 2007). Furthermore, the Victora *et al.* (2003) hypothetical curves for DOI must be borne in mind. According to their model, inequalities in adoption of child health interventions are to be expected in the early phases of programmes adopting combined approaches e.g. universal interventions alongside specific programme actions designed for lower SES people i.e. targeted groups (Victora *et al.,* 2003). Furthermore, these authors' research group have described an "*Inverse Equity Hypothesis*", arguing that this is the corollary to Tudor Hart's (1971) earlier "*Inverse Care Law*" (this proposes that the availability of good medical care will vary inversely with the health-need of a population). They hold that inequalities reductions will only follow later in an intervention cycle, when the more affluent groups have been saturated by interventions and achieved new minimum achievable levels of morbidity (Victora *et al.,* 2000) from the interventions and at the point that only comparatively small further reductions are possible for the relatively advantaged. McLaren *et al.* (2010) believe that the likelihood of population strategies worsening health inequalities will depend where on the continuum between 'structure' and 'agency' programmes are located. Maximum inequalities benefit will potentially arise from multiple intervention strategies and coverage (Manuel & Rosella , 2010).

Tugwell *et al.* (2006) proposed an *'Equity Effectiveness Loop'* with similarities to earlier depictions of planning/audit cycles. However, their focus is firmly on equity. These authors consider that information on both 'risk' and 'response' across the whole SES gradient is essential in the transition from '*mere'* measurement of inequalities to the design of effective inequalities strategies. This framework incorporates individual risk, SES and population health perspectives.

1.10 A Community Development (CD) approach

Community development has often been associated with HP (Epstein *et al.,* 1973). 'Community Development' (CD) is more than the use of participatory techniques e.g. peer education or user involvement (Ewles & Simnett, 1999; Kennedy, 2003). *The National Occupational Standards in Community Development Work* document (Paulo, 2003) defines evaluation as a key principle of this approach (Baum *et al.,* 2006).

Kennedy (2003) considered process, intention, motivation and means of delivery as the *a priori* determinants of success from CD. Pyett (2002) and Popay (2006) likewise question the authority of professionals to themselves define health problems and policy on behalf of communities. The peoples' involvement in CD contributes the '*lived experience*'. Thereby, it has a political nature at odds with traditional scientific research (Cornwall & Jewkes, 1995; Beresford, 2007). Abelin *et al.* (1988) highlighted a potential drawback connected to the power-sharing necessitated by CD. Previously, bureaucracies themselves decided on resource deployment, *via* hierarchies in which 'clout' and stature was assessed by budgetary span of control (e.g. the NHS). It has even been suggested that '*critical consciousness raising*' in communities can be dangerous to the proponents (NHS) careers (Tones, 2000b). Critical consciousness raising in CD is the process of sharing knowledge and information with communities to the extent that they begin to feel compelled to take actions on their own behalf. Previously, much of the required knowledge was vested in the professions and within the NHS etc. who consequently made the decisions on resource deployment. The suggested desire to restrict access to knowledge-based resources (Tonnes, 2000b) is connected to protectionism among professions and bureaucrats who sometimes wish to resist developments which may lead to devolution of budgetary and line-management spans of control. In many public systems it is these features of job descriptions which confer career grade and pay point advantages for individuals. This type of reward and status system can theoretically put public servants in conflict with the wider goals of society.

Some difficulties experienced by academics in association with CD research are related to a norm in academia for quality assessment being related to peer reviewed publications, rather than success in bringing about meaningful health outcomes in real communities by scientific endeavour, i.e. so called '*translational research*' [TR] (Marincola, 2003; Woolf & Johnson, 2005; Baum *et al.,* 2006; Cooksey, 2006; Feldman, 2008). Nevertheless, renewed European and American interest in (and funding for) TR provides potential for populations to benefit (Cooksey, 2006; van Driel *et al.,* 2007; Woolf, 2008). Furthermore, the Cochrane Equity Field Editorial Team (Tugwell *et al.,* 2006) have recognised the difficulties with conventional sources and grading of evidence in inequalities research and the need for different study designs and other sorts of evidence.

1.11 Common risk factor approach

The concepts of 'risk factors' and 'protective factors' arise from epidemiological studies and describe core environmental or individual markers indicative, respectively, of increased and decreased likelihood of an adverse outcome. Diverse problems can share common risk factors (Small, 2000) and this recognition has led to strong criticism of past preventive programmes (Department of Health, 2005a; Watt, 2007). Common risk factor approaches acknowledge that many chronic states arise from complex multifactorial common risk factors (Fejerskov, 2004; Department of Health, 2005a).

1.11.1 Examples of the interplay of common risk factors

A review of factors associated with later delinquency (Wasserman *et al.,* 2003) identified risk factors in infancy, which would equally be associated with poor health (including oral health). The authors assert that it is essential that future interventions focus on improving the early-years life experience. Early childhood is identified as an especially sensitive period with respect to individual influences (Wasserman *et al.,* 2003). The concept of 'cumulative risk' (Small & Luster, 1994) suggests that the more of these types of risk factors present, the greater the likelihood of negative outcomes across a spectrum of health and social conditions. The corollary suggests that acting to mitigate common risk factors has the potential to more efficiently and effectively bring about improvements across a spectrum of conditions (Department of Health, 2005a). Contemporary approaches in the U.S. now focus on a 'risk and protective factor model' theoretical framework in which (*all identifiable*) risks are minimised and protective factors maximised, as part of a common agenda (National Youth Violence Prevention Resource Centre, 2001; Centre for Disease Control, 2008).

1.12 Evaluation of Community Development (CD) Programmes-whose values?

A review of 'user involvement-based research' has found this to be effective in addressing inequalities (Turner & Beresford, 2005). However, different stakeholders have different values and expectations when it comes to assessing evidence and the extent to which valued goals have been achieved (Raphael, 2000; Tones, 2000; Whitelaw *et al.,* 2001; Rychetnik & Wise, 2004). Scientific evaluations require large sample sizes, costly expenditures, prolonged time-frames and advanced data analysis (Green & Tones, 1999). Evaluation difficulties are proportional to the levels of programme activity and the degree of complexity of component intervention strands. Thus, health promoters often settle for process evaluations (Steckler *et al.,* 1994). Nevertheless, some authors do believe that when there is a 'community mission' (i.e. the aim and objectives are to confer improved health outcomes at community level) formative analysis of the community and a process evaluation is sufficient (Mittelmark *et al.*, 1993; Nutbeam *et al.,* 1993) as epidemiological outcomes can be too remote (Green & Tones, 1999).

1.12.1 Community programmes: a study design-effectiveness-assessment trade-off?

There are no historic underlying evaluation models or rules of evidence for CD (McQueen, 2000; McQueen, 2001) and this has discouraged innovative research (Sanson-Fisher *et al.*, 2007). Rychetnik *et al.* (2002) maintain that while a RCT design is optimal (when it comes to acceptance for publication), it represents only one marker of research quality. Mixed methodologies and observational studies are of value (Oakley *et* *al.,* 1995; Ansari *et al.*, 2001; Montana State University Billings, 2007). It has been suggested that quantitative observational research underestimates outcomes. Nevertheless, observational designs have not been found to underestimate the size of intervention effects, when compared directly to RCTs (Benson & Hartz, 2000; Concato *et al.,* 2000; Ioannidis *et al.,* 2000). Furthermore, a review by Kilbourne *et al*. (2006) suggested that an *a priori* requirement for inequalities programmes is CD-based implementation.

1.13 Evaluation of Health Education and Health Promotion programmes

1.13.1 Randomised Controlled Trials

Systematic review of results from multiple Randomised Controlled Trials (RCT) remains the 'gold-standard" in the hierarchy of evaluation methodologies (Pawson *et al.,* 2005). The RCT research design is important for small scale limited intervention Health Education studies. Nevertheless, it is not considered appropriate for large scale community programmes which are by nature complex-, context- and interaction-dependent (Israel *et al.,* 1994; Ansari *et al.,* 2001; Asthana & Halliday, 2006; Kilbourne *et al*., 2006). By design, RCTs have limited external validity (Kilbourne *et al*., 2006). Nevertheless, a majority of medical researchers persist with the notion that RCT is the only valid way of assessing outcomes evidence (Tones, 2000a).

Health Promotion differs substantially from allocation of a drug or surgical procedure to volunteer individual subjects. At population HP level, RCT allocation has been considered: a) artificial, b) possibly unethical, c) unable to avert contamination of ideas (Nutbeam *et al.,* 1993) and d) ideologically unsound (Tones, 2000a; Tones, 2005).

Furthermore, a systematic review criticised RCT studies which did not underpin interventions with behavioural theories (Hardeman *et al.,* 2002). However, the continued emphasis on '*downstream'* (secondary- or tertiary-preventive) individualised approaches is of questionable authority, when aiming to reduce health inequalities (Davey Smith *et al.,* 2001). A critique of evidence of effectiveness from health inequalities interventions suggests that reliance on systematic review of RCTs would lead to the conclusion that '*almost nothing works*' (Asthana & Halliday, 2006) and procedurally sound studies would be excluded. The evidence–base has been distorted thus (Green & Tones, 1999). However, Jackson & Waters (2005) considered that even improved reporting of public health programmes is unlikely to overcome publication bias in favour of RCTs. Future evaluation must distinguish between failure of an evaluation and failure of the actual intervention(s) (Rychetnik *et al.,* 2002).

Dependence on RCT study design *per se* as the predominant inclusion criterion for effectiveness reviews in public health has been further condemned (Elliott & Popay, 2000; Rychetnik *et al.,* 2002; Asthana & Halliday, 2006), as the resulting reports fail to adequately take account of factors such as appropriateness, quality and relevance at community and/or population level. The methodology of RCT is designed to 'wash-out' (i.e. control for environmental and contextual) factors which are the essential explanatory components and it remains questionable whether RCT findings can be generalised into real-life contexts (Pawson *et al.,* 2005).

1.13.1.1 A very prominent type II error

Davey Smith *et al.* (2001) have criticised the Acheson inquiry's evaluation of evidence underpinning the *Independent Inquiry into Health Inequalities* (Acheson, 1998) by citing a comment made by one of the evaluation group:

> "Our recommendations are quite medical because those are the sort that tend to have evidence behind them". (Laurence, 1998).

The task of the Acheson inquiry was to recommend actions which would decrease health inequalities, not merely improve health. The evaluation group suggested that Income Support has been carried out and while theoretically this could have improved health outcomes, the review group did not examine for improved inequalities outcomes (Davey Smith, 2003). Nevertheless, it would take more than just a little more money for a few to bring about reductions in health inequality. In societies with high levels of income inequality there are wide-spread societal and structural characteristics which predispose to inequality in health and nothing short of progressive taxation (i.e. policy intervention at the macro-level) will bring about the necessary redistribution (Davey Smith, 2003). There is thus a mismatch between the evidence and policy. Further concerns relate to political expedience (Asthana & Halliday, 2006) in an evidence-based culture, as '*lack of research-evidence'* is often used as a tactical excuse (Weiss, 1979). Thus, in inequalities research, a "vast array" of innovative intervention will never receive mention in effectiveness reviews (Mielck *et al*., 2002).

1.13.2 Alternative evaluation design-new paradigms for Health Promotion

A recent Medical Research Council (MRC) framework designed for developing and evaluating complex intervention programmes (Campbell *et al.,* 2000) did acknowledge circumstances where alternative study designs to RCT studies were more appropriate and identified that sometimes the process of development itself (e.g. evidence from systematic reviews, epidemiology and expert opinion) can leave no doubt that an intervention will be beneficial and this in itself can be justification for implementation, without the need to bear the cost of a definitive evaluation within a specific context (Pearce, 2000; Campbell *et al.,* 2007). Oliver *et al.* (2005) have made similar recommendations for effectiveness reviews of public policy.

The principle of '*judicial review*' (akin to the process used to determine guilt in courts of law) of HP interventions (Green & Tones, 1999; Tones, 2000a) uses two levels of outcome i.e. '*the balance of probability*' and a higher level *'beyond reasonable doubt'*. However, studies relevant to politicians (agendas) can be more attractive products than high quality research and 'money-talks' i.e. financial impact is the best way to attract funding (Petticrew *et al.,* 2004). Researchers are said to be obsessed with methodological issues whilst the public just want 'what works'. Furthermore, Susser (1994) considered that ecological study designs may be obligatory, apt and appropriate.

There have been longstanding calls for evidence/information drawn from '*all kinds of people*' (e.g. researchers, staff implementing programmes, staff in multidisciplinary partner agencies, parents, carers and children within communities) to be included (Weiss, 1979). Elliott & Popay (2000) have suggested that revisiting and reinterpreting the underpinning assumptions of existing research are among the skills which researchers could bring to (health inequalities) policy formulation. However, there is no universally accepted framework for synthesising the results of mixed evidence (Glasgow *et al.,* 1999; Mays *et al.,* 2005). Studies are considered to be most valuable when they have significance at political and social levels not merely at statistical and clinical levels (Sanson-Fisher *et al.*, 2007).

A literature review has combined expert opinion from the fields of public health and 'grading methodology' (Weightman *et al.,* 2005) to develop and pilot future assessment frameworks for public health interventions which include *all* relevant supporting evidence (i.e. quantitative and qualitative from interventions and observations). These authors conclude that RCT design is not always feasible or appropriate in community settings. A further recently published analytical structure for health inequalities interventions includes multiple domains of 'upstream' influence e.g. state-welfare provision and social structures (Asthana & Halliday, 2006).

1.13.3 Evaluation and review of complex health interventions (CHIs)

While simple experiment alone tests effectiveness of a single treatment (Campbell *et al.,* 2000; Pawson *et al.,* 2005), public health interventions for communities or populations tend to involve complex interventions (Rychetnik *et al.,* 2002). The MRC's researchers have considered complex health interventions (CHIs) problematic to develop, record and replicate (Campbell *et al.,* 2000). This is partly due to variations and uncertainties about the active components. This type of evaluation resonates with the '*judicial review'* evaluation design described earlier. A variation on this type of evaluation process has been called '*Realist Review'* by Mittlemark *et al.* (1993) and Pawson *et al.* (2005). These authors describe *Realist Review* as a process designed to discover how complex interventions work and to answer the questions:

> "WHAT is it about this kind of intervention that works, for WHOM, in what CIRCUMSTANCES, in what RESPECTS and WHY?" (Pawson, *et al.,* 2005).

Furthermore, the very conditions which make CHIs work alter, as an intended or unintended consequence. This has led to MRC etc. recommendations that CHIs are considered to have distinct phases, akin to those in drug development or as parts of an iterative process (Campbell *et al.,* 2000; Jarlais *et al.,* 2004; Armstrong *et al.,* 2008). However, researchers who have actually implemented the MRC framework have commented that, in practice, theoretical and modelling phases occurred simultaneously, but this did not negate their benefits in identifying dissonance between key stakeholders and opportunities for refinement (Murchie *et al.,* 2007).

More recent recommendations include a further model, less closely analogous to the phases of drug development i.e. not necessarily linear/cyclic (Pawson *et al.,* 2005; Braveman, 2007; Craig *et al.,* 2008). Campbell *et al.* (2007) have suggested that while their earlier framework was hugely influential, even the MRC acknowledged that it needed revision (Craig *et al.,* 2008). Meanwhile, Campbell *et al.* (2007) further concluded that the developmental stage of a proposed intervention leads to one of three circumstances: a) the intervention does not merit a large randomised trial within the proposed situation; b) clarity and no lingering doubt that it will be beneficial and should therefore be implemented or c) that while it is accepted that doubts linger, there are satisfactory expectations of effectiveness which merit a rigorous definitive trial, given the required costs and time. Bambra *et al.* (2010) hold that rapid evidence reviews combined with a distillation/prioritisation methodology was effective in producing a reasonable pragmatic foundation for the Marmot review group's evidence-based policy formulation (Marmot *et al*., 2010) to address health inequalities.

1.13.3.1 Evaluation of programmes with aims to decrease inequality

'The *Marmot Review*' (Marmot *et al.,* 2010) authors were convinced that with respect to aims to decrease inequality

> "Success is more likely to come from the cumulative impact from a range of complementary programmes than from any one individual programme and

> through more effective, coherent delivery systems and accountability mechanisms." (Marmot *et al.*, 2010).

Furthermore, Whitehead *et al.* (2004) consider evaluations of complex public health interventions to be most worthwhile to the evidence-base on inequalities when they comprise of an "*evidence jigsaw*" i.e. a matrix of evaluations from many dimensions of programmes.

Moreover, the need to better understand inequalities outcomes was highlighted in relation to materials contributing to the Acheson Inquiry (Acheson, 1998)

> "It was disappointing to see that there was little empirical evidence about the effectiveness of strategies for reducing health inequalities. The material submitted contained a wealth of data documenting inequalities,……….but there was little about effective interventions (partly reflecting the recent state of research in this field nationally and internationally)." (Macintyre *et al.*, 2001).

1.14 The evidence–base for Dental Health Education (DHE)

Dental Health Educators have *The Scientific Basis of Oral Health Education, sixth edition* (Levine & Stillman-Lowe, 2009) and have had the predecessor volumes as a contemporary source of consensus guidance with respect to dental topics. This latest edition lays out contemporary opinion and the levels of scientific evidence underpinning each recommendation, ranging from level A (very strong evidence-base from Meta-analysis and/or systematic reviews) to level C (no large body of scientific evidence-base, but support from expert consensus). Vested interests often have goals at variance to those of public health (Sheiham, 2000). All advice given to the public on dental caries must be in accordance with the evidence-base, as it is essential to give accurate and consistent messages e.g. on sugar restraint (Rayner *et al.*, 2003; House of Commons, 2007) and by use of simple language (Sprod *et al.*, 1996). Reviews have indicated that the public and professions are confused about dental HE/HP efficacy and effectiveness (Sutton & Sheiham, 1974; Brown, 1994). Dentists' and dental teams' brief interventions have had only minimal transient effectiveness in moderating e.g. oral hygiene (Kay & Locker, 1997) and diet (Dyer & Robinson, 2005). Moreover, it is felt that current knowledge is seldom put into effect (Sheiham *et al.*, 2011).

Groups not attending dental practice are likely to present particular challenges (Sprod *et al.*, 1996). Nevertheless, random cohort studies of intensive home-based dental Health Education over sustained time frames were found to be effective in preventing caries in infants (Kowash *et al.*, 2000). Notwithstanding that shifts in dental health knowledge have been achieved by education programmes (Kay & Locker, 1998), as with general health, there is a complex dynamic relationship between dental knowledge and behaviours (Daly *et al.,* 2002). However, the settings approach is important in improving the public's dental health knowledge (Sprod *et al.,* 1996).

1.15 Limitations of Dental Health Education

A review, over the decade 1982-1992, of Dental Health Education (DHE) and Dental Health Promotion (Brown, 1994) rated change in oral (dental) health as the highest level of outcome. Conclusions indicated that there were limited theoretical frameworks, inadequate statistical analyses, convenience samples and minimal follow-up periods and that all of these had undermined DHE research. No evidence of outcomes effectiveness was found in a review of DHE campaigns, as although reported knowledge and attitudes usually improved, there was no evidence that change in dental health occurred (Kay & Locker, 1996; Kay & Locker, 1998).

1.15.1 The risk of increasing inequalities following DHE

In Scotland, Dental Health Education is said to have led to increased inequalities in dental knowledge, attitudes and behaviour in the medium term (Schou & Wight, 1994). However, although much cited in the literature this study was not subject to controls or blinding. Nevertheless, in another study significant increases in inequality at all ages have been described with respect to reported dental attendance in the previous year, check-ups in the past six months and the intention to visit a dentist in the next six months:

> "…the social gradient by DepCat has increased markedly" (Malam *et al.,* 2004).

1.15.2 Targeting and evolution of the 'directed population approach'

This risk of further increasing inequalities has led to calls for better targeting of future intervention programmes (Sprod *et al.,* 1996; Kay & Locker, 1997; Armfield *et al.,* 2008; Shaw *et al.,* 2009). One example of a high-risk individual caries preventive strategy failed to produce additional benefits or cost-effectiveness (Hausen *et al.,* 2000). Nevertheless, health gains have been reported following targeting by school-based cluster (Jackson *et al.,* 2005). Fejerskov (1995 & 2004) maintains that there is insufficient sensitivity and specificity to identify high-risk individuals. However, he does convincingly argue that it is possible to beneficially alter the distribution of populations' dmfs by interfering with the major causes of caries development in *'designated parts of the total population'* by varying the intensity of what is essentially a whole population strategy. Although high-risk children are most often found in less privileged areas, they do not live exclusively in these types of areas (Tickle, 2002). Burt (1998) advocates a mixed approach to maximise cost-effectiveness, commencing with whole population approaches, reserving costly elements for targeting to all children in particular geographic areas rather than individuals i.e. a so called '*directed population approach*' (Batchelor & Sheiham, 2002; Batchelor & Sheiham, 2006; Sagheri *et al.*, 2008). This accords with what Marmot *et al.* (2010) proposed similarly i.e. a '*proportionate universalism*' in which actions must be universal, but scale and intensity must be in proportion to the degree of disadvantage. However, the difficulties in achieving satisfactory sensitivity and specificity when seeking to implement such strategies have been highlighted recently in modelling studies (Brewster, 2010).

1.16 Models of Oral Health Promotion (OHP)

1.16.1 The biomedical model

The mechanistic era following the industrial revolution led to analogies between body anatomy and machines. The initial waves of dental treatment provided after the establishment of the NHS were known as the extractive phase and the restorative phase (Pitts et al., 1998). Worn out or diseased oral body parts i.e. the teeth or parts thereof were removed and replaced by prosthetic dentures and latterly by fillings or more advanced restorations. For several decades these modalities resulted in the dominant individually focused Primary Care-based clinical practice with a tendency for good (dental) health to be viewed as a commodity. This type of approach towards health and to dental health has received criticism in the respective *Kerr* (Scottish Executive, 2005), Steele (2009) and Global Oral Health Task Group (Sheiham *et al.*, 2011) reports as knowledge and skills have developed to enable a more preventive era.

1.16.2 The preventive approach

A well know idiom suggets that '*prevention is always better than cure*'. However, it has remained until now a secondary concern, compared to the treatment of manifest oral disease (Steele, 2009). There is increasing realisation that interventions are required at individual and population levels, with effective prevention strategy capitalising on *all* opportunities for apposite intervention (Audit Commission, 2002; Daly *et al.*, 2002; Steele, 2009).

1.16.3 The salutogenic approach towards dental health improvement

First described by Antonovsky (1979), 'salutogenic' models of health reject the traditional medical dichotomy: *health vs. illness,* instead considering health as a continuum. Salutogenic approaches encompass the factors responsible for causing and supporting good health along a continuum. The concept is strongly linked to peoples' SOC, as aforementioned (Antonovsky, 1996). Approaches which target high-risk individuals have been criticised, as caries experience occurs throughout populations (Batchelor & Sheiham, 2002). Therefore, the principal emphasis should be at population level, if oral health is to improve (Watt, 2000 & 2007; Milsom & Tickle, 2010). Salutary factors i.e. levels of education, good housing quality, safe working practices and supportive public policy are considered to be *de facto* determinants of oral health outcomes (Watt, 2002a; Watt, 2007). Fisher-Owens *et al.* (2007) proposed a conceptual model of the influences on children’s oral health.

1.16.4 Anticipatory Care

In Scotland, ‘*The Kerr Report’* (Scottish Executive, 2005a) formally heralded an emphasis on ‘anticipatory care’ and an evolving model with reduced dependence on episodic, disjointed care by medical (dental) professionals towards team-based approaches embedded in communities. This accords with Fejerskov's (2004) description of the paradigm shift necessary for cost-effective future management of caries. These ideas underpin the contemporary ‘*Childsmile’* model of Oral Health Promotion which involves multidisciplinary teams with enhanced skill-mix in four co-ordinated programme elements: 1) Core Toothbrushing programme; 2) *Childsmile* Practice - promoting oral health from-birth; 3) *Childsmile* Nursery - providing an appropriate preventive programme in nursery school-setting and beyond and 4) *Childsmile* School - providing school-based dental service from four years-of age and beyond (NHS Scotland, 2007; Shaw *et al.,* 2009; Macpherson *et al.*, 2010; Turner *et al.*, 2010). Moreover, the Steele Report (2009) similarly calls for salutogenic approaches commenting that:

> “The NHS in 2009 is still dealing with, and paying for, the consequences of disease that developed more than 50 years ago…….. the cycle of intervention and repair (that) is the legacy of a different era ……………………. Making the transition from dental activity to oral health as the outcome of NHS dental service will be a challenge for everybody, but it is essential if NHS dentistry is to be aligned with the modern NHS.” (Steele, 2009).

Steele (2009) further maintains that future reward systems should to be aligned to oral health outcomes. Moreover, Lester (2008) has suggested that future NHS 'pay-for-performance' schemes could actively take account of health inequalities.

1.17 Factors influencing OHP programme effectiveness

1.17.1 An effective anti-caries agent

Since their introduction in the 1960s, fluoride dentifrices have brought about reductions in caries in all industrialised countries (Konig, 1993; Bratthall *et al.,* 1996; European Commission, 2005) due to their widespread social acceptance. They are generally held to be the most important contributory factor towards the low caries prevalence occurring now in these societies (Bratthall *et al.,* 1996; Goldman *et al.,* 2008). While resultant caries reductions can seem small when compared to water fluoridation, this can be attributed to the short duration frequently associated with clinical trials, as opposed to water fluoridation studies measuring lifetime exposures. Extended fluoride toothpaste use can produce similar benefits to water fluoridation (Burt & Eklund, 2007).

Systematic reviews of clinical trials data have concluded that, independently of water fluoridation, regular toothbrushing with fluoride dentifrice will control caries (Kay & Locker, 1998; Marinho *et al.,* 2003a; Twetman *et al.,* 2003; Walsh *et al.*, 2010) with additional effectiveness accruing to high caries incidence populations from: supervised *versus* unsupervised brushing, higher frequency of use and higher concentrations of fluoride and a low number needed to treat to save 1 DMFS (Walsh *et al.*, 2010).

However, although the preventive potential of fluoride toothpaste is directly related to its fluoride concentration (Stephen *et al.,* 1988; Walsh *et al.*, 2010), evidence is not yet unequivocal for effectiveness of fluoride dentifrice in the deciduous dentition (Walsh *et al.*, 2010) or the most appropriate fluoride concentrations for young children (Ammari *et al.,* 2003; Walsh *et al.*, 2010), in spite of a direct association between fluoride concentration in dentifrice and caries prevented fraction in the young permanent dentition (Twetman *et al.,* 2003; Walsh *et al.,* 2010). Nevertheless, systematic review of prevention of early childhood caries considered fluoride-based interventions effective, but found insufficient studies available to unequivocally favour a particular method of delivery (Ammari *et al.,* 2007). Programmes which did not involve at least once daily brushing with fluoride dentifrice were ineffective, while those which led to adoption of fluoride containing agents e.g. dentifrice with >550ppmF^-, produced accumulated benefits with time.

1.17.1.1 Fluoride dentifrice-not a universal panacea

However, Dental Health Promotion (DHP) programmes which are reliable in establishing (regular) brushing behaviour have yet to develop (Kay & Locker, 1998). This may be related to the relative affordability of even low-cost fluoride dentifrices in various societies, as it has been estimated that the financial resource required to purchase an annual supply rages from 0.02% of annual household expenditure in the UK compared to as much as 4% in Zambia (Goldman *et al.,* 2008). Although there is international recommendation for daily toothbrushing with an affordable fluoride dentifrice (European Commission, 2005), there are persistent calls for more research, improved study design (Kay & Locker, 1997; ten Cate, 2004), active participatory approaches and responses to people's perceived needs (Sprod *et al.,* 1996).

Recently concerns have arisen e.g. in the Irish Republic (IR), with respect to potential risks of enamel fluorosis from fluoride ingestion from dentifrice early in the life-course, additional to that from community water fluoridation (Clarkson *et al.*, 2003, Browne *et al.*, 2005). Further, concern relates to use of topical fluoride from F^- dentifrice alone (Wong *et al.*, 2010). This has resulted in contemporary recommendations in the IR that infants residing in areas with fluoridated water supplies should avoid the use of fluoridated toothpaste below two years of age and that the quantity of dentifrice used thereafter should be regulated to a pea-sized amount (Browne *et al*, 2005; Dental Health Foundation, 2010). However, a recent Cochrane Review of the benefits and risks of fluoride toothpastes concluded that the frequency and the volume of F^- dentifrice used by young children (<six years of age) were less important causes of fluorosis than children's use of preparations with higher concentration of F^- i.e. ≥1000ppm F^- and age at commencement of use i.e. at < 12 months of age (Wong *et al.*, 2010). Thus, for the youngest age group, the Cochrane Review recommends dentifrice with F^- <1000ppm when development of fluorosis is the principal concern. The selection of the F^- concentration for dentifrice should always be based on a caries risk-benefit analysis.

1.17.2 Professional issues affecting OHP

As indicated earlier, the Steele Report (2009) suggests that due to the lack of incentive in the NHS remuneration systems, not all NHS Dental Practitioners practice OHP to the fullest extent. This concern has been echoed in a Lancet editorial (3rd January 2009).

In relation to paradigms in health care, lag-times from innovation to implementation have reportedly been e.g. between eight and 30 years (Landrum, 1998). Furthermore, Rogers (2002) suggested that diffusion of prevention takes even longer than other changes, because the perceptions of potential relative advantage are distal, less observable and potentially susceptible to undermining influences.

1.18 The common risk-factor approach towards improved dental health

In keeping with studies in the general health and sociological literatures, a range of factors are associated with poor dental outcomes e.g. low birth weight; teenage/single mothers with poor educational attainment and residing in poor/deprived communities etc. commonly confer excess risk of dmft>0 by five years of age (Gratrix & Holloway, 1994; Hinds & Gregory, 1995; O'Mullane, 1995; Sweeney & Gelbier, 1999; Mattila *et al.*, 2000). The strength of the respective relationships between parental occupational status and five-year-olds' dental health was twice that for toothbrushing behaviour and four times that for sweet consumption (Schou & Uitenbroek, 1995). Social factors, not individual dental visiting behaviours, account for most of the variation in dental health among children and adults (Nadanovsky & Sheiham, 1994; Sanders *et al.*, 2006) and it is for this reason that caries is likely to remain a substantial problem for some sections of society (Fejerskov, 1995; O'Mullane, 1995).

A seminal inspirational text by Sheiham (1995) laid out a plausible 'common-risk factor approach' to dental health improvement. Wider examination suggests that this early description of an oral health application of the 'common-risk factor approach' precedes other descriptions. The model focused on the development of comprehensive strategies involving multidisciplinary working to address common-risk factors e.g. nutrition, hygiene, smoking cessation and accident reduction, with populations (Sheiham, 1995; Sheiham, 2000). This type of approach is now widely advocated (Nunn, 2006; Fisher-Owens *et al.*, 2007; Selwitz *et al.*, 2007) and is considered fundamental to global improvement of oral health (Petersen *et al*., 2005b; Petersen, 2009; Sheiham *et al*., 2011).

Studies of five-year-olds in England found that early school performance related to 'reading-readiness' etc. could explain 41% of variation in mean dmft score in state primary schools (Muirhead & Marcenes, 2004). While schools with comprehensive HP curricula exert beneficial effects on children's dental health (Moyses *et al.*, 2003), a review paper suggested that the corollary is also demonstrable (Gussy *et al.*, 2006). A critical review suggested that contemporary OHP programmes should develop all of the strategic aims of the Ottawa Charter (Sprod *et al.*,1996). Furthermore, there should be role-development for public health dentists, beyond educators, to become consumer advocates and change agents within diverse networks (Nowjack-Raymer, 1995; Sheiham, 2000). This can encourage all concerned to share agendas, to identify the common risk factors and the salutogenic factors (Sheiham & Watt, 2000). Daly *et al*. (2010) consider that community interventions adopting this type of approach provide an exciting opportunity for OHP.

1.19 Combined approaches for dental health improvement

Neither a 'whole population' approach nor a 'high-risk individual' approach, alone, aimed at caries prevention is considered adequate to improve dental health and decrease inequalities (Fejerskov, 1995; Shaw *et al.*, 2009; Milsom & Tickle, 2010).

A hybrid, the 'directed population approach' has been advocated (Fejerskov, 1995; Watt 2005; Batchelor & Sheiham, 2006; Shaw *et al.*, 2009).

Population level interventions involved in GGHB's Oral Health Promotion programme and the *Childsmile* programme adopted combined interventions and included Health Visitors (HVs), the nursery setting (Naven & Macpherson, 2006), free resources for dental health e.g. toothbrushes, 1000ppm F^- dentifrice and supervised nursery toothbrushing (NHS Greater Glasgow, 2005). Furthermore, over and above these universal aspects, all children considered 'at additional risk' aged one to three years of age and resident in areas of deprivation were further targeted to receive additional supplies of F^- dentifrice (Naven & Macpherson, 2006). This is in keeping with contemporary recommendations for differentially more intensive distributions of resources to reflect the SES gradient (Tugwell *et al*., 2006a; Marmot *et al.*, 2010).

Slade *et al.* (2006) demonstrated that lifestyle factors did attenuate SES dental health inequalities in infants. However, these factors did not completely explain why dental caries was more prevalent in children from SES deprived households. They suggest that for otherwise advantaged children, the risk of delaying onset of toothbrushing is mitigated/buffered by other protective factors associated with their SES status. Gibson & Williams (1999) also showed that the effectiveness of toothbrushing in infancy was greater in non-manual households. The relationships between childhood dental disease and factors e.g. parenting-stress, social support, caregiver self-efficacy and neighbourhood are considered to be poorly understood (Tinanoff & Reisine, 2009).

1.20 History of policies towards dental health improvement in Scotland's children

1.20.1 Target-setting as an incentive towards improvement

Since publication of the first dental health target for Scotland's children i.e.: 60% of five-year-olds should have dmft=0 in *Health Education in Scotland-A National Policy Statement* (The Scottish Office Home and Health Department, 1991) there has been an increasing emphasis on producing children's dental health gains at individual, community, population and national levels in Scotland. When the original dental health target was not reached it was reiterated further in *The Oral Health Strategy for Scotland* (The Scottish Office, 1995), to be achieved by the year 2000. When the target failed to be achieved yet again, it was restated by government once more, this time to be achieved by 2010. Increasingly, attainment (or lack of it) has been linked to the emergent accountability frameworks for NHS Boards in Scotland. The devolved Scottish government's consultation paper *Working Together for a Healthier Scotland* (The Scottish Office Department of Health, 1998) emphasised the need to also overcome health inequalities, while improving children's health. The later publication of Scotland's two health White Papers (The Scottish Office 1999; Scottish Executive, 2003a) heralded new approaches towards child health improvement and supported an even greater drive towards reduction in health inequalities focused on early years interventions.

The White Paper on Health, *Towards a Healthier Scotland* (The Scottish Office, 1999) also made the dental health target explicit. This publication had the effect of reinforcing that working towards achievement of the dental target carried a much wider responsibility than just that for the dental profession.

A public consultation on children's dental health *Towards Better Oral Health in Children* (Scottish Executive, 2002a) included a description of a Greater Glasgow Pre-Five-Year-Old Oral Health Gain Project (Greater Glasgow Health Board, 1999 & 2001) as an example of good practice, at the time of publication. Thus, the OHP programme led by the author of this thesis was included in the Scottish Executive's national consultation document, as an example of a successful dental health improvement strategy with SES deprived groups in Glasgow, Scotland. This Glasgow OHP programme consequently influenced development of the Scottish Executive's free fluoride dentifrice distribution pilot programme (Naven & Macpherson, 2006) and the overall national strategy for children's dental health improvement published later in *An Action Plan for Improving Oral Health and Modernising NHS Dental Services* (Scottish Executive, 2005a). This action plan, colloquially named as the '*Scottish Dental Action Plan*' proceeded to outline an ambitious framework for improving children's dental health and reducing dental health inequalities, especially among young children. The framework later became known as the *Childsmile* National Demonstration Programme.

1.20.2 Inequalities become a top priority for action

Furthermore, by this later time, the health and social inequalities agenda was becoming a top priority for the UK and Scottish governments (Scottish Executive, 2003b; Department of Health, 2006) and reinforced the aforementioned earlier published demands for dental health improvement in children (The Scottish Office Home and

Health Department, 1991; The Scottish Office, 1995; The Scottish Office, 1999), while at the same time again highlighting the need to reduce dental health inequalities.

1.20.3 An evidence review and development of strategies for children's dental health improvement

To support dental health improvement practice in Scotland, The Scottish Intercollegiate Guidelines Network (SIGN) commissioned, synthesised and published a contemporary evidence-based Guideline for '*Prevention and Management of Dental Decay in the Pre-School Child, November 2005*' (Scottish Intercollegiate Guidelines Network, 2005). This SIGN Guideline has categorised an early peer-reviewed report of the 'common-risk factor', Ottawa charter-based OHP programme which in part forms the subject of this thesis (Blair *et al.,* 2004) at evidence level 2^{+} i.e.

> ".....a well conducted cohort study with low risk of confounding/bias and a moderate probability of a causal relationship with the reported dental health outcomes." (Scottish Intercollegiate Guidelines Network, 2005).

Scotland's evidence review conducted by SIGN thus endorsed the approach outlined later in this manuscript (Chapter 3). However, the conclusion of a later review of evidence indicated that it is other factors e.g. society and environment, as well as those related to community, which will affect (dental) health (Mackinney *et al.,* 2006).

Substantial new sustained investment in children's Dental Health Promotion began developing new models of anticipatory care as advocated in the Kerr Report, *Building a Health Service Fit for the Future* (Scottish Executive, 2005a) e.g. building complementary relationships with the *'Triple P'* positive parenting programme and the *Starting Well* Pilot programmes established in GGHB from *circa* 2000 (Killoran-Ross *et al.,* 2005). These integrated general and OHP programmes involve multi-professional partnerships and are being developed *via 'Action Research'* (Wann, 1953) and '*Theory-Based'* methodologies (Green, 2000; Cottrell & McKenzie, 2011).

The previously mentioned *Childsmile* programme was the specific strategic response to the '*Scottish Dental Action Plan*' (Scottish Executive, 2005b) and is complementary to the foregoing generic HP programmes. At present '*Childsmile*' work streams involve home, community, dental practice, nursery and primary schools' settings in Scotland. Each programme element (i.e. *Childsmile Core*; *Childsmile Practice*; *Childsmile Nursery* & *Childsmile School*) has rolled-out to give continuity of the complementary models across all of Scotland. The intensity of these *Childsmile* interventions vary according to local community health needs, thus combining whole-population and '*directed population*' approaches as:

> "Health inequalities become more disturbing if preventive strategies are unable to provide at least equivalent benefits for lower SES groups." (Slade *et al.,* 1996)

1.20.4 Strengthening of the national accountability framework for Health Boards in support of 'Childsmile'

In the past while reiterating commitment to reducing inequalities, evidence-based practice and accountability, the only new dental health target (PI) contained in the relatively recent *Better Health, Better Care Action Plan for NHS Scotland,* (The Scottish Government, 2007) pertained to increasing dental registration rates of 3-5 year-old children to 80%, by 2010. This was because action on, and measurement of, this activity is considered to be the responsibility of the NHS. The Scottish Government continues to use periodic target setting to hold each Scottish Health Board accountable for achieving implementation of interventions for their local populations. The revised PIs now known as 'HEAT Targets', contain specific objectives for health improvement including dental e.g. *NHS Scotland, Performance Targets - Health Improvement*

> "*At least 60% of 3 and 4 year olds in each SIMD quintile to have fluoride varnishing twice a year by March 2014.*" (The Scottish Government, 2010)

The above HEAT target (The Scottish Government, 2010) was devised specifically to support the implementation of *Childsmile Nursery* and *Childsmile* Practice across NHS Board areas in Scotland and aims to ensure that a 'directed population' approach is reflected in the PI/monitoring arrangements.

1.20.4.1 Further developments to ensure a competency-based *Childsmile* programme

Childsmile has already developed accredited training programmes for Dental Care Professionals (DCPs) in Scotland to address the OHP workforce's K&S needs (NHS Education Scotland, 2010) and their career pathways. Furthermore, DCPs practising within extended dental teams do appear to be enthusiastic about their enhanced OHP competencies (Holme *et al.,* 2009).

1.21 Limitations of this review

There is a substantial body of evidence of effectiveness from clinical trials to support a variety of clinical preventive therapies delivered by dental professionals at the individual level (Rozier, 2001). Likewise, there is extensive evidence in support of fluoride as a therapeutic agent at the population level e.g. fluoridated water (Centre for Reviews and Dissemination, 2000). However, a review of the respective literatures is beyond the scope of this thesis and will not be included in this selective review. In Scotland, in spite of political commitment and substantial investment towards improving dental health (Scottish Executive, 2005b), to date, there has been insufficient political will to implement water fluoridation schemes. This is in spite of evidence that the SES gradient for dental caries is much flatter in fluoridated areas (Riley *et al.,* 1999). While fluoridated milk is available in the research arena, fluoridated salt (NaF 0.047%- 0.064%) has become available since mid-2007 in Scotland (Südsalz, 2007). The SIGN Guideline 47 (Scottish Intercollegiate Guidelines Network, 2000), *Prevention of Dental Caries in Children at High Caries Risk*, considered fluoride tablets/dietary supplement use in Scotland to be generally haphazard with poor compliance among the children most '*at-risk*'. Supplements have been considered unsuitable as a public health intervention due to complexity and lack of consensus on dosage schedule (Holt *et al.,* 1996), although their use does remain appropriate when professionally prescribed for high-risk individual children with favourable compliance (Riordan, 1993a; Consultants in Dental Public Health, 1998). As the key causes of dental health inequalities have been said to lie in the different patterns of use of non-milk extrinsic sugars (NMES) and fluoride toothpaste (Watt & Sheiham, 1999) within different socio-economic groups, this review will therefore concentrate on associated interventions in which communities take responsibility on their own behalf.

1.22 Evaluation of Dental Health Promotion Programmes

Sprod *et al.* (1996) concluded that 'very few papers' in the literature aimed to produce prevention of dental caries *per se* as their health outcome measure. Publication of process data alone provides limited insights into the extent of changing practices (Brown, 1994). Despite the fact that systematic reviews can address specific questions about limited dental health interventions, they are not useful in assessing complex interventions comprising of multiple interventions and outcomes (Harris, 2007). However, Nutbeam's (1998b) comprehensive evaluation model encompasses multiple outcomes, including morbidity and mortality, and has been adapted for OHP programmes by Watt *et al.* (2006) to capture dental health promoting actions, intermediate outcomes and eventual (dental) health and social outcomes. Furthermore, as already suggested, 'Theory-Based' methodologies (Green, 2000; Cottrell & McKenzie, 2011) are being included in Scotland's *Childsmile* programme (NHS Scotland, 2007) which has adopted the MRC's (Medical Research Council) framework for evaluation of complex interventions (Campbell *et al.*, 2000; Craig *et al.,* 2008). The need for complementary expertise and multi-professional inputs for evaluations of complex OHP programmes is advocated by the WHO (Petersen & Kwan, 2004).

1.23 International distribution of childhood caries

Described as a major public health problem (Ekman, 2006; Nunn, 2006; Cheng *et al.,* 2008; Armfield *et al.,* 2009), the distribution of caries is global and has substantial health, economic and societal consequences for affected individuals, communities and nations. It is one of the most prevalent diseases of humankind. It can occur throughout dentate life and is a major cause of tooth loss. It is a multifactorial disease involving complex dynamic relationships. However, the best predictor of future caries in the permanent dentition is presence or absence of caries at age five years of age (Haugejorden & Birkeland, 2002) and in adolescent 12-year-olds, D_3MFT could explain more than 91% of caries in later years (Haugejorden & Birkeland, 2006).

Nevertheless, caries is no longer considered entirely preventable (Fejerskov, 2004). Among the susceptible, its commencement is in infancy with the extent and the severity mediated by diet, fluoride, presence of enamel hypoplasia, participation in preventive activities and age at acquisition of *Streptococcus mutans* etc. (Harris *et al.,* 2004). In spite of declines in caries prevalence, it remains endemic even in industrialised nations (Marthaler, 2004; Edelstien, 2006). At the beginning of this century, the WHO estimated that caries still affected between 60-90% of school age children and the vast majority of adults in developed countries (Petersen, 2003a). A secular trend, ascribed to the widespread adoption of fluoride toothpaste in Western European countries occurred in recent decades. A decline in dental caries prevalence was observed as the adoption of fluoride toothpaste for regular home use increased (Marthaler, 2004, Marinho *et al.*, 2009). However, in spite of marked dental health improvements, the distribution of caries has remained skewed towards socio-economically disadvantaged groups and recent immigrants (Marthaler, 2004; Spencer, 2004). Reductions in the frequency of use of discretionary topical fluoride, not migration *per se,* are said to account for the reversal in the decline of caries in young children being reported by some countries by the late 1990s (Haugejorden & Birkeland, 2002; Spencer 2004).

1.24 Dental health inequalities

As already suggested, due to high prevalence, dental caries is a major public health problem on a global scale. However, a disproportionate burden of caries falls upon those already experiencing economic and social disadvantage or living at the margins of society (Edelstein & Douglas, 1995; Mouradian *et al.,* 2000; Petersen, 2003a; Watt, 2005; Aro-Yusuf *et al.*, 2009; Do *et al.*, 2010; Sheiham *et al.*, 2011). The ‘gap in (*dental*) health’ between those individuals and groups experiencing the poorest health and those with better health is variously termed disparity, variation, inequality or inequity in health. Nowadays, it would be considered to infringe concepts of social justice, if overall improvements in dental health indices were achieved at the expense of increased inequalities (Shaw *et al*., 2009).

1.25 Dental health gradients

Inequalities in dental health mirror the gradients reported for general health and have become the focus of increasing political and research interest (Sabbah *et al.,* 2007; Watt, 2007; Do *et al.,* 2010). Statistical modelling exercises have elicited gradients in self-rated fair and poor oral health, tooth loss and negative impacts of oral health by decile of neighbourhood disadvantage, after adjusting for age, sex, education and household income (Turrell *et al.,* 2007). Income and area-based SES measures were similarly predictive of edentulousness gradients (Jamieson & Thomson, 2006).

Children's dental health surveys conducted by the Office of Population Census & Surveys (now the Office for National Statistics[ONS]) have included Scotland from 1983. These studies have indicated that age-specific caries prevalences in children follow marked geographic gradients. Caries prevalence is consistently recorded as being lowest in England, higher in Wales and Scotland, and highest in Northern Ireland (Todd & Dodd, 1985; O'Brien, 1994). This north/south, east/west variation, with highest disease levels towards the north and west of the United Kingdom, has been confirmed by the surveys co-ordinated by the British Association for the Study of Community Dentistry (Pitts *et al.,* 2007). Donaghy (2006) believes that the direct association between caries and lower socio-economic groups has now been established beyond doubt.

Almost perfect linear gradients were demonstrated in analyses of caries prevalence by Carstairs Score/DepQuin of postcode sector of residence of five- and 12-year-old children, respectively (Sweeney *et al.,* 1997; Sweeney *et al.,* 1998). All subsequent Scottish Health Boards' Dental Epidemiological Programme (SHBDEP) and successor National Dental Inspection Programme (NDIP) population surveillance in the age groups has confirmed the relationship (Pitts *et al.,* 2000; Dental Health Service Research Unit, 2003; Merrett *et al.,* 2004; Merrett *et al.,* 2005; Merrett *et al.,* 2006; Merrett *et al.,* 2007; Merrett *et al.,* 2008).

The '*National Diet and Nutrition Survey of 1½ to 4½ Year Olds*' found a similar array of socio-economic factors related to high caries prevalence to that described previously for generalised poor health and social outcomes (Hinds & Gregory, 1995). Children from homes where the head of the household is in a "*manual*" social class have higher disease levels than those from higher social classes. Family units having the respective attributes: i) living in households in receipt of Income Support or Family Credit; ii) the mother lacking educational qualifications and iii) with lone parentage, were associated with higher levels of caries. This report was able to associate variations in dietary behaviours, early toothbrushing, use of fluoride dentifrice and maternal dental visiting behaviour to caries outcomes. In Glasgow in 2001, 40% of families with dependent relative children were headed by a lone parent (Walsh *et al.*, 2010a). In Scotland, children from advantaged communities continue to have less caries experience than those from relatively deprived districts (Pitts *et al.,* 2007). The direct relationship between being *"less well off"* and poorer childhood dental health also persists in the Irish Republic, in spite of water fluoridation (Whelton *et al.*, 2004).

It is recommended that for studies of children's health inequalities, both parents' social class should be taken into account, as use of the social class of just one may overlook important factors (Zurriaga *et al.,* 2004). Likewise, when information on household-based and area-based SES is available, both should be used, as each appears to have a role in explaining the character, degree and aetiology of dental health inequalities (Murray & Mackay, 2004).

1.26 Distribution of childhood caries in Scotland

Immediately prior to the establishment of a Pre-Five-Year-Old Oral Health Gain Project in Glasgow (Greater Glasgow Health Board, 1999) the Office of Population Census and Surveys was of the view that caries had declined in Scotland's five-year-olds over the previous decade, during which the reported prevalence of $d_3mft>0$ reduced from 74% to 55% and mean d_3mft declined from 3.2 to 2.3 (O'Brien, 1994). However, based on a much larger sample size, likely to be more representative of the population's socio-economic distribution, the 1993 Scottish Health Boards' Dental Epidemiology Programme (SHBDEP) report (Pitts *et al.,* 1994) indicated a Scottish mean d_3mft remaining at 3.2 and a prevalence of 62% $d_3mft>0$ in the five-year-olds. This report suggested that the trend towards reducing levels of decay observed in the previous three biennial SHBDEP reports had halted (Pitts *et al.,* 1994; Sprod *et al.,* 1996). A retrospective review of UK trends in the age group confirmed that statistically and clinically significant reductions in dental caries in the deciduous dentition observed from 1973 to 1983, slowed in the 1990s and halted by 2003 (Pitts & Topping, 2007).

In 1993, whilst Grampian, the mainland Health Board Area with the 'best' reported dental health statistics for the age group indicated mean $d_3mft=2.35$, and 46.5% with $d_3mft=0$, Greater Glasgow's equivalent values were mean $d_3mft=4.25$, with a prevalence of 26.2% $d_3mft=0$ (Pitts *et al.,* 1994). While this was indicative of regional geographic and socio-economic inequality, it was not until publication of the "*appendment*" to the 1995/96 SHBDEP survey report that the full extent of Scottish socio-economic inequalities in five-year-olds' caries distribution became evident (Sweeney *et al.*, 1997; Sweeney *et al.*, 1999). Children resident in the most disadvantaged DepCat 7 Scottish districts according to Carstairs 1991 score and the most advantaged DepCat 1 districts had respective mean $d_3$mft scores of 4.87 compared to 1.48, and % with $d_3$mft=0 of 19.8% and 62.4%. Sweeney *et al.* (1997) highlighted the limited capacity, at that time, of the NHS to directly bring about socio-economic improvements in communities. The report's conclusions suggested that local action with multi-sectoral partners would be required to influence the factors associated with dental health outcomes in the age group i.e. diet, oral hygiene, use of fluoride dentifrice and regular dental attendance. Furthermore, although there were indications for interventions to be targeted towards the most deprived populations, who are least likely to be practising tooth brushing by one year of age or to be registered with a dentist (Hinds & Gregory, 1995), studies mentioned earlier had already demonstrated the greater strength of association between caries and social class than with dentally related behaviours (Schou & Uitenbroek, 1995).

1.27 The concept of equity

If dental health inequality is to be considered an inequity, it would require that the difference in health outcomes at age five-years would be amenable to change, as well as being generally considered unfair or unjust. While it is desirable to increase the overall proportion of individuals with absence of disease and to reduce the severity of disease, as already suggested, this would infringe social justice if such improvements were at the expense of increased SES inequalities (Shaw *et al.*, 2009).

1.28 Where are we now in the UK with respect to caries inequalities?

Caries epidemiological data of five-year-olds has continued to be collected decennially in the UK and *circa* biennially in Scotland. There is consistent contemporary evidence from the ONS that UK five-year-old children attending deprived schools (in which >30% of children are in receipt of free-school meals) continue to have a disproportionate burden of caries morbidity, when compared to those attending non-deprived schools (Steele & Lader, 2004).

Data from the Scottish Health Board's Dental Epidemiology Programme (SHBDEP) and the National Dental Inspection Programme (NDIP) indicate a trend towards increasing polarity in caries distribution in five-year-olds in Scotland. There are rising proportions of children in the "*no obvious caries experience*" category while during 1993-2003, there was, however, little change in the proportion of children with the severest (most advanced) dental caries, which still affected 15% of children (Pitts & Topping, 2007). The 2008 NDIP five-year-old report continues to show a marked SES gradient in prevalence by DepCat. However, in comparison with a previous survey (2003), there were by 2007/08 indications that the most deprived DepCat 7 group had achieved differentially greater absolute gains compared to their DepCat 1 peers, over the interval (Merrett *et al.*, 2008).

No systematic evaluation using recognised tests of inequality with dental health data has been undertake in Scotland, to date. The international literature on health inequality and its measurement is extensive and will be examined in the following sections with a view to determining appropriate methodologies for such a study.

1.29 International inequality in general health

1.29.1 Inequality between countries

In an ecological study of health and inequalities, epidemiology is necessary to consider the effects of time, person and place. Mortality rates, especially of infants are considered to be the barometer of general health in populations. Although average life expectancy has steadily improved in many developed countries (World Health Organisation, 2002a), improvement has not been observed across all segments of the population and marked health inequalities persist between countries e.g. a 48 year difference in life expectancy between Sierra Leone and Japan (Marmot, 2005). All countries consider inequalities in health to be unacceptable and this has been articulated in the Declaration of Alma-Ata:

> “The existing gross inequality in the health status of the people particularly between developed and developing countries as well as within countries is politically, socially and economically unacceptable and is, therefore, of common concern to all countries.” (World Health Organisation, 1978)

In spite of these fine words, longitudinal World Bank data for 207 countries from 1960-2001 demonstrated a significant relationship between health inequality and rates of extreme poverty, rural population, female illiteracy, access to improved water, immunization rates and low per capita expenditure on healthcare. There were indeed many instances of increasing inequalities. Trend data showed under–5s mortality declining over the period, however, this slowed most between 1990 and 2000 especially in the ‘worse-off’ countries (Ruger & Kim, 2006) and child and adult health inequalities related to social, economic and health sector variables increased over the period. Tackling health inequalities requires multidimensional approaches and attention to geographic concentrations of poor health.

1.29.2 Inequality within countries

Higher income groups have been found to be statistically significantly favoured with respect to self-rated health in industrialised countries (Van Doorslaer *et al.,* 1997). The highest levels of inequality in self-perceived health were reported in the USA and UK, while Sweden, Finland and former East Germany had the lowest inequality in self-perceived health. Meanwhile, Mackenbach & Kunst (1997) suggested that broadly similar levels of inequalities in health outcomes were found in all countries studied and confirmed that risks of morbidity and mortality were greatest in lower socio-economic groups. However, although relative inequalities were reportedly larger than average in Sweden and Norway for both morbidity and mortality, it was France which scored most poorly of all for both absolute and relative inequality. The authors concluded that their data did not support the hypothesis that inequalities were smaller in comparatively egalitarian countries (as previously perceived), describing a paradox, in that, in more socially mobile countries eventual achieved social position may depend on personal attributes (e.g. health) and ‘selection for health’ may underlie the larger than expected inequalities.

A study of countries with the highest *per capita* gross national income investigated the relationship between income inequality, obesity, diabetes-related mortality rates and daily calorie intake (Pickett *et al.,* 2005). Obesity was unrelated to average income and in females reportedly independent of average calorie intake. Nevertheless, there was a positive association between income inequality and morbidity and mortality related to obesity. The authors attribute this to the psychosocial impact of social position or relative income and/or psychological processes.

1.29.3 Inequality in the UK

Commissioned in the late 1970s, but not published until 1980, the *Black Report* (Black, 1980) was a sentinel publication on health inequalities. Black’s group produced incontrovertible evidence which demonstrated the relationship between poverty and material disadvantage as major determinants of morbidity and mortality. They suggested that inequalities in health had worsened in the UK since the foundation of the National Health Service (NHS). This trend continued into the 1990s for both relative and absolute inequality in England (Phillimore *et al.,* 1994). In Scotland, similar worsening of inequalities were ascribed to increasing relative deprivation and concentration of disadvantage in the City of Glasgow (McLoone & Boddy, 1994). Black’s conclusions suggested that health was more influenced by social factors such as unemployment, income level, education, housing quality, diet and general and social environment than failures in NHS systems. People’s health behaviours can remain constrained by societal factors over which they have little or no control (Black 1980; Whitehead, 1992; Acheson, 1998).

Black (1980) proposed a raft of policies by which health inequalities could be addressed e.g. health goals, tax changes, benefit increases and restrictions on the sale and advertising of tobacco. At an estimated ‘*outrageous*’ cost of £2bn per year, the proposals were seen as “*quite unrealistic in present day or any foreseeable circumstance*” (Patrick Jenkin, Secretary of State, 1980), by a government which nevertheless felt the need to suppress publication. A later interpretation of historical impact concluded:

> “Two decades later……..., so far as the growth and consolidation of research into health inequalities was concerned, the Black Report's 'non publication' gave the area a greater impetus for development than it otherwise would have had. Its value as a symbol was considerable while in practical terms its recommendations remained to be implemented.” (Berridge, 2003).

Variations in Health: What Can the Department of Health and the NHS Do? (Department of Health, 1995) did not propose setting objectives to decrease variations in health until some 15 years post-Black.

1.29.3.1 Historical resonance?

It has been reported that there was an 'astonishing level of cross party support' from mainstream UK politicians for the ideology of Wilkinson & Picket (2006), that '*a more equal society is better for all*' (Guardian, 14th August 2010). This was made explicit in political campaigning for the 2010 UK general election in which Prime Minister Cameron envisioned the '*big society*' (Guardian, 14th August 2010). There have since been savage reactions to this concept from 'right-wing think-tanks' in both the UK and USA. It is suggested that the notion that contemporary economic 'cuts-programmes' may result in increasing economic inequality and therefore to more crime, poorer educational outcomes, increased morbidity and violence is '*too dangerous an idea*' to let stand (Guardian, 14th August 2010). Only time will tell if this hostility from professional '*ideas wreckers*' is indeed another '*Black*' moment for society. Subsequent indications from the http://www.equalitytrust.org.uk/blog are that it may be.

1.29.4 Inequality in Scotland

Differences in life expectancy of residents in deprived areas, compared to those in affluent areas, in Scotland are statistically significant and reportedly increasing. Compared to residents in affluent areas, residents in deprived areas “*lose 15 years of* *life*" (Scottish Executive, 2005a). Furthermore, the WHO recently published a report by Marmot (2008), which starkly describes "*inequalities killing people on a grand scale*", even in contemporary Glasgow:

> "A child born in a Glasgow, Scotland suburb (Calton) can expect a life 28 years shorter than another living only 13 kilometres away (Lenzie)." Marmot (2008).

This is in keeping with other descriptions in the literature of a so-called '*Glasgow Effect*' on health, after controlling for SES/deprivation and social class etc. (Watt & Ecob, 1992; Sooman & Macintyre, 1995; Leyland, 2004; Hanlon *et al.,* 2005; The Scottish Government, 2008; Glasgow Centre for Population Health, 2009; Walsh *et al*., 2010a). Although Walsh *et al*. (2010a) maintain that the excess effect is seen across virtually the whole Glasgow population, males and females, those in deprived and non-deprived neighbourhoods etc., they do suggest that it was not seen in the very young. Gray & Leyland (2009) were able to demonstrate that part of the '*Glasgow effect'* on health was related to both poorer SES profile and social patterning in the city. There were reported similarities with observed morbidity and mortality profiles in Liverpool and Manchester, in the past. However, since the early 1970s, Glasgow citizens' position has worsened relative to these cities (an excess mortality in the order of 8%) and deprivation does not explain the difference (Walsh *et al*., 2010a). Even so, aspects of health are considered to transcend a SES explanation (Gray, 2007). However, on the other hand Popham (2006) ascribes these types of observations to the already known effects of SES position and differences in employment status and has dismissed notions of any unidentified 'Scottish effect'

1.30 Possible explanations for variations in health

1.30.1 General health experience: socio-economic position (SEP), life-course or person?

The area in which a new born lives is dependent on family ties, parental work status and affordability of housing. These in turn affect the immediate living environment and availability of social support networks for the family and most notably the child, as these will affect educational opportunities during development. Later, both area of residence and educational outcome will impact on job opportunities (Shaw *et al.,* 2001). Although individuals do make choices in relation to these factors, choices are most constrained by the absence of financial resources.

The Black Report (1980) postulated: '*artefact*', '*selection*', '*behavioural*' and '*materialist*' explanatory models for the observed inequalities. Contemporary explanations include '*health selection*' in which health determines social position; '*social causation*' in which social position determines health and '*indirect selection*' in which the social factors that operate on an individual early in life determine both health and social position (Marmot *et al.,* 1997). While the latter theory infers that improvement in adult life circumstances will have little impact on current generations of adults, it does suggest that improving conditions for children have the potential to improve the health of future generations of adults. This accords with current population health improvement models and Early Year's Policy which promote preventive anticipatory care (Scottish Executive, 2005a).

Those most able to consistently exercise beneficial choices tend to be those who have already exercised choice earlier in life e.g. which university or career to follow and whether to move to a more expensive house in a more affluent area (Shaw *et al.,* 2001). It was the increasing proportions of men in higher social classes in England and Wales over the period 1971-1991 resultant from '*health-selection'* which accounted for 16% of the reduction in all deaths by 1991 (Heller *et al.,* 2007). Contemporaneously, the 'gap' in mortality rates between the higher and lower social classes increased.

By the same token, a 2006 review (Leigh & Jencks, 2006) found that adults were less likely to be in employment if they suffered from ill health or had responsibilities of childcare. Areas with poor health may have family incomes which exhibit greater inequality. Thus, low income can lead to poor health and poor health can lead to low income.

1.31 Influences on health inequalities: political context, place and time

1.31.1 International

International comparison showed UK health inequality was greater relative to its degree of income inequality than that found in other industrialised countries. This was unexpected and the reason for this could not be identified (Van Doorslaer *et al.,* 1997). Perhaps some of the explanation could lie in the degree of inequality in power, which it has been suggested is better able to explain population health outcomes than *per-capita* income, likewise political and civil rights rated on ordinal scales (Torras, 2005).

International data from wealthy nations have indicated that countries with greater trade union membership and political representation by women had better child mortality profiles (Lynch *et al.,* 2001). However, more recent research (Zimmerman & Bell, 2006), using census data from the USA, has argued that the association between ecological variables on predetermined health outcomes is modest, whilst the level of 'state-spending' on welfare is positively associated with improved physical health outcomes.

1.31.2 UK-political factors

UK studies examining geographic areas with boundaries 'frozen' as in the 1950s 'old county boroughs' across Great Britain, examined cross-sectional standardised mortality ratios over the period 1950-1998 (Shaw *et al.,* 2001). Results showed a correlation between the political nature of successive UK governments and changing ratios of inequality. Ratios of inequality increased most of all during periods of Conservative (Con.) administration and decreased consistently under Labour Party government. While they did not return to their previous high level under Heath (Con.), at the end of the leadership of Thatcher and Major (Con.), the gap between the highest and lowest morality deciles indicated that those in the poorest mortality areas were more than twice as likely to die before age 65 (Shaw *et al.,* 2001).

1.31.3 UK-place factors

Mapping of the parliamentary constituency areas with the poorest health in Britain measured by Standardised Mortality Ratio (SMR) under 65 years of age (Shaw *et al.,* 2001), shows that the poorest health experience is to be found in Glasgow (2.3 x the average), Manchester, the North East and Southwark and Bermondsey in central London (1.6 x the average). The areas with the 'best health' are clustered around the South of England and Sheffield. This is now considered to be a rich-poor divide rather than simply a north–south divide (Shaw *et al.,* 2001). Infant mortality rates in the poorest constituency areas compared to the most affluent constituencies showed that the poor areas were worse by a factor of four (Shaw *et al.,* 2001).

Health outcomes in geographic areas are related to processes believed to occur and accumulate throughout the life-course. Furthermore, the effect of migration from less affluent to more affluent areas within Britain tends to exacerbate inequalities in health between areas with respect to health, wealth and life-outcomes. Those moving to better-off areas tend to be better-off themselves than those they leave behind (Brimblecombe *et al.,* 1999). Analysis of the British Household Panel Survey data, indicated that lifetime migration patterns of men accounted for the major inequalities in health (ill health and premature mortality) between districts (Brimblecombe *et al.,* 2000). Thus, increasing socio-economic polarisation in Britain over recent decades has increased health inequalities in social and spatial terms. Poor people, in poor areas have become poorer and those with more advantages have been able to accumulate even more advantage, thereby reinforcing inequalities. However, this is not inevitable and the ‘gap’ can be narrowed as evidenced in the 1960s and early 1970s (Shaw *et al.*, 2001).

1.31.4 Scotland

The distribution of social class among mothers in Scotland changed dramatically over the interval 1980-2000, during which the proportion of mothers with ‘undetermined social class’ almost quadrupled to 15% and the proportion of single mothers rose from 9% to 26%. A study of more than 1.25 million live singleton births during the interval assessed social class inequalities related to adverse neonatal events (Fairley & Leyland, 2006). The Relative Index of Inequality (RII is one of the complex measures of relative inequality taking into account the full SES distribution, which will be more fully described later in this theses) reduced throughout the 1980s for all adverse birth outcomes (Fairley & Leyland, 2006). However, during the course of the 1990s the RII increased for preterm births and those ‘small for gestational age’. By the late 1990s, neonatal inequalities were greater than they had been at the beginning of the 1980s.

1.31.5 Implications

The fact that health inequalities are not of fixed magnitude, varying between countries and over time, leads some to believe that inclusion of reduction of inequalities in the aims of health policy makers is not ideologically fanciful and strategies that simultaneously address people’s life- and work-circumstances hold potential to bring about change (Marmot *et al.*, 1997). The WHO (2010) advocate that health equity now becomes a marker of government performance.

1.32 Interaction between social, psychological and biological determinants

In a thought provoking monologue entitled ‘*The Impact Of Inequality. How To Make Sick Societies Healthier*’, Wilkinson (2005) asserts that reductions in health inequality will be unlikely without real social and political progress to enable forthcoming generations to live in societies which are both more egalitarian and environmentally sound. He holds that contemporary levels of hostility and less sociable societies impact on the anxieties and insecurities of citizens, which themselves feedback, to create more violence and inequality. Furthermore, market economics undermine public spiritedness and the market produces less social and indeed sometimes anti-social psychology, by promoting narrow individualist self-interest (Wilkinson, 2005). Moreover, widening income differences have ‘*socially corrosive effects*’ which lead to alienation from the ‘*real social*’ purposes of work (Wilkinson, 2005).

A Glasgow Centre for Population Health review suggests that place, space, attitudes and beliefs all impact on health and that the efforts of individuals on their own behalf are constrained by the quality of their environment, socio-economic and psychosocial context (Jones, 2007). A further evidence review describes universal socio-economic inequalities in health in all countries for which there are data (McLean, 2010), regardless of whether SES is determined by level of education, occupational class or income (Mackenbach *et al.,* 2003). All these factors are interrelated and while each represents a different dimension of SES, the effects of each are mediated by psychosocial processes (Kristenson *et al.,* 2004) and their effects accumulate over the life-course (Ben-Shlomo & Kuh, 2002; Power *et al.,* 2007). Furthermore, the pervasive gradient in health outcomes, across the SES spectrum, demonstrates that it is position within the SES hierarchy which is important for health (Marmot & Wilkinson, 1999). The social distribution of physiological-risk is related to the distribution of SES social patterning and gradients (Adler & Snibbe, 2003; McLean, 2010). Moreover, an extensive body of literature describes that it is social factors that are at the root of health inequalities (McLean, 2010).

Although it is concluded that critical events *in utero* and along life's pathway are both predictive factors for many morbidities, precise predictive combinations are unclear (McLean, 2010). Many authors now believe that childhood conditions are an important predictor of adult health outcomes, regardless of eventual achieved SES (Vagero & Leon, 1994; Davey Smith *et al.,* 1997; Davey Smith *et al.,* 1998; Brunner *et al.*, 1999; Power *et al.*, 2007; Galobardes *et al.,* 2008).

Social class in early and in later life independently contribute to health inequalities experienced in later life. The influence of childhood health on later adult health has been estimated in regression analyses studies to contribute up to 10% of the increased risk of poor health in lower socio-economic groups (van de Mheen *et al.,* 1998). Although this contribution in itself may not seem very large, a very strong relationship was evident between cumulative socioeconomic position over the life-course and poor health (Power *et al.,* 1999).

Furthermore, Burns (2007) demonstrated the striking radiographic effect on brain development by three years of age from extreme neglect, compared to normal nurture and stimulation. He proceeded to classify stress as positive (tolerable and short-lived incurred coping with normal events), tolerable (could affect brain development, but relieved by supportive relationships e.g. natural disaster or bereavement) and toxic (prolonged, highly active stress response, associated with abuse, enduring maternal depression and neglect). He concluded that there is now clear evidence that early life circumstances have distinct biological effects. Psycho-biological stresses contribute to an individual's embodied resilience, sense of, and ability to 'control' and adapt throughout life (Kristenson *et al.,* 2004).

Many UK policy initiatives have attempted to separate social and economic inequalities from their health consequences (Wilkinson, 2007). It is a mistake to believe that health inequalities will change due to policies which leave the majority of society untouched (Wilkinson, 2007).

Even prior to the most recent socio-economic recession and associated events, the benefits of bringing work and economic institutions under forms of egalitarian control within democratised co-operatively controlled systems were advocated (Wilkinson, 2005). However, the need for more knowledge about the detailed pathways to health inequality is even more important in political climates that are inhospitable to the major social and political change that would be required to impact on health inequalities.

1.33 Dental health experience - behaviour, SEP, or something else?

In a systematic review of risk factors for caries in children up to the age of six years, Harris *et al.* (2004) noted 102 statistically significant relationships to socio-demographic, dietary, oral hygiene, feeding, oral flora and other factors. Thus, caries aetiology is clearly very complex. When commenting on dental health inequalities in Denmark, Petersen (1990) favoured the '*materialist*' and '*behavioural*' theories, noting the lower caries levels among 'officials' *versus* 'workers'. There is evidence that materialist aspects e.g. cost of treatment and cost of accessing treatment are relevant factors in under-developed nations (Petersen *et al.,* 2005a; de la Fuente-Hernandez & Acosta-Gio, 2007) and developed countries e.g. UK (Sisson, 2007). Notwithstanding this, it is debateable whether better dental health is the product of asymptomatic dental attendance *per se* (Kay,1999; Batchelor, 1999). Kay (1999) instead argues that better dental health in more advantaged SES groups may be attributed to:

> "..differences in lifestyle, attitudes, behaviour and access to health providing products, foods and services rather than being due to the effectiveness of preventive dentistry." Kay (1999).

Studies controlling for SES, found that adult oral health was predicted by childhood dental health and additionally by childhood advantage or disadvantage and SES (Thomson *et al.,* 2004). This led to calls for interventions to tackle the determinants of health. In reviewing potential explanations for inequalities in oral health, Sisson (2007) cautions that there is a need to differentiate between material and materialist explanations. The former examines the relationship between SES and substantial assets e.g. nutrition, housing and amenities, whilst the latter refers to things less tangible like position in the social order, as material assets alone do not provide the full explanation. In international comparisons, Hobdel *et al.* (2003) concluded that SES variables alone could explain circa 50% of the prevalence of caries in 12-year-olds. Bernabe & Hobdell (2010) demonstrated with data from 48 countries that while there was an inverse relationship between *per capita* gross national income and mean dmft in five- to six-year-old children. Beyond a certain level of income in the relatively more prosperous countries, there was a more significant relationship between income inequality score (Gini coefficient) and dmft score. Furthermore, there are parallels with Schou & Uitenbroek's (1995) aforementioned study and the results of Gibson & Williams (1999) large-scale regression analysis of UK data, which indicated that among pre-school infants the strength of association between SES and caries exceeded that of sugar consumption (x 3) and toothbrushing (x 2).

Doubt has thus been cast upon the limited potential of individualist focused behavioural interventions to bring about reductions in oral health inequalities (Watt, 2002; Sabbah *et al.,* 2009), since human beings are influenced by such a myriad of social, economic and environmental factors e.g. the mitigating effect of exposure to fluoridated water (Slade *et al.,* 1996; Jones & Worthington, 2000). Contemporary theories suggest that behaviours are not freely selected, but are predicated by social norms and habits which vary between socio-economic groups (Sisson, 2007). To change peoples' behaviours requires changes to their environment (Sheiham *et al.*, 2011).

1.34 Methodological issues in socio-economic status measurement

1.34.1 General

Education, occupational class and income are all appropriate socio-economic indicators to demonstrate inequalities in morbidity and mortality rates (Mackenbach & Kunst, 1997). Nevertheless, debate persists with respect to the pathways of inequalities, causality, methodologies for the measurement of health inequalities and the underlying techniques for stratifying and segmenting population groups. Regidor (2006) described ambiguity in interpretation and conceptual overlap between measures of ‘socio-economic position’ and of the social determinants of health. He suggests that researchers have still to reach a consensus as to which dimensions of socio-economic position (SEP) are the most important for evaluation of interventions aiming to reduce inequalities for each specific health outcome of interest. Examples of concepts of the social determinants were: the layers of influence on health surrounding people that theoretically could be modified e.g. personal behaviour, social and community influences, living and working conditions, food supplies, access to essential services, supplies and cultural and environmental conditions (World Health Organization, 2003). Seven priority themes for future research into health inequalities have been proposed: socio-economic status (SES) differences across industrialised nations, their step-wise gradients, psychosocial influences, the hypothesis of biological programming *in utero* or infancy, modification of behaviours and evaluation of interventions (Macintyre, 1997).

1.34.2 Eliciting the social gradients

While the social gradient in health (morbidity and mortality) is consistent with an association with poverty, inequalities are not restricted to the poor. The mortality studies in Whitehall and Wisconsin (Marmot *et al.,* 1997) are unlikely to have included the lowest SES groups, nevertheless, sensitive and consistent gradients in mortality, morbidity and psychosocial health statistics were observed along with substantial underlying inequalities.

Contemporary debate is now more focused on the consequences of material living conditions than on occupational position. Multivariate modelling studies have examined the relative contribution and overlap of ‘material resources’, ‘qualifications’ and ‘occupational position’ in explaining social differences in mortality among more than 80,000 employed European adults (Geyer & Peter, 2000). Analyses of the relative contributions of material factors (e.g. disposable household income, housing tenure and perceptions of ‘financial difficulties’) and behavioural factors (e.g. smoking, alcohol consumption, dietary habits and physical activity) indicated that the material and behavioural factors accounted for more than half of the occupational class related differences in self-rated health among women and one third among men (Laaksonen *et al.,* 2005).

Although Wilkinson’s (1997) comparison of health inequality ‘within’ and ‘between’ societies indicated that the ‘within’ society differences were closely related to social stratification and hierarchal position, this relationship did not hold for ‘between’ societal differences (e.g. countries or states).

1.35 Demographic measures

1.35.1 Census derived occupational class and alternatives

From its commencement, the decennial census in England (1801) distinguished between those employed in agriculture, trade and manufacturing. From 1951, the Registrar General's Social Classification was determined by occupation of male head of household (Southall, 2003). However, the census data 2001 were based on a new system which reflects continued evolution of population subgroup descriptors (Economics and Social Research Council, 2006; National Statistics Online, 2007). The recently introduced National Statistics Socio Economic Classification (NS-SEC) replaces previously used classifications in all official UK analyses (Erikson & Goldthorpe, 2002) and has provoked discussion as to its relative predictive power in association with health outcomes (Macintyre *et al.,* 2003). The NS-SEC, based on the Erikson, Goldthorpe and Portocarero (1979) classification was originally devised to measure social mobility and considers 'occupational class' of subjects in terms of employment relations i.e. whether employer, employee or self employed; the labour market conditions; work situations; the degree of autonomy and important prospective benefits e.g. pension entitlement, job security and career opportunities. Users are cautioned that the NS-SEC is essentially a categorical measure, not a continuum, as the theoretical basis is qualitative (Erikson & Goldthorpe, 2002; Macintyre *et al.,* 2003). Sophisticated access to Scottish national 2001 census data aggregated at various levels is *via* the General Register Office for Scotland (2007) and for UK level is *via* the UK Data Archive (University of Essex, 2010).

1.35.2 Limitations of the NS-SEC as SES indicator

Multilevel modelling studies of longitudinal data from the British Household Panel Survey (Chandola *et al.,* 2003) examined self-reported health in relation to NS-SEC social-class for subjects' most recent occupation (Taylor *et al.,* 2006). Individual occupational class had a relatively strong effect on the self-rated health of economically active adults. However, peoples' SES advantage related to their household had the greatest effect, when this was measured by the Cambridge Scale which captures friendship, lifestyle, diet and social support (Chandola *et al.,* 2003).

1.35.3 Other potential shortcomings

The longitudinal changes in social class groupings complicate comparisons over time. Additionally, it is noteworthy that the census in each constituent country of the UK is different, as is the output geography. Thus, comparisons across national boundaries should be made with caution (Economics and Social Research Council, 2006). Furthermore, the NS-SEC is unable to distinguish some significant inequality (Chandola, 2000).

The Registrar General's Social Classification should not be equated with income scale, as incomes data do not form part of the UK census. Macintyre (1997) considered occupational SES as an indicator of embodied life chances, exposures and experiences, which influence health outcomes. However, in considering whether there is a 'best way' to measure SES, it has been recommended that household rather than individual measures of social position and older measures of occupational social class such as Registrar General's Social Classification and Social Grade, rather than newer measures should be used if one wishes to demonstrate strong associations between SES and health. The caveat is that the ways in which SES position and health are measured should relate to one's underlying beliefs about their links (Macintyre *et al.,* 2003).

1.35.4 Income and health

It has been hypothesised that greater income inequality results in worse population health. Current explanation for the negative association between income inequality and health relates to two mechanisms. Firstly, the stress or frustration brought about by invidious social comparisons correlate powerfully with poor health (Wilkinson, 1999 &1999a; Stewart, 2006), suggesting that income inequality is systematically related to the character of social relations and the social environment of society; secondly, through a political mechanism in which growing inequality translates into an erosion of social cohesion, cutbacks in social spending and depleted human capital investment (Kawachi & Kennedy, 1999). While Machenbach (2002) acknowledged the numerous papers reinforcing the association between income inequality and correlations with poor health, he concluded that the most important contextual factor for health was individual income. Therefore, it is unsurprising that systematic reviews of income inequality and health (Macinko *et al.,* 2003; Wilkinson & Pickett, 2006) have suggested that there is evidence both for and against the relative income hypothesis, independently from absolute levels of national income or wealth. However, these reviews did not support the direct influence of income on health; rather it was viewed as a proxy for something else e.g. psychological, social, economic, behavioural, political and/or environmental determinants of health. Notwithstanding this, virtually every study examined confirmed the universal relationship between individual incomes and health outcomes, even in industrialised countries with generous health and welfare systems. Limitations of studies cited arose from a combination of: limited data, questionable data quality, non-comparable study designs, radically different conceptual frameworks and different analytical methodologies.

Although income quartile does (usually) produce a consistent gradient in relation to health outcomes, its usefulness is limited as income information is difficult to obtain except in specialist surveys (Grundy & Holt, 2001) and there is response bias (as poor as 60%) with loss of both tails of the income distribution (Wilkinson, 1997).

1.35.5 Alternative assets and health

Although the income inequality hypotheses does appear to be a 'conventional wisdom' within the field of public health, relatively little consideration has been given to this hypotheses by social and behavioural scientists (Mellor & Milyo, 2001). Thus, public health's conclusions may be premature. Paradoxically, in some low income countries e.g. Costa Rica and Cuba, health status is generally good, whilst the wealthiest country in the world, with respect to *per capita GDP* (the USA) ranks only 12th, amongst industrialised countries for 16 indicators of health (Asafu-Adjaye, 2004).

Shaw *et al.* (2001) and Baum (2005) have argued that the epidemiology of wealth rather than income should become the future focus of public health research. As wealth accumulates over time and generations, it may be a better life-course indicator itself. The Family Affluence Scale (FAS) has been proposed as a common index of socio-economic status for use in comparisons between countries (Batisita-Foguet & Fortiana, 2004).

Interdisciplinary collaborations between demographers, epidemiologists, economic historians and economists have been advocated (Feinstein, 1993; Tapia Granados, 2003) as these disciplines working together could better explain the influence of macro economics and population dynamics etc. on health and inequalities.

1.35.6 Education and health

There is an expanding body of evidence correlating socio-economic circumstances to educational attainment. In epidemiology, education is frequently used as an indicator of socio-economic position (e.g. Benzeval *et al.,* 1995; Galobardes *et al.,* 2006a). The historical basis can be found in Weberian theory (Liberatos *et al.,* 1988). Instead of concentrating on the relationship of wealth with the means of production (e.g. factories, land and wealth) as cause and outcome of social stratification, Weber's theory postulates that society is stratified along three different dimensions namely class, status and party (or power). Status is prestige or honour in the community and implies access to advantage based on cultural and social networks, while power is related to political context. Together these three domains create hierarchies and groups sharing common market positions that bestow mutual life-chances. Educational attainment is used to assess the knowledge-based assets of individuals and groups and since formal education is usually completed by young adulthood, it is highly associated with parental characteristics.

Education straddles Weber's class and status dimensions and can affect behaviour, practice and ultimately lifestyle and social networks. It remains popular as a single measure of SES due to the simplicity of collection. The number of years in education can be measured as a continuous variable or selected categorical variables and is considered less complex and less sensitive to collect than income or occupational class information (Liberatos *et al.,* 1988). It also provides access to certain occupations, thus, acting as a proxy for other variables. Prevalence of literacy and higher education also perform well in explaining health outcomes (Torras, 2005). Multiple regression analysis studies have shown that educational status, when combined with income, had the ability to outperform the New Zealand Socio-economic Index in predicting cardio vascular disease (CVD) risk factors (Metcalf *et al.,* 2007) and was alone able to elicit a more consistent SES gradient in CVD risk factors than income alone. Furthermore, education is considered to be a judicious choice as a single measure for epidemiology, as it is available for all individuals regardless of gender, ethnicity or employment status in adulthood (Winkleby *et al.,* 1992). It is more stable for most adults over a lifetime than either occupation or income (Liberatos *et al.,* 1988). Nevertheless, parts of the health effect of each: education, income and occupational class can be mediated by the other two variables and interrelationships should always be considered (Lahelma *et al.,* 2004). Potential drawbacks of education as a SES indicator are that it can mask social mobility and other confounding effects related to cohorts (in recent decades more individuals have completed high school, college and university than their predecessors, but it could be questionable whether they are of higher SES).

Although the rate at which every additional standardised year of education decreases mortality is relatively constant across a range of Western European countries, each extra year of education exerts a circa two fold effect in the USA (Feinstein, 1993).

Some of the explanation for the increasing political attraction towards investment in education is because education is such a significant predictor of health and improved health diminishes the depreciation rate of human capital (Asafu-Adjaye, 2004).

1.35.7 Education and dental caries

Corresponding with reviews of the generic health literature, no single common measure of SES was found in a study of caries variation involving 27 global sites (Pine *et al.,* 2005). Several potentially explanatory SES classifications were explored and maternal education beyond respective countries' statutory school leaving age was selected by an international research collaboration as generally applicable for international comparisons (Pine *et al.,* 2005). Other studies have utilised 'completed years of education' (Chen, 2002; Bastos *et al.,* 2007). This accorded with findings in which the dental health of five-year-olds (Mattila *et al.,* 2000; Finlayson *et al.,* 2007a) and older children (Sagheri *et al.,* 2008; Perera & Ekanayake, 2008) were all highly correlated with maternal level of education, vocational qualification, occupation and family affluence.

1.36 Social capital and health

Wilkinson (1997) has suggested that an increasing body of evidence supports a relationship between insecurity and mortality. Cohesive social relations e.g. during World War II, may be protective to health. The pathways to ill health-related behavioural outcomes show social gradients and relationships with poor self-esteem and rely heavily on psychosocial mediation of behaviour e.g. the very well-established association between violence and social inequality (Wilkinson, 1997). The material facts of inequality have psychosocial effects that lead to systemic and mental health consequences (McEwen, 2008). It is thus plausible that similar pathways operate for other behavioural outcomes e.g. teenage pregnancy, obesity and trust—which all seem to be related to inequality, as well as demonstrating social gradients (Wilkinson, 1997). The Chief Medical Officer (Scotland) believes that so-called '*toxic stress',* especially in childhood explains much of the excess poor health experience in Glasgow, Scotland (Burns, 2007). The emerging research seems to confirm that psychosocial processes emanating from low social status have health effects *via* common-risk pathways to health and many of the other social problems prevalent in poorer areas (Wilkinson & Picket, 2006).

Pathways from decreased socialisation and hostility in communities lead to health inequalities and violence connected to status, stigma and the need for respect among males, especially in low SES communities (Wilkinson, 2005). The most potent psychosocial risk factors in modern society are the aforementioned stresses in early childhood, low SES and having few friends (Wilkinson, 2005). The concept of being disrespected is so central as a cause of violence within the USA prison system that it is abbreviated to slang e.g. "*he dis'ed me*" and this similarly has been a reported cause for violence in Scotland (Glasgow) e.g. Jimmy Boyle is said to have used terminology about lack of status and respect, as the justification for his use of gratuitous violence (Wilkinson, 2005). Lack of respect is most problematic in places where inequality is greatest. When deprived of the (other) things people use as markers of status, those at the bottom become sensitised to being viewed by those above as inferior and may become locked in a self-defeating cycle to defend their pride and dignity (Wilkinson, 2005).

The negative effect on health of social hierarchies is most significant in societies with bigger income differentials (Wilkinson, 1997). The most important antecedents of health-status are social and economic characteristics (Dunn & Dyck, 2000) and Marmot *et al.* (2008) believe that the poor health of poor people and the SES gradient is due to the unequal distribution of health-damaging experiences and furthermore that it is not a natural phenomenon, but instead is the consequence of poor social policies, unfair economic arrangements, bad politics and programmes.

On the other hand, high levels of community social cohesion are postulated to mitigate against the effects which income inequality and area deprivation have on mental health outcomes (Fone *et al.,* 2007). One mechanism which has been suggested, is that people exposed to smaller income differences experience their social environment as less hostile and more hospitable. Wilkinson (1997) described our fellow human beings as being potentially "*our most feared adversaries and competitors*", or, our "*greatest source of comfort and solace*".

It is therefore plausible that the prevalence of chronic stress in communities determines the social environment and psychological well-being. Furthermore, recent reviews found substantial and consistent associations, independent of individual characteristics, between area-context and variations in health (Diez Roux, 2004; Riva *et al.,* 2007). Factors such as positive mental attitude and well-being do seem to provide important protective mechanisms against life-stress, with the converse leading to vulnerability to poor health (Marmot *et al.,* 1997).

Muntaner & Lynch (1999) maintain that earlier descriptive models which concentrated on poverty and health behaviours as the (*main*) determinants of population health were deficient, as they failed to consider 'class-relations' which may explain how inequalities are generated. Class formations are considered to have the ability to engender reductions or increases in social cohesion. In both the USA and Britain under past leaderships, inadequate explanatory models have been used to hold communities accountable for their own morbidity and mortality rates, which Muntaner & Lynch (1999) described as community level '*victim-blaming*'. Wilkinson (1999) contends social cohesion is *de facto* indicative of the level of underlying psychosocial risk, known to be closely related to health. He suggests that it is the apparently ephemeral nature of social cohesion that leads to scepticism about its role. Furthermore, Wilkinson holds that social status and social affiliations are among the most powerful influences on health in the developed world with respect to Population Attributable Risks (this metric will be discussed in detail later in this thesis). He believes that antipathy between hierarchical groupings across inequalities of power exert substantial (negative) influences on health, *versus* supportive social groupings between equal members of society. Mitchell *et al.* (2009) considered social cohesion makes a plausible contribution to an area's 'resilience' (i.e. low mortality in spite of SES adversity).

Lynch *et al.* (2000) cautioned that failure to study structural and interpersonal relations would play into the hands of the political right and the danger of a rhetoric asking, why can't we all just get along, like one big happy family? This was past justification for dismantling the welfare state and diminishing the power of labour unions in both the USA and UK. The authors cite Marxist theory suggesting that we are not one big happy family but:

> "……..are divided into the haves and the have nots; the exploiters and the exploited; the enfranchised and the disenfranchised…..segmented by economic, racial, ethnic and gender inequalities that receive institutionalized political, legal and corporate sanctions" (Lynch *et al.,* 2000).

Further, they believe that if social capital has the propensity to bring about increased inclusiveness, human rights, social justice, full political and economic participation, then indeed public health should invest (Lynch *et al.,* 2000).

Zeirsch *et al.* (2005) concluded that the constructs underlying social capital i.e. trust, connection, reciprocity and civic action are complex. The Glasgow Centre for Population Health (Walsh *et al.*, 2010a) report that in Glasgow, compared to Scotland as a whole, there was much poorer social participation when measured by voter turnout and religious affiliation. These authors speculate that 'societal breakdown' may be part of the cause of the city population's poorer than expected health record (Walsh *et al.*, 2010a) by citing Emile Durkheim's (1984) concept of 'anomie' i.e. a breakdown of normal social and moral norms generating a less integrated society, in which previous norms no longer apply and do not control peoples' behaviours.

However, Weber's ideology suggests that individuals may nevertheless actively contribute to their own life chances if their ability is developed to beneficially trade their education, skill and personal qualities to achieve social gains in the 'marketplace' (Lynch *et al.,* 2000).

1.36.1 Social capital and oral (dental) health

An early review of inequalities in dental health (Petersen, 1990) highlighted the contribution of "*weak social network relations"* to poor dental health. Generally, it is children from low income families who experience the highest prevalence and burden of oral disease and for whom the consequences impact upon their growth, function, behaviour and comfort, with inequalities extending into adolescence and young adult-life (Edelstein, 2002). Among other adverse health indicators, Scottish children born to parents from the lowest income quintile were more likely than others to have been weaned onto unhealthy diets and to have poor dental health (The Scottish Government, 2008a) and there have been suggestions that the dental health of children in the most deprived areas is improving coincidentally with greater dental service access. An ecological study specifically examined the association between social cohesion and dental caries prevalence. Relative income inequality expressed by the Gini coefficient (positive), levels of participation in democratised community budgetary decision-making (negative), and the rate of homicides (positive) were associated with the onset of dental caries in Brazilian children (Pattussi *et al.,* 2001) with the Gini, alone, able to account for 49% and 31%, respectively, of the variation in % with DMFT=0 and mean DMFT (in 6-12-year-old children, caries detection level not stated). Furthermore, oral health benefits were conferred on children resident in deprived areas who concurrently attended schools in which there were supportive environments (Moyses *et al.,* 2003). Newton & Bower (2005) have drawn on a model described earlier by Brunner *et al.* (1999) in an effort to map the ways in which social capital impacts on oral health. These authors argue that both psychosocial stress and social capital are reflections of levels of fiscal control and structures, but are somewhat critical at the model's absence of dimensions for time, health services and policy. Nevertheless, they conclude that complex interlinking social, psychosocial and material pathways are associated with oral health (Newton & Bower, 2005).

However, the findings reported in one cross-sectional multilevel modelling analysis of caries risk- and protective-factors among low income communities found that while maternal levels of fatalism about oral health almost tripled their children's risk of developing caries by five years of age, somewhat counter-intuitively, their levels of stress about parenting was protective against caries (Finlayson *et al.,* 2007a, 2007b & 2007c), as was longer parental education and belonging to a two-parent household (Hjern *et al.,* 2001), along with their degree of self-belief in being capable of implementing regular daily toothbrushing into their child's routine (Pine *et al.,* 2004). This generally accords with other cross-sectional studies which found that parenting stress, alone, was not an explanatory variable for early childhood caries (Quinonez *et al.,* 2001; Tang *et al.,* 2005). However, there is a need for well-designed studies to assess child and maternal stress and subsequent prevalence of infant caries, as caries prevention guidelines for '*at high-risk*' children can be ineffective (Petti, 2010).

1.37 Miscellaneous demographic factors, potential confounding for general health and dental health outcomes

1.37.1 Introduction

A thorough consideration of the literature on each of the following demographic factors: rurality, ethnicity, age, gender, migrant or marital status, family structure etc. and health is beyond the scope of this review. However, all are strongly and independently associated with health outcomes, but are rarely sufficient alone to predict health inequalities without additional information to indicate disadvantage. In exploring the relationship of variables related to the epidemiology of health inequality it may be necessary to control or standardise for their effects (and other factors).

1.37.2 Rurality

Although rurality *versus* urban residence has received attention since the earliest history of epidemiology, a recent systematic review comparing contemporary health overall in urban and rural areas was unable to find aggregate health benefits from either urban or rural residence (Peters & Jackson, 2005) after taking other factors into account. Nevertheless, issues of concern in rural areas are different in nature to those in urban centres e.g. housing, education, employment, population age structure, transport and access to health services. Communications and social services are all of great relevance to individuals and communities in non-urban areas, areas of declining industry; areas on the fringe of large urban conurbations; areas with mobile populations and areas with varying levels of travelling or migrant families etc. (Sure Start Evaluation Development Project, 1999).

1.37.2.1 Rurality and caries

In common with the general health literature, there is no consistent international relationship between deciduous caries experience and urban/rural habitation. Small studies predominate and indicate that deciduous caries prevalence in rural areas may exceed that of urban centres (Doyle, 1977; Antunes *et al.,* 2006; Perinetti *et al.,* 2006; Mello *et al.,* 2008; Ohsuka *et al.,* 2009) whilst the converse is also true (Varenne *et al.,* 2006; Maserjian *et al.,* 2008). Differences were variously ascribed to socio-demographic and environmental factors, brushing habits, child rearing practices etc. and diet (MacKeown & Faber, 2004). In Scotland the principal determinant will be SES.

Levin *et al.* (2006) demonstrated that it was possible to assign urban/rural status to postcode data from the 2002/03 P1 NDIP survey, although this type of analysis is not routine. However, an apparent urban/rural difference lost significance after adjusting for deprivation. Nonetheless, areas defined as 'accessible-rural' had an Odds Ratio for five-year-olds' $d_3mft>0$ lower than that of the four main cities (this is likely to reflect comparative affluence in the commuter-belts). A later secondary analysis of 2007/08 P1 NDIP data suggested that once more the ORs for $d_3mft>0$ among urban children were greater than those for children resident in more rural districts (Levin *et al.*, 2010).

1.37.3 Ethnicity

There is an extensive international literature documenting study of disparities in health related to ethnicity. One of the starkest examples relates to the 20-year gap in life expectancy between Australian Aboriginal and Torres Straight islanders and the Australian average (Australian Human Rights and Equal Opportunity Commissioner, 2008). Ethnicity is not measurable on a gradient and recording of ethnicity has always been considered problematic in routine data collection (Carr-Hill & Chalmers-Dixon, 2005) with minority groups being classified variously by self and/or researchers e.g. according to nation-state, defined by language, nationality or origins. Furthermore, some vulnerable groups may not be recorded as minorities e.g. the Irish. Ethnicity, therefore, is a complicated demographic factor which is yet another dimension in the description of person, over and above SES.

1.37.3.1 Ethnicity and caries

The inclusion of ethnicity as a variable is not routine in caries epidemiology studies in the UK/Scotland. Some suggest that ethnicity may no longer be relevant in the UK, as it could divert attention from more important variables such as income and social class (Watt & Sheiham, 1999). However, ethnicity should not be overlooked, as in some geographic areas it has substantial effects over and above that of deprivation e.g. in the USA (Bedi *et al.*, 2000; Edelstein, 2002; Cheng *et al.*, 2008), in Australia (Jamieson *et al.*, 2006) and in children of Pakistani origin living in Glasgow there was significantly poorer oral health than among white contemporaries (Conway *et al.*, 2005; Conway *et al.*, 2007). Likewise, first generation infants born of migrant non-Western mothers resident in European countries experienced dental health inequality, when compared to that of contemporaries with first-world origins (Willems *et al.*, 2005; Ferro *et al.*, 2007). However, while mixed race was associated with increased risk of caries among infants when compared to both blacks and whites in a developing country (Postma *et al.*, 2008), in the USA white refugee children were reported to be 2.8 times as likely to have dmft>0 (caries detection threshold, cavitation 0.5 mm diameter with brown colouration on cavity walls) as white American children, whilst African refugee children had only half the likelihood of dmft>0 of both white and black American contemporaries

(Cote *et al.,* 2004). The impacts of social-welfare policy changes reportedly have had differential impacts on dental health inequalities between ethnic groups (Thomson *et al.,* 2002).

1.37.4 Age

Age is a relatively easy variable to categorise in developed countries and is associated with morbidity and mortality gradients e.g. mortality is relatively high up to four years of age and diminishes rapidly in later childhood. In males, death rates rise steeply in adolescence and continue to increase, whereas the rise is gradual for females (Carr-Hill & Chalmers-Dixon, 2005). As people age they suffer from wear and tear and therefore increasingly experience illness that is highly correlated to premature mortality (Shaw *et al.,* 2001). Interpretation of age gradients in generic epidemiology can be problematic, as changes may be attributable to either aging, cohort effects or both.

1.37.4.1 Age and childhood caries

Due to the effects of time in the caries process, reporting of caries incidence and prevalence should be age-restricted (Moles & dos Santos Silva, 2000; Levin, 2005). This will help to ensure that variation in disease experience is not partially due to variation in length of exposure of tooth tissues to the oral environment (Eslamipour *et al.*, 2010). It is thus important to adjust for age, when assessing whether apparent dmft/DMFT effects may have been modified (McDonagh *et al.,* 2000; Lencova *et al.,* 2008). Exfoliation and eruption further complicate caries epidemiology and it is usual for dmft and DMFT effects to be reported separately.

1.37.5 Gender

Nearly all health data differentiate by gender at the time of recording and assume that there will be different morbidity and mortality distribution profiles for each (Carr-Hill & Chalmers-Dixon, 2005). The issue of gender is inextricably linked to inequalities in developing and developed countries. In the developing world, female literacy rates and access to education are strongly related to the life-course of children, while in older post-industrialised societies e.g. the UK, the economic-base has shifted from one characterised predominantly by full-time manual or manufacturing jobs for men, to increased service industry opportunities for females. The respective unemployment rates for Scottish females and males were as low as 4.8% and 6.0% in 2003 (Scottish Government, 2003).

1.37.5.1 Gender and caries

The relationship of caries with gender is considered complex and there are interactions with other factors (Dasanayake *et al.,* 2002). Reports on the association between gender and deciduous caries from developing countries have suggested there likely is no relationship (Wyne, 2008; Alves *et al.,* 2009; Bonanato *et al.,* 2009). Although information on gender is collected in UK caries surveys and reporting may adjust for potential confounding effects, it is not customary to report separate caries outcomes by gender in UK child caries epidemiology e.g. SHBDEP/NDIP. Nevertheless, studies from developed countries have directly reported significant, but varying associations among their populations and inward migrants (Verrips *et al.,* 1992; Declerck *et al.,* 2008). Several studies have recognised potential confounding and controlled for gender as a confounding factor in caries analyses (e.g. Vanobbergen *et al.,* 2001; Milsom *et al.,* 2003). Furthermore, in older child groups, girls had more positive dental attitudes than boys (Ostberg *et al.,* 1999) and greater dental service usage (Dasanayake *et al.,* 2002). However, reported differences in fluoride dentifrice use between genders were considered "*too small to matter*" (Haugejorden, 1996). Nevertheless, there is contemporary evidence of a persistent gender inequality related to daily toothbrushing among Scottish schoolchildren (Currie *et al.,* 2008; Levin & Currie, 2009) and their European counterparts (Shenk & Knopf, 2007).

1.37.6 Family structure, marital status and stability

In addition to the SES of the household, family structure is important in several respects e.g. household size, number of adults and children, their respective genders and the relationship between different household members. In the past, social class had little effect on the domestic trajectories taken by men and women in adult life. The vast majority married in their early twenties, had their first baby within three years of marriage and remained together until death. This relatively uniform progression has been replaced by pathways strongly predicated by both social class and gender. Those from non-manual backgrounds, sheltered from poverty are deferring marriage and parenthood (often indefinitely), whilst the disadvantaged take a divergent pathway with early- and lone-parenthood determining the life-course of working-class women, leading to pronounced gender and class differentials (Graham, 2000). There has been a decline in families headed by a married or cohabiting couple and a proportional increase in those headed by a lone-parent. Over the period 1970-2002, the proportion of lone-parent families has risen from 8% of families in 1971 to 27% in 2002. This can predominantly be accounted for by families headed by lone mothers (Office of National Statistics, 2004). The increasing trend towards cohabitation makes marital status a more complicated variable than previously, to the extent that some official data (e.g. in Sweden) no longer attempts to differentiate (Carr-Hill & Chalmers-Dixon, 2005).

Changes in labour markets, family structure and housing are increasing spatial polarisation of poverty and wealth in the UK, with a move away from mixed distribution of employed and non-employed within households, to corresponding increases in two-earner and no-earner households (Nickell, 2004). UK studies in 1991 indicated that overall, 27% of households with children were living in poverty (range 13% to 53%, when comparing the best to worst areas i.e. > a four fold difference). In Scotland and Glasgow by 2001, respectively, 18% and 36% of dependent children were living in workless households (Scottish Government, 2003). Infant and child mortality rates are positively associated with poverty (Shaw *et al.,* 2001). Even in the 'healthiest' and most affluent areas more than 1:10 children live in impoverished households and will not therefore benefit from area-based policies seeking to support those in the most deprived areas. Only universal provision or interventions targeted at individuals will reach all children in poor households (Macintyre, 2008). However, it is unlikely that welfare provision alone can compensate for the '*class specific inheritance*' of socio-economic inequality found in all modern societies (Erikson & Goldthorpe, 2002). Children whose origins lay in disadvantaged groups had to display far more merit (i.e. educational attainment, IQ and effort) than children from more advantaged origins in order to eventually achieve an equivalent class position (Breen & Goldthorpe, 1999).

1.37.6.1 Caries and family factors

Within Europe and North America, family prosperity has been shown to be significantly associated with positive dental health behaviours (Maes *et al.,* 2006). Negative indicators of oral health include overcrowding, high levels of paternal punishment and belonging to 'reconstituted families' (Maes *et al.,* 2006). Nevertheless, in Scotland the following family factors were related to positive toothbrushing behaviours in adolescents: a) relative family affluence and SES, b) perceptions about fair parenting, c) the degree of closeness to one or more parent, d) breakfast eating, e) family meals taken together and not going to bed hungry (Levin & Currie, 2010). Furthermore, children without their biological father resident with the family at their time of birth were at 40 times excess risk of having experienced toothache by age six years (Bastos *et al.,* 2008). A high internal locus of control within the family had a protective effect with respect to development of caries in pre-school children (Chase *et al.,* 2004; Lencova *et al.,* 2008). This contrasted with households with negative general health and dental health attitudes among parents (Segovia-Villanueva *et al.,* 2005; Fukuda *et al.,* 2007; Leroy *et al.,* 2008).

Although the relationship between family characteristics e.g. absence of one parent predisposing to increased caries risk was weak (Maes *et al.,* 2006), there was evidence that fathers were nevertheless an important influence on a child's dental development (Brandao *et al.,* 2006; Cortallazzi *et al.,* 2008). Of concern, children living with one parent, or with other people, were substantially more likely to report having had oral pain in the previous four weeks (Pau *et al.,* 2007). Other influences of the family relate to their cultural perceptions and beliefs about oral hygiene and diet (Adair *et al*., 2004; Dye *et al*., 2004; Mobley *et al*., 2009).

1.38 Neighbourhood conditions and housing

In epidemiology, housing characteristics give an indication of the material aspects of socio-economic circumstances. Housing-related factors are often used as SES indicators in both industrialised and non-industrialised countries and may be specific to the areas for which they were developed. The factors most strongly associated with socio-economic position are housing tenure, whether 'owned outright' or 'in the process of being purchased by mortgage' or rented from a private or social landlord and the extent of household amenities, which themselves act as markers of material circumstance and possible mediators of disease e.g. access to hot and cold running water etc. (Galobardes *et al.,* 2006a). In general, people with low SES are more likely to have increased exposure to unfavourable neighbourhood characteristics which plausibly contribute to health inequalities (Voigtlander *et al*., 2010). Furthermore, population density at parish level exerts a dominant dose-response related to chronic disease mortality (Chaix *et al.,* 2006). Within the West of Scotland there was reportedly a statistically significant association between poor psycho-social health and perceptions of inferiority about the worth or value of subjects' privately owned or rented house /flat. Those believing that their home was worth less compared to others, experienced poorer scores for self-esteem, mastery and anxiety (Ellaway *et al.,* 2004). However, the meaning of these types of factors varies by culture, context and cohort. Nevertheless, the degree of cohesion felt in neighbourhoods of residence in Glasgow was able to predict self-assessed health and mental illness etc. (Ellaway *et al.,* 2001).

1.38.1 Neighbourhood effects on dental caries

Neighbourhood deprivation indices e.g. at aggregated postcode sector level have explanatory potential for oral health and oral health related behaviours (Locker, 2000) and are considered to have advantages in inequalities research, as postcode is routinely collected on most health records and densities of those with poorer health can be easily identified (and targeted). While most neighbourhood indexes combine material factors to produce a SES score, recent multilevel modelling studies in Brazil have suggested that the level of neighbourhood empowerment is negatively associated with high burdens of dental caries in adolescents (OR 1.49), independently of conventional risk factors (Pattussi *et al.,* 2006). Further, studies have indicated that 47.2% of community level variance in three-year-olds' mean dmft (at the WHO basic threshold i.e. cavitated or undermined enamel) could be explained by community-level rather than individual-level factors (Aida *et al.,* 2008). This is in keeping with the findings of Armfield (2007), who reported that some specific discrete area-based measures of SES held explanatory potential over and above that of a composite area-based SES index and could make a unique contribution (in some cases superior) in explaining caries variance/inequalities among four to sixteen-year-olds in a very large study in Australia. Other inequality studies have noted detriment to oral health accruing from area-SES beyond that expected from SES indicators of individual households alone (Willems *et al.,* 2005; Jamieson & Thomson, 2006). Socio-economic characteristics of neighbourhoods were associated with oral health, independently of the SES attributes of the individual residents (Turrell *et al.,* 2007). Furthermore, poorer adults residing in relatively affluent areas appeared to have the effect of low individual income mitigated by a beneficial area effect. However, affluent individuals living in poor areas did not lose their dental health advantage (Sanders *et al.,* 2008). It was demonstrated in Scotland that irrespective of carriage of cariogenic micro-organisms:

> "….infants living in areas of high deprivation had significantly more caries than those from more affluent areas". (Radford *et al.,* 2000)

Additionally, the SES of school attended had the greatest explanatory power in predicting poor dental health at five- and ten-years of age in a French ecological study which also explored a variety of family-based variables (Enjary *et al.,* 2006). Jamieson *et al.* (2006) therefore recommend that the deprivation of 'area' be taken into account over and above that of households when targeting interventions aimed at maximising oral health gains. Notwithstanding the above and contrary to current understanding, although Bower *et al.* (2007) were able to demonstrate an association between adult dental health and area deprivation in Scotland, they concluded that this could mostly be explained by household and individual level factors.

1.39 Life-course and dental health

Most recent of all the contemporary theoretical models, the life-course is considered to have the greatest potential for providing a comprehensive explanation of social inequalities in oral health, as it can contribute materialist, behavioural and psychosocial indicators to give an understanding of causation (Sisson, 2007). The principal mechanisms proposed are an 'accumulation model', a 'critical period's model' (Peres *et* *al.,* 2005; Sisson, 2007) and a ‘social-origins hypotheses’ (Peres *et al.,* 2007). A recent review of the determinants of oral health inequalities concluded that ‘upstream’ interventions at socially critical developmental periods hold more potential than individualised downstream ‘behavioural’ approaches towards reducing dental health inequalities (Watt, 2007). Socio-economic status in infancy was a predictor of dental health status later, in adolescence and adulthood (Poulton *et al.,* 2002; Thompson *et al.,* 2004; Skeie *et al.,* 2006). Life-course caries-effects were also observed among the very elderly (Krustrup *et al.,* 2008). It is postulated that this effect was not mediated by upward social mobility after infancy (Poulton *et al.,* 2002; Peres *et al.,* 2007).

Nunn (2006) concludes that all with an interest in future generations must engage. These sentiments resonate, as most infants do not come into contact with the dental profession, it is increasingly recognised by the international community that inter-disciplinary strategies will be essential if population dental health inequalities are to be decreased (Mouradian *et al.,* 2000; Goldfield & Kilpatrick 2007). This is particularly so for refugee children who are more likely to become established with medical than dental services (Cote *et al.,* 2004). However, there will always be a place for specialist Paediatric Dental clinical services for those individuals with very complex dental needs.

1.40 Composite area-based measures of SES

1.40.1 Introduction

Ecological or area-based indicators (ABIs) are used to derive measures of SES applicable to geographic small areas (Galobardes *et al.,* 2006b) and have now superseded earlier individual level composite indicators e.g. Hollingshead’s index of social position, Duncan Index etc., which have not been updated in line with changes in the occupational classification (Galobardes *et al.,* 2006b). Etches *et al.* (2006) recommend a ‘basket approach’ for indicators, with selection relying on a sound underlying conceptual framework with standardisation to avoid selection bias and those merely ‘feasibility-driven’. However, in practice, ABIs are commonly derived from aggregated individual or small area data derived from census or other administrative databases (Galobardes *et al.,* 2006b). In their review, Pickett & Pearl (2001) found that most locality-based measures used boundaries developed for political purposes as proxies for *de facto* communities/neighbourhoods. They argue that local health services catchment areas would be preferable. Nonetheless, since ABIs are able to characterise areas on a continuum from affluent to deprived, this is less relevant for ecological programme interventions than for clinical services.

The ‘cost’ to residents’ health and well-being of being disadvantaged has been described as greatest in geographic areas where income inequality is largest and likewise the benefits of being advantaged are greater as inequality increases within areas (Albrecht & Albrecht, 2007).

1.40.2 International application

International use of ABIs extends from allocation of public funds, to use as a proxy for the SES of the residents (Galobardes *et al.,* 2006b). Aggregated area statistics may use simultaneously a number of individual variables e.g. proportion of unemployed, proportion in manual occupations etc. or may be combined to produce a single weighted composite index e.g. the Carstairs score. Several composite indices of deprivation are available for use when the object of analysis is a geographic area. They are used to give a concept of place as the unit of analysis and are helpful for evaluation of the geographic distribution of socio-economic inequities in health. ABIs of socio-economic status can be considered to be meaningful indicators of relative socio-economic context in their own right and are not solely ‘proxies’ for individual level data, providing information about an area’s characteristics, the composition of the residents and their relationships to health outcomes (Krieger, 1992; Krieger *et al.,* 2003a). Of the indicators tested, ‘percentage below poverty’ was the most sensitive to expected socio-economic gradients in health related to race, ethnicity and gender. This variable performed as well as complex composite measures such as the Townsend Index (Townsend *et al.,* 1988), with respect to children’s health outcomes. Census measures of economic poverty were most strongly associated with children’s health, performing better than education, occupation or wealth in demonstrating gradients (Krieger *et al.,* 2003b).

Meanwhile, New Zealand researchers found that the small-area census variables e.g.: communication; income; employment; transport; support; qualifications; housing tenure and living space, controlled for household composition and making-up the NZDep9-index were able to produce sensitive gradients in life expectancy by gender, race and ethnic group (Tobias & Cheung, 2003).

Galobardes *et al.* (2007) assert that more or less any of the measures of socio-economic position will capture and describe point prevalence of health inequalities, if indeed they exist and recommend an assortment of indicators within a life-course framework to provide opportunities for exploring aetiological pathways across social groups, time and place. It is therefore important to select a socio-economic indicator to complement the aims and objectives of each research study. Although clustering of poor health was found to be greater in ‘neighbourhoods’ than postcode-sectors, for practical purposes the choice of geographic classification hardly had any impact on the magnitude of health differences by area deprivation (Reigneveld *et al.,* 2000).

Monitoring trends in health inequality poses additional difficulties in obtaining time-series health data according to a particular indicator of SES (Galobardes *et al.,* 2007). Any measure selected must maintain the same meaning and context across time, geography, age, ethnic group and gender. Specific indictors are not equally applicable in every country (Batisita-Foguet *et al.,* 2004) and the need to 'fix' selected variables in advance of data collection restricts ability to later respond to newly emerging research issues or insights (Feinstein, 1993).

Spatial variations in socio-economic deprivation and demographic environments are of fundamental interest to epidemiologists, as they are risk-factors in their own right and are potential confounders and effect-modifiers in ecological studies of environmental-risk and intervention (Small Area Health Statistics Unit, 2007). Thus, their interpretation is of considerable research interest. Some morbidities show strong relationships with indicators of socio-economic disadvantage e.g. households without a car, single parent households and those associated with ownership, but others exhibit only modest relationships (Saul & Payne, 1999). Ideally, systems measuring socio-economic status for use in studying health inequalities will meet the following criteria: they will be grounded in theory; based on data which can be collected reliably and easily and sufficiently sensitive to permit identification of a manageable number of groups ranked along a logical hierarchy, so that gradients can be investigated (Grundy & Holt, 2001).

1.40.3 The ecological fallacy

Care must be taken to avoid the 'ecological fallacy' (Robinson, 1950), a term which describes the significant error which can occur if a researcher assumes that inferences arising from an ecological analysis pertain to individuals within or across a group (Piantadosi *et al.,* 1988; Small Area Health Statistics Unit, 2007; Shaw *et al.,* 2007).

However, birth-weight studies comparing ABIs to individual-data suggest a risk, if any, related to an underestimation of individual's socio-economic inequalities in health (Subramanian *et al.,* 2006).

Similarly, in other studies' comparisons e.g. postcode level health *versus* individual outcomes underestimated individual health inequalities (Hyndman *et al.,* 1995; Galobardes *et al.,* 2006b). The larger the geographic area, the greater are the reported risks of individual misclassifications. However, the advantages of composite ABIs are: i) statistical efficiency and ii) simple presentations of results (Pickett & Pearl, 2001) which generally outweigh the disadvantages (Galobardes *et al.,* 2007). Providing there are large effect sizes, this will be of little relevance.

1.40.4 Area-Based Indicators in Great Britain (GB) and Scotland

NHS health service evaluations commonly use composite indices of deprivation (Galobardes *et al.,* 2007) e.g.: Townsend Deprivation Index (Townsend *et al.,* 1988), Jarman Underprivileged Area Score (Jarman, 1983) and Carstairs Deprivation Index (Carstairs & Morris, 1989). Each uses slightly different blends of census-derived information. These indices were developed in an attempt to explain variations in health with reference to material deprivation (Morris & Carstairs, 1991) for use by health services. Census, population, mortality, cancer register and health service records are now expected to contain a postcode identifier, universally. This allows data to be derived for small area level (usually ward or postcode sector and more recently data-zone) in the investigation of locality-based health events (Carstairs, 1995). Carstairs and Townsend Indexes correlate well with SMR and morbidity data, while the Jarman Index is more clearly related to bed-days and hospital-based measures. All of these indicators have been widely used to estimate SES in UK investigations of health inequalities. In spite of the fact that postcode sectors do not generally have socially and economically homogeneous populations, the Carstairs score based at postcode sector collapsed into seven categorical variables i.e. DepCat 1 (most affluent category) to DepCat 7 (most disadvantaged) has been widely used in Scotland as a means of measuring inequalities in health outcomes related to socio-economic position (McLoone, 1994; Scottish Executive, 2004).

The Measuring Deprivation Subgroup (2004) of the Information and Statistics Division Geography, Census and Deprivation Group, Scotland recommends that in all studies utilising retrospective data:

> “...trend analyses including data from pre-1997 can only be analysed using Carstairs postcode-sector based deciles……..The whole data range (including the post-1997 years) should be analysed in this way”. (Measuring Deprivation Subgroup, 2004)

Some authors have reported that educational qualification or social class paired with a geographic deprivation indicator performed better in analyses than a geographic indicator alone and were easy to collect (Grundy & Holt, 2001). Others have suggested that although area-based measures may reflect social composition at extreme scores, it is likely that middle range scores contain relatively heterogeneous populations (Macintyre, 1997).

While it had been suggested that ABIs of disadvantage and individual socio-economic indicators contribute independently to health risk (Davey Smith *et al.,* 1998), more recent multilevel modelling studies by Leyland (2005) contradict this earlier conclusion. His West of Scotland studies found that the dominant relationship was area deprivation, measured by Carstairs score (1991) and the fit of the model was not improved by inclusion of any individual risk factors (Leyland, 2005). This confirmed the Carstairs and Morris (1989) findings that it was the '*much worse'* deprivation *per se* which accounted for excess mortality in Scotland when compared to England and Wales. Therefore, the choice of SES measure to be applied must be made in context and it should lend explanatory power to inequality models (Jamieson & Thomson, 2006).

1.40.5 Area-based indicators and dental health

Readers have been cautioned not to rely on any one composite ABI to predict variation in children's mean DMFT (Morgan & Treasure, 2001). Nevertheless, DepCat was able to elicit consistent SES-sensitive caries gradients for $d_3$mft/D_3MFT counts and prevalence across Scotland among five-year-old and twelve-year old children (Sweeney *et al.,* 1998; Sweeney *et al.,* 1999). DepCat effects have been reported in all SHBDEP/NDIP reports published since 1997/98. In addition, DepCat could discriminate between groups of pre-five-year-old children with significantly poorer dental health within a deprived urban area of inner city Glasgow (Sweeney & Gelbier, 1999). Locker & Ford (1996) found that use of an area-based measure of SES could discriminate variations in aspects of oral health in adults as effectively as an individual self-reported SES measure. Antunes *et al.* (2002) used spatial analysis techniques i.e. clustering analysis to investigate the association between caries-risk in districts and social classification variables among children. The potential of individual *versus* population-based strategy for preventing caries has been compared (Locker, 2000; Burt, 2005). These studies highlighted the efficacy and cost-benefits of using existing data to target geographic areas and community settings at the high-disease-end of the skewed caries distribution.

1.40.6 Other clustering of poor dental health

English early school performance result scores, the percentage of children receiving free school meals, degree of parental control, child behaviour and the Jarman score of school address etc. were each independently associated with mean $d_3$mft scores in infants (Gratrix & Holloway, 1994; Hinds & Gregory, 1995; Muirhead & Marcenes 2004) and as mentioned previously, deprivation status of school-zone was also useful for identification of dental inequalities (Enjary *et al.,* 2006).

1.41 Contemporary Indexes of Multiple Deprivation

Contemporary measures of multiple deprivations in the UK have moved on beyond only census derived information to reflect the complexity of influences. Separate indexes have evolved for each of the UK territories and all aim to measure deprivation consistently within their geographic area. Each comprises similarly of a wide variety of mainly non-census-based indicators and have prompted index-development further afield (Testi *et al.,* 2004). In England, Wales and Northern Ireland, respectively, the IMD-2000/2004, Welsh IMD (Carr-Hill & Chalmers-Dixon, 2005) and the 'Noble Index' (Noble *et al.,* 2001) were developed by The Social Disadvantage Group, University of Oxford to provide multi-faceted indexes for application at small area level. Since they do not use the same assortment of variables, results from each may not be directly compared (Carr-Hill & Chalmers-Dixon, 2005).

The first Scottish Area Deprivation Index based on non-census data at postcode sector level (Kearns *et al.,* 2000) incorporated six domains selected on theoretical grounds (and data availability) to represent the dimensions of urban deprivation i.e. housing, health/morbidity, education, crime, unemployment and poverty and preceded the Scottish Indices of Deprivation (Social Disadvantage Research Centre, 2003). This correlated closely with traditional Census indexes e.g. Townsend and Carstairs. Subsequent development of The Scottish Index of Multiple Deprivation, SIMD, (Scottish Executive, 2004a; Scottish Executive, 2006; Scottish Government, 2009) built on this work and included the additional domain: geographical access, further evolving the methodology to be applicable to the whole of Scotland. In this review, SIMD will be used to illustrate further development of the concept outlined above.

The SIMD 2004 contained 31 indicators across six individual domains appropriately aggregated and weighted i.e. Current Income; Employment; Housing, Health; Education, Skills and Training and Geographic Access to Services and Communications (Scottish Executive, 2003c & 2006) and in addition to identifying small area concentrations of multiple deprivation, SIMD was designed to fairly reflect urban and rural differences. Only indicators with the same urban and rural meaning and context are included e.g. 'no car' is not included due to the underlying difference in necessity. Ranking is available at the small area geographic level of '*data zone*'. There are 6,505 data-zones across Scotland. The 'data zone' denoted one is the most deprived and that 6,505th is the least deprived.

The updated SIMD 2006 incorporated recommendations from the University of Glasgow (Scottish Executive, 2006) and more recently contains 37 indicators and an additional domain i.e. crime. Each 'data zone' has a population of between 500 and 1,000 household residents (median 769), homogeneous social characteristics and a compact shape (Scottish Executive, 2004a & 2007). The local authority area with the largest national and local share of the 15% most deprived 'data zones' in Scotland, 2006, was Glasgow City with 34% and 48%, respectively. Although, by 2009 there were net decreases in the number of 'data zones' in Glasgow falling into these categories, respectively, to 31% and 43%. The next highest national share of the 15% most deprived 'data zones' (2009) was just 9% in North Lanarkshire Local Council's area. This shows that compared to other geographic areas, multiple deprivation is far more concentrated in the Glasgow City Council area.

The overall SIMD and most domains are not directly comparable between 2004, 2006 (Scottish Executive 2006a) and 2009 (Scottish Government, 2009). It is important to always consider the SIMD as a relative measure of deprivation. Few of the component variables are absolutes. The index must be considered as a series of cross-sectional snapshots and not be used as a measure of absolute deprivation within a 'data zone' nor to quantify absolute change over time. However, as SIMD has a stable geographic basis it may be used to track relative change over time.

The association between individual domains from IMDs and health have been explored (Jordan *et al.*, 2004; Measuring Deprivation Subgroup, 2004; Adams & White, 2006). Investigation of relationships between health and (S)IMDs with, and without, inclusion of a 'Health' domain arose from concerns related to the inclusion of a 'Health' domain in an index used to measure SES associations with health. Even in the absence of income deprivation, poor health was still found to be a form of deprivation which was exacerbated in the presence of other deprivations and so there is considered to be theoretical justification for the inclusion of the health domain in (S)IMDs (Adams & White, 2006). Although the SIMD measure excluding health and geography domains was consistent in outperforming the combined SIMD, the magnitude of difference was relatively small and there are benefits from consistency of use of the combined SIMD across Scottish health and public administration systems (Measuring Deprivation Subgroup, 2004).

Almost all 'data zones' classified by overall SIMD as among the most deprived, were assessed as deprived according to four or more domains in 2009 (Scottish Government, 2009). This provides insights into the ways that multiple different deprivations are associated. The 2009 report (Scottish Government) suggests that income deprivation has risen across Scotland since 2006 and that this is likely due to the combined effects of the economic recession and the recent incorporation of Tax Credit information into SIMD, which permitted identification and inclusion of those in work, but on low pay. In 2009, Glasgow had the largest share of both income-deprived and employment-deprived individuals of working age in Scotland. However, this is reportedly improving over time (Scottish Government, 2009).

With respect to the 'health domain' Ayrshire & Arran, Greater Glasgow & Clyde and Lanarkshire NHS Board areas have consistently contained the highest concentrations of the most health-deprived datazones (Scottish Government, 2009) and the SIMD report explicitly identifies Scotland's East-West health divide. Furthermore, over two thirds of the most overall deprived SIMD datazones have been in the most health-deprived datazones. The SIMD 2009 report's authors comment that while this is to be expected, contemporary changes to the causes of ill health will only show many years down the line (Scottish Government, 2009).

Overall, at 'data zone'-level, combined SIMD compared well to Carstairs measures with respect to association with health. Adoption of SIMD is estimated to lead to loss of precision of health inequalities of between 3-26% compared to the respective best available measures (Measuring Deprivation Subgroup, 2004).

1.42 Use of routine data sets

In spite of the fact that much of public health knowledge i.e. answers to non-therapeutic questions is derived from observational research into aetiology, prognosis and risk-benefits (Glasziou *et al.,* 2004; Vandenbroucke *et al.,* 2007), there is a reported paucity of reviews of epidemiological studies within the general population (Pocock *et al.,* 2004). Cross-sectional reviews of clinical databases across the UK concluded that their potential had not been realised; there was great variation in their age; size; geographic coverage; scope; the quality of their data; respective representation of women, the elderly and ethnic minorities and thus their potential usefulness was questionable (Unal *et al.,* 2003; Black *et al.,* 2004). With respect to inequalities research, compiling large aggregated databases from routine and non-routine sources is not straight forward (Cummins *et al.,* 2005a; Cummins *et al.,* 2005b). Nevertheless, while administrative difficulties are acknowledged, the compilation of large comprehensive retrospective datasets is advocated to permit development of large scale statistical models to disentangle effects and interactions between socio-economic status and health (Feinstein, 1993). Petticrew & Roberts (2003) call for greater utility of 'non-trial data', as much of the information on community impacts of interventions takes this format. Moreover, since data are crucial for decision-making at all levels of an (*health*) enterprise, it would seem to be prudent to maximise return on the original investment in data collection (Tayi & Ballou, 1998), as unlike other physical resources, data are not consumed and may be re-used extensively (Tayi & Ballou, 1998). Meanwhile, researchers are cautioned severally that:

> "It is possible technically to combine collections of data that were never meant to be combined."
>
> "……the (*future*) data….uses may be only partially known."
>
> "..if the data items are made available across divisions on an *ad hoc* basis, as would be the case with a data warehouse, then something needs to be done to resolve the inconsistencies."
>
> "..the capability of judging the reasonableness of the data is lost when users have no responsibility for the data's integrity and when they are removed from the gatherers. Such problems become increasingly critical as organisations implement data warehouses."
>
> "It is of fundamental importance to have an overall plan or blueprint for ensuring the quality of the information product…..A recurring theme……………is the need for continual feedback from users to ensure that the data's quality is maintained" (Tayi & Ballou, 1998)

Four dimensions of data quality: accuracy; completeness; consistency and timeliness have been described (Ballou & Pazer, 1985). Wang & Strong (1996) added an additional data quality taxonomy, namely: intrinsic; contextual; representational and accessibility. Both of these classifications maintain contemporary relevance (Xu *et al.,* 2002). Further, critical factors pertinent to quality data-collection are described as: adequate training; support from top management; communications; management of employee relations and data-quality controls (Xu *et al.,* 2002).

Notwithstanding the above, secondary data and 'data pooling' can minimise otherwise prohibitive costs from multiple large-scale primary data collections (Huston & Naylor, 1996). Furthermore, pooled observational data hold great potential for community health services' evaluation of general populations receiving 'care' under usual conditions (Cubbon, 1987; Huston & Naylor, 1996). The Meta-analysis of Observational Studies in Epidemiology (MOOSE) group has provided a reporting checklist for the following observational studies: etiological, effectiveness and studies with historical controls (Stroup *et al.,* 2000) and suggests that Meta-analysis of such studies may be one of the few ways to assess efficacy and effectiveness. Coulter (2001) considers dentistry to be lagging behind medicine with respect to making best use of health services research to inform effectiveness, outcomes, policy and practice.

Moreover, observational data may even be utilised to explore new paradigms about potential causations, as observational studies are now considered by the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) consensus statement to have potential to be sufficient to confirm or refute new ideas (Vandenbroucke *et al.,* 2007).

In spite of being relatively time consuming compared to reproduction of primary analyses, secondary analysis of original datasets is highly preferable (Erikson *et al.,* 1979). Checklists for studies reporting secondary data analyses and cross-sectional observational data have been published and both the study design and rigor in reporting, should be no less than for primary scientific research (Huston & Naylor, 1996; Stroup *et al.,* 2000; Vandenbroucke *et al.,* 2007). A principal criticism of previous publications has been that data quality are generally not discussed (Pocock *et al.,* 2004).

A major drawback of routine datasets is that researchers are restricted to fields which have been collected previously (Feinstein, 1993; O'Donnell *et al.,* 2008). However, the contemporary research question must always be pertinent and not tailored to fit the aggregated data i.e. as in 'data dredging' (Huston & Naylor, 1996; Pocock *et al.,* 2004).

1.42.1 Context

The Scottish Public Health White Paper's first requirement of demonstration intervention programmes is to reduce inequalities by tackling adverse life circumstances (The Scottish Office, 1999). Relatively scant attention had been directed towards identification of consensus methodologies for measuring changes in inequalities in health until the publication of '*Long Term Monitoring of Health Inequalities, First Report on Headline Indicators*' (The Scottish Government, 2008a). This seems paradoxical, as reduction of socio-economic health inequalities is a central tenet of Government policy. Moreover, Low (undated) concluded that the key distinctions which must be made in choice of metric are: i) variation in health *versus* socio-economic inequalities and ii) the absolute *versus* relative gap. Furthermore, Low (undated) has suggested that health improvement and health inequalities targets are inconsistent with each other and that governments are disingenuous for seldom being specific as to which they are referring, thus potentially leaving scope for "false claims about progress".

However, controversy, debate and lack of clarity remain evident within the international arena, as to which methodology is most appropriate for particular health status indicators. It has been generally agreed that there is no single best way of measuring inequality that would be appropriate under all circumstances (Wagstaff & van Doorslaer, 2002 & 2004; Regidor, 2004a; Kepple *et al.,* 2005; Harper *et al.,* 2008).

1.42.2 Evolution of methodologies for general health inequalities measurement

Historically, inequalities measurement has largely developed in association with the economics of income distribution. Early review exposed drawbacks associated with a variety of the possible inequalities measures for application to health data (Wagstaff *et al.*, 1991). A subsequent discussion document prepared by the WHO, *Measuring Socio-economic Inequalities in Health* (Kunst & Machenbach, 1994) classified potential measures as either simple or complex. Mackenbach & Kunst (1997) described a 'framework' of inequality measures in the context of the WHO European region's desire to track changes over time. This too described advantages, limitations and the complementary relationship of the simple and complex measures, concluding that since none was intrinsically superior; the choice of measure should depend on the outcome of interest. Bilheimer & Klein (2010) still consider that estimation of health inequalities presents particular challenges. Furthermore, that evaluation of evolving methodologies for measuring inequalities should be a priority for researchers for the next decade (Bilheimer & Klein, 2010).

Recent systematic review by the UK Eastern Region Public Health Observatory (erpho) led to publication of criteria for selection of a 'basket' of indicators of inequality devised to support local action towards the national equity targets (Flowers & Pencheon, 2004) broadly similar to those published in *Inequalities in Health-Report of the Measuring Inequalities in Health working Group* (Scottish Executive, 2003b). Erpho selected criteria by which to assess measurable dimensions of inequality. These are that an indicator should be: i) routinely published, ii) updateable at intervals at least 3-yearly, iii) robust enough to detect changes over time, iv) capable of being interpreted, v) and even if not routinely published, the data to calculate the indicator should be routinely collected. However, at this time the Scottish Executive restricted its recommendations to simple measurement of relative inequality (ratios) between the most affluent and most deprived SES groups, whilst recommending that further work be undertaken to develop more complex measurements to take into account the whole distribution of a health entity, in addition to the extremes (Scottish Executive, 2003b). This preceded *Measuring Socio-Economic Inequalities in Health: a Practical Guide*, published by the Scottish Public Health Observatory, ScotPHO (Munoz-Arroyo & Sutton, 2007).

Meanwhile, the US Department of Health and Human Services Centres for Disease Control and Prevention (CDC) published 11 contemporary guidelines related to measuring health inequalities (Keppel *et al.*, 2005). The guidelines recommend measuring health inequalities with reference to rates, ratios, percentages and proportions or other quantifiable measures with respect to groups in a 'domain' or populations. A domain is defined as a set of groups that defines individuals with respect to a specific characteristic and which should be specific enough to allocate an individual into only one group. The CDC guidelines may be summarised as follows: i) the reference point should be explicit and the rationale for the choice should be provided, ii) if comparisons are made, the most favourable group's outcomes should be used as the reference point and the outcomes should be expressed as adverse events (e.g. caries experience, not $d_3$mft=0) iii) it is necessary to measure inequalities in both absolute and relative terms in order to understand their magnitude/trends, iv) all indicators should be expressed as adverse events when using relative measures to compare inequalities, v) paired comparisons should be used if the objective is measurement of inequalities between each group within a domain, vi) summary measures may be used to quantify the extent of inequality across all groups within a domain, vii) conclusions based on the summary measures should always be interpreted in association with the group-specific incidence/prevalence data on which they are based, viii) in deciding whether to weight the component groups within a summary measure, the reason for calculating the summary measure should be considered, ix) the magnitude of component groups should be considered when assessing inequalities impacts, x) when there is interest in how health varies with a characteristic defining domains, summary measures which take into account the respective magnitude of this factor in groups should be employed, xi) a confidence interval should be shown with each measure of inequality, whenever possible. Furthermore, we are cautioned that the choice of inequalities measure can predicate the outcome (Williams & Doessel, 2006).

1.42.3 Areas of consensus

Although controversy continues as to which of the potential measures is most appropriate, there is consensus that a variety of measures should be employed with any individual dataset (Regidor, 2004b; Harper & Lynch, 2005; Williams & Doessel, 2006; Harper *et al.*, 2008; The Scottish Government, 2008) and that choice is not free of value judgements (Williams & Doesel, 2006). Harper *et al.* (2008) consider that attempts to evaluate trends in health disparities require judgements about which conception of disparity is important for the question at hand. Furthermore, choices about the reference point from which to measure and whether: a) to measure in absolute or relative terms and b) to weight on particular sub-groups of interest (e.g. the poor or the least healthy) should be explicit (Harper *et al.*, 2008). Although choices are often framed as methodological, they reflect value judgements (Harper *et al.*, 2008). Thus, the reasons for choosing one, versus another, should be made clear at the outset (Harper *et al.*, 2008).

However, one should adopt the fewest number of tests, which will nonetheless enable the most complete and accurate interpretation of available data. It is considered important to always measure both absolute and relative inequality and not to pick and choose between them for different health events (Regidor, 2004b). Furthermore, the impact of public (health) policies should, where possible, include measures based on SES ranking to permit assessment of relative effectiveness (Regidor, 2004b).

1.43 Tests of inequality (generic literature)

The metrics of inequality are considered difficult to understand and a dry subject to digest. This is especially so in the abstract, without specific data to report or consider. One of the most straightforward contemporary texts on the subject is probably: *The Handbook of Inequality and Socio-Economic Position. Concepts and Measures,* written by some of the pre-eminent authors in the field: Shaw, Galobardes, Lawlor, Lynch, Wheeler and Davey-Smith (2007) and readers may wish to refer to this or other review papers which have been published previously (Wagstaff *et al.,* 1991; Kunst & Mackenbach, 1994; Regidor, 2004a; Regidor, 2004b; Harper & Lynch 2005).

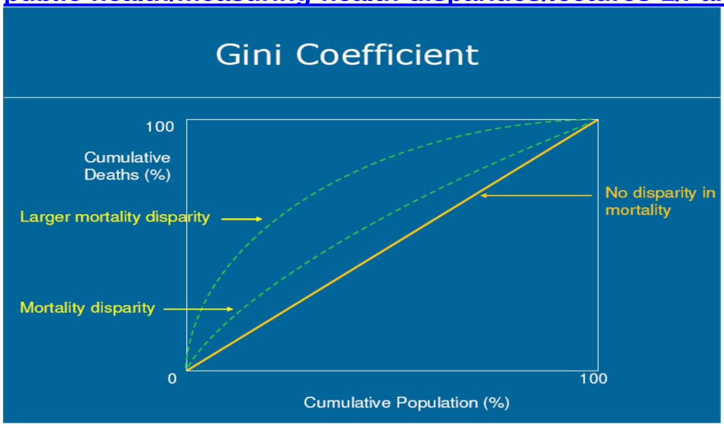
Nonetheless, a number of selected concepts and tests of inequality occurring in the general health inequalities literature have been considered with respect to the main body of this thesis. The so called 'simple measures' of inequality may be described as i) *simple absolute inequality* i.e. the absolute difference between a reference group and another group, ii) *simple relative inequality* i.e. the relative difference or ratio between a reference group and another group and iii) *the range of inequality* (the difference between the top-ranked SES group and the bottom group) and in practice these simple tests are most often performed between the extreme SES groups in a SES ranking. Further inequality tests colloquially known as the 'complex measures of inequality' include a variety of tests from the genres of statistics and income economics and, of these, the following tests occur most commonly in the health literature. The selected complex statistical and inequalities tests are i) 'Odds Ratio' (OR), which is the ratio of the odds of a health event in one group versus the odds of the same in another exposed group, ii) the 'Receiver Operator Curve' (ROC), which plots the sensitivity to '1 minus specificity' for any predictive test or exposure and may be used with ranked scores on a deprivation index to predict a health outcome and the resultant c values calculated from the area under the curve (the predictive potential of an explanatory variable is strongest for c values closest to 1.0). This is analogous to using 'deprivation' as a test for presence or absence of a health outcome, and thus, ROC plots may be used to assess the impact of exposure to relative deprivation on the outcome of interest [the most easily understood explanation for a non-statistician found by this author was by Smith, 2009], iii) regression-based measures (weighted and unweighted), iv) the Slope Index of Inequality (SII), v) the Relative Index of Inequality (RII), vi) measures of disproportionality based on Lorenz curves i.e. Gini coefficient and Concentration Curves & the Concentration Index (CI); vii) the Population Attributable Risk (PAR) and several other miscellaneous measures. A brief outline description of the more complex measures is presented.

1.44 Lorenz curves

1.44.1 The basis of the Gini coefficient

Lorenz curves in health inequalities measurement plot the cumulative distribution of a health outcome against the cumulative distribution of the population, ranked by health status e.g. as illustrated in Figure 1-1. This univariate distribution is the basis for the calculation of the Gini Coefficient that is estimated from the ratio of area between the Lorenz curve (green-dashed) and the line of equity, divided by the area under the line of equity (yellow). These measures quantify inequality in dispersion across a whole population (Murray *et al.*, 1999; Regidor 2004) irrespective of SES, and are advocated by some for 'reviewing' total inequality at individual level (Silber, 1982; Le Grand, 1987; Machenbach & Kunst, 1997; Murray *et al.*, 1999; Gakidou & King, 2001). Nonetheless, there is contrary opinion that these measures potentially confuse, mislead and therefore that they should not be used alone (Houweling *et al.*, 2001; Jasso & Kotz, 2008). The further the Lorenz curve is from the line of equity, the greater is the disparity or inequality (Lynch & Harper, 2005). However, the Gini coefficient only shows how unevenly health, or any other variable, is distributed according to its population share. When applied conventionally, a Gini coefficient value of zero indicates perfect equality e.g. every member has the same income, whilst a value of 1 denotes perfect inequality e.g. all of the income is held by one individual with everyone else having none (Shaw *et al.*, 2007).

Figure 1-1: an example of the Gini Coefficient derived from the Lorenz curve for mortality %(Reproduced from: Lynch & Harper, 2005, http://michigan.educommons.net/school-of-public-health/measuring-health-disparities/lectures-1/Part-III.pdf)



1.44.1.1 'The Robin Hood Index' or inverse-Gini coefficient

Kennedy *et al*. (1996) described the Robin Hood Index (RHI) for use in incomes inequality analyses as: the maximum vertical line between the line of equality and the line of equity in the depiction of the Gini coefficient curve. This value, expressed as a percentage, signifies the proportion of income (variable), which would have to be redistributed to produce equity by this measure. The RHI does not appear to be much used to describe inequalities in health distributions, although it has been used to describe inequality in GP provision across populations (Wilkinson & Symon, 2000; Theodorakis *et al.*, 2006). However, Shaw *et al*. (2007) do describe the use of the 'Robin Hood Index' as the Gini Index, none-the-less interpreted the other way round, to show how unevenly health is distributed.

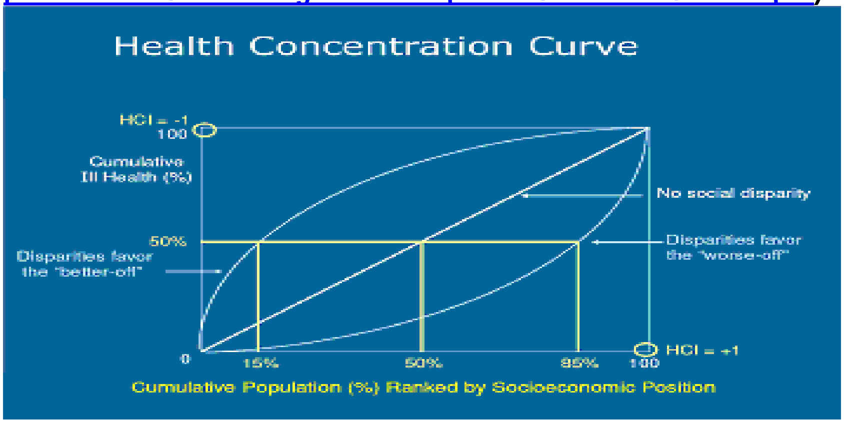
1.44.2 The Concentration Curve (CC) and Concentration Index (CI)

The Concentration Index (relative) is calculated and interpreted in a similar way to the Gini-Coefficient and compares the cumulative distribution of a health event in individuals ranked by their different SES groups. All individuals are included in the calculation of CI and this measure is sensitive to redistribution of individuals across the SES categories. This makes the CI especially suitable for comparison of SES-related inequalities over time and between places. In computing the CI the health statistics in the average SES group provide the reference value to which the relative comparison is made. As illustrated in Figure 1-2, instead of the population being ranked by health status, it is first ordered by social group status and the cumulative proportion of the population within each, ordered according to their SES ranking on the x- axis, are plotted against their share of total health on the y-axis to produce a Concentration Curve [CC] (Wagstaff *et al.,* 1991; Regidor 2004a; O'Donnell *et al.,* 2008). The CC may thus be considered as an extension of the Lorenz Curve which includes SES, but CC may only be used when SES is strictly hierarchical (Regidor 2004a; Shaw *et al.,* 2007). In this example in Figure 1-2, (as is the convention) the SES ranking is arranged according to increasing affluence (x- axis) and results in the Concentration Curve lying below the diagonal signifying that the inequality in distribution of the outcome of interest favours the worse-off (Kakwani, 1977; Wagstaff *et al.,* 1991; Kakwani *et al.,* 1997; O'Donnell *et al.,* 2008). If the converse was the case and the selected SES index plotted increasing deprivation instead of increasing affluence, a curve below the diagonal would indicate that the inequality in distribution of poor health is concentrated in the SES deprived. Munoz-Arroyo & Sutton (2007) have published an example of the CC computed with increasing deprivation along the x-axis.

The resulting Concentration Index (CI) is defined as twice the area between the CC and the line of equity taking values between -1 and +1, the former value denotes that all the morbidity is concentrated in the most disadvantaged person (Munoz-Arroyo & Sutton, 2007). Because the CI reflects the SES dimension and takes account of the population size in the different SES groups, it is considered superior to the simple measures of inequality (Gerdtham *et al.*, 1999; O'Donnell *et al.*, 2008).

Nevertheless, the Concentration Curve and CI have not been widely used in health research as they are considered unfamiliar and possibly difficult to interpret (Lynch & Harper, 2005; Shaw *et al.*, 2007). However, a transformation i.e. multiplication of the absolute value of the CIx75 is proposed by Koolman & van Doorslaer (2004). This makes interpretation of the CI easier. After transformation, the CI may be interpreted as the amount (percentage redistribution required) of health which would have to transfer from the relatively advantaged to the relatively disadvantaged to achieve equity i.e. for the CC to correspond with the diagonal (Koolman & Doorslaer, 2004; Munoz-Arroyo & Sutton, 2007). The potential to plot curves is useful for communicating change in health inequality to policymakers (Shaw *et al.*, 2007) and so it is becoming more popular (Jones & Nicolas, 2004).

Figure 1-2: an example of the Concentration Curve derived from the Lorenz curve (Reproduced from: Lynch & Harper, 2005, http://michigan.educommons.net/school-of-public-health/measuring-health-disparities/lectures-1/Part-III.pdf)

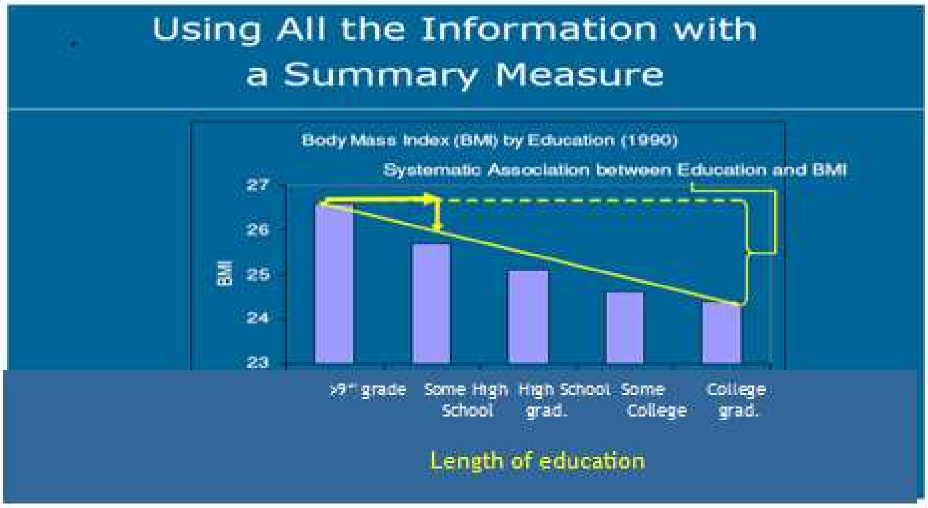


1.45 Regression-based measures

1.45.1 Simple regression-based measurement

In the regression-based techniques, the assumption is made that the relationship between the variables is linear and is represented by the slope of a line, as in the example illustrated in Figure 1-3, showing Body Mass Index (BMI) by educational attainment. This type of measure which may be used to summarise relative risk (Steenland *et al.*, 2002), is used to review the relationship between the two variables and may be unweighted (as in the example below) or weighted by group size (Lynch & Harper, 2005).

Figure 1-3: an example of the regression-based measurement (unweighted). (Reproduced & adapted from: Lynch & Harper, 2005, http://michigan.educommons.net/school-of-public-health/measuring-health-disparities/lectures-1/Part-III.pdf)



1.45.2 Complex regression-based measures: the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII)

1.45.2.1 SII

The Slope Index of Inequality (SII) is an absolute measure of inequality based on the regression of the mid-point value within the range of values for each SES group across the cumulative distribution (Lynch & Harper, 2005) e.g. if the lowest ranked SES group comprises 12.9% of the population the mid-point in this range of the distribution would be 6.5, if the next SES group encompasses the next 4.1% of the distribution the cumulative range for this next group would be 13.0-17.0 with a mid-point of 15.0 and so forth, through all the SES groups. However, it is dependent on strict ordering of groups (Manor *et al.*, 1997) and a premise that the regression estimate will not deviate significantly from linear (Regidor 2004a). The SII calculation uses these intra-SES group median values and takes account of the population share of each SES group (Wagstaff *et al.*, 1991; Regidor 2004a). The regressed value represents the hypothetical absolute difference in a health outcome between the worst-off and hypothetically best-off person in a population (Lynch & Harper, 2005; Shaw *et al.*, 2007). The SII is nonetheless indicative of the total experience of the individuals within the whole population (Keppel *et al.*, 2005; Munoz-Arroyo & Sutton, 2007). It has strong advocates (Wagstaff *et al.*, 1991; Low & Low, 2004) mainly due to its consistency with local populations (Low &

Low, 2004). However, the SII should not be used uncritically, as it is dependent on a linear relationship between the SES deprivation indicator and the health outcome of interest. Thus it is not inherently suited for inequalities analysis of mortality and personal incomes data (Adams, 2005). Nonetheless, its use was robustly defended later for use with e.g. composite ABI indices which are said to better reflect the wider SES determinants of health and which have a much stronger relationship with health outcomes than the aforesaid (Low & Low, 2005). Moreover, the SII may be weighted to reflect the SES distribution in the denominator population and is advocated for use in health inequalities measurement the UK and Scotland in recent reviews (Munoz-Arroyo & Sutton, 2007; Marmot *et al.*, 2010).

1.45.2.2 RII

The Relative Index of Inequality (RII) may be considered to be a relative version of the SII and is itself computed from the SII (Regidor 2004a; Keppel *et al.,* 2005; Pamuk, 2007). RII is considered useful for making comparisons between an outcome of interest in different geographic places or in different cohorts (Shaw *et al.,* 2007). Furthermore, inequalities estimates derived from RII are said to be less influenced by extremes of the exposure distribution (Shaw *et al.,* 2007), as it measures the health variable with reference to average population health (Harper & Lynch, 2005). The RII is sensitive to changes within individual SES groups, in addition to changes across the SES gradient (Regidor 2004a).

1.46 The Population Attributable Risk (PAR)

The term Population Attributable Risk (or %PAR as used herein) is a measure of disease frequency and can be described as the reduction in prevalence that would be observed if the population were entirely unexposed (to whatever), compared with their actual exposure pattern (Rothman & Greenland, 1998). It appears in the literature under 14 other names (Gefeller, 1990; Gefeller, 1992). With respect to inequalities measurement, this metric describes the proportion of a health event/problem within a whole population which would be prevented if the health experience of the most advantaged group (generally considered to have the most favourable health statistics and to be unexposed to deprivation) could be generalised to the whole population (Gefeller, 1992; Benichou, 2001; Regidor, 2004b; Harper & Lynch, 2005). The %PAR therefore measures the potential impact of control measures in a population, and thus is relevant to decisions in public health. It is advocated for estimation of the proportion of disease caused and/or prevented by exposures and/or interventions (Miettinen, 1974; Walter, 1976; Gefeller, 1992; Regidor, 2004b). Furthermore, it is considered to be the method of choice when the aim is to decrease the impact of SES on the burden of a health problem in the population. However, a disadvantage of %PAR is that when comparing different populations, it requires that the reference category is similar in each population being compared.

1.47 Other considerations

1.47.1 The 'scale of the problem'

Contemporary expert opinion in the UK (Marmot *et al*, 2010) has suggested that there should be consideration given to whether the type of health inequality being considered is in fact a substantial problem with a high prevalence. From a public health point of view, when results may be used to argue for resource allocation, this is understandable. The proponents thus argue that a measure of the 'scale of the problem' of a particular inequality should always be integral to analyses of inequalities.

There is some support for this in the literature e.g. Kepple *et al.* (2005). Nevertheless, the issue is not uncontroversial, as in the light of *a priori* agreement that systematic health inequality is undesirable, it is questioned e.g. in relation to a small minority ethnic group, why the relative size of the group should matter (Harper *et al.*, 2010).

1.47.2 Normative positions & value judgements

Other controversies relate to choices of inequalities tests and the normative position of researchers, consumers of inequality data and society with respect to what each considers to be important e.g. geographic population size, decisions whether to weight data, the groups to compare (choice of reference group), choices between relative and absolute measures etc. (Harper *et al.*, 2010). The conclusion seems to be that there are inexorable value judgements implicit in all inequalities interventions (Macintyre, 2007) and tests (Williams & Doessel, 2006; Harper *et al.*, 2010). For these reasons, a 'raft' of measures should be applied to assess and present the distribution (within the constraints of the data) from the variety of angles and value judgements (Williams & Doessel, 2006). The National Institute of Health and Clinical Excellence (NICE, 2007a) has recently consulted the public on the issue of how to reach 'social value judgements' over and above conventional 'scientific value judgements'.

1.48 Issues related to the dmf indices

1.48.1 Introduction

In spite of its widespread use for *circa* 65 years, there are concerns about use of the dmf index (particularly in relation to the m and f components) for quantifying tooth surface caries morbidity, due to the impacts of treatment on this score. We are cautioned that allocating the maximum value of missing surfaces will over-estimate inequalities, whereas discounting 'm' will cause an underestimate (Spencer, 1997; Broadbent & Thomson, 2005) on this scoring system. Other methodological concerns relate to trial outcome estimations (Stamm, 1984), especially in environments with increased reported prevalences of children who do not develop caries extending into dentine (d_3) i.e. a commonly used threshold of diagnosis in caries surveys (Spencer, 1997). Criticisms relate to merely ‘counting lesions requiring treatment interventions’ rather than accurate observation and recording of the continuum of the carious process (Spencer, 1997). However, in spite of reported shortcomings, it remains the most important measure in dental epidemiology (Broadbent & Thomson, 2005). It is used extensively in programme evaluation. However, researchers have been cautioned that use of cross-sectional dmft survey data, alone, without consideration of demographic aspects carries the risk of Type 1 error due to confounding factors (Burt, 1997).

1.48.2 Skewed distribution (zero-inflation)

Currently, caries distributions in developed countries are unlikely to be normally distributed (Petersen, 1990; Spencer, 1997; Burt 1998; Fabien *et al.,* 1999; Lewsey *et al.,* 2000; Macek *et al.,* 2004; Armfield, 2005; Javali & Parameshwar, 2007). The customary reporting of the mean dmft value and population percentage with dmft=0 in child populations, which have positively skewed caries distribution, may conceal the tail in the distribution i.e. the comparatively few in number with substantial burdens of disease (Macek *et al.,* 2004; Dugmore, 2006; Levin *et al.,* 2009). Therefore, to understand the true distribution of caries morbidity it is necessary to examine the whole age specific distribution (Armfield, 2005). Lewsey & Thomson (2004) reported that zero-inflated Poisson and zero-inflated negative-binomial modelling are useful in overcoming the effect of skew and in understanding patterns of cross-sectional SES-related caries distributions and associated influences on prevalence. Several studies have adopted this approach (e.g. Lewsey *et al.,* 2000; Javali & Parameshwar, 2007; Levin *et al.,* 2009). However, unlike Bratthall’s (2000) earlier proposal of the Significant Caries Index (SIC), alternative models can be complex and less readily amenable to intuitive interpretation.

1.49 Issues related to quantifying variations in (dental) health

1.49.1 Context

Dental health status was considered of lesser importance to only smoking in pregnancy and breast feeding with respect to recognised indicators of children's health inequalities in *Improving Health in Scotland–the Challenge* (Scottish Executive, 2003). Political imperative in Scotland, and beyond, necessitates an evaluation of potential methodologies for measurement of inequalities in caries prevalence. Manuel & Rosella (2010) argue that assessment and understanding of a population's baseline-risk is the prerequisite for population heath planning and failure to use improved methodologies for these purposes is inexcusable.

1.49.2 Measurement of inequalities in dental health distribution

Although there has been evidence of interest in the topic of dental health inequality for some time (Petersen, 1990; Watt & Sheiham, 1999), the group dmf/DMF mean and % with dmf/DMF=0, alone, seem to be the only values presented in some papers reviewing inequalities in caries distribution (Edelstein & Douglas, 1995; Watt & Sheiham, 1999).

These represent the simplest quantifications reported in the literature and compare *absolute* count values between groups, expressed as percentage prevalences of an *a priori* selected outcome, or the corollary, alongside mean values (Schou & Wight, 1994; Slade *et al.,* 1996; Bower *et al.,* 2007). Such differences relate to 'absolute' inequality and are alone too superficial to be convincing measures of inequality or change in inequality. Alternatively, when ratios between group values are compared, the estimation of magnitude described is that of 'relative' inequality (Slade *et al.,* 1996; Holst, 2008; Armfield *et al.,* 2009) and may be of value when combined with other outcome metrics. A statistical value: 'the adjusted *Odds Ratio*' for presence of a health outcome is often used to indicate the elevated likelihood of caries in one SES (or other) group versus another e.g. dmft>0 (Hjern *et al.,* 2001) and usually pertains to comparison between selected socio-economic extremes or other pairs (Levin *et al.,* 2009). Nevertheless, while useful, this tells nothing of the distribution of health between all members of the population of interest and it is possible that the gap between those at the top and bottom of a SES spectrum could remain the same while inequality was increasing or decreasing between intermediate groups (Carr-Hill & Chalmers-Dixon, 2005). While an already large body of multidisciplinary general public health literature is debating relative merits, appropriateness and emerging consensus in the field of inequalities measurement, relatively little has been published in comparison related to quantification of dental health inequalities. It seems that national and international consensus has yet to develop with respect to the most appropriate methodologies to apply to measurement of dental health inequality. With some notable exceptions, dental authors tend to appear to present caries summary statistics, but in the main to avoid directly addressing the issue of inequality. This may be deliberate, oversight, or due to dental researchers not yet having systematically explored available methodologies with collaborators who have thorough understanding of the epidemiological issues.

1.50 Difficulties in quantifying dental health inequality noted in the literature

1.50.1 Caries count data (simple)

Critical examination of The World Oral Health Report (Petersen, 2003 & 2003a) illustrates some of the difficulties inherent in measurement of dental health inequalities. The report documents longitudinal child caries trends in developed countries (from previously higher levels) versus developing countries (from previously lower levels) by use of only mean DMF trend data (Petersen, 2003; Petersen *et al.,* 2005a). Marked trends towards convergence of mean DMF scores were evident between developed and developing countries from 1981-1986 and while undoubtedly the 'gap' decreased over the period, this would not be considered as a reduction in dental health *inequity* between developing and developed countries, as the 'cost' is a worsening mean score in the developing countries. When these data were combined to give the mean for all countries, the combined data showed no overall change, amply demonstrating the potential for larger group summary statistics to mask underlying trends. Notably, the WHO makes no comment about measurement of dental health '*disparity*,' '*skew*' or '*inequality*' in its paper.

1.50.2 Transition from caries count data alone for inequalities estimation to incorporation of statistical testing

There is little contemporary consensus in this field. Some authors continue to report mean dmft (SD) only, and to test significance of association with a variety of co-variables (Aida *et al.,* 2008), whilst others state a preference for reporting mean dmft/DMFT (95%CI) and relative ratios (Jamieson *et al.,* 2006; Armfield, 2007) or Odds Ratios alone (instead of mean dmft) because of the skew in distribution (e.g. Leroy *et al.,* 2008).

Even the recent 2005/06 British Association for the Study of Community Dentistry (BASCD) survey of five-year-olds' dental health reported the mean and %=0 for dmft and components (Pitts *et al.,* 2007). In spite of the tantalizing hints of small statistically significant improvements in inequality in northern regions of England and in Scotland, data in this paper compared no empirical indication of direction or magnitude of change in absolute and relative inequality, even by simple measures. Although successive Scottish epidemiological survey results published since 1994 have shown that there has been variable modest improvements in the proportions of children in each DepCat category who have no obvious caries at the d_3 level (Merrett *et al.,* 2007), it remained unclear what effect, if any, this may have had overall on five-year-olds' dental health inequalities until Levin *et al.* (2009) published their analyses reporting Odds Ratios (ORs) and Relative Risks (RRs) for $d_3$mft>0 and $d_3$mft counts.

1.50.3 Poisson regression modelling of caries data

In attempts to overcome some of the challenges of caries data, dental authors have previously proposed statistical modelling based on Poisson distributions (Hujoel *et al.,* 1994). A Poisson distribution is defined as the distribution of random events in which one event has no influence on any other occurrence. Poisson methodology is currently topical in the dental literature (e.g. Ismail & Sohn, 2001; Manci *et al.,* 2004; Barbato *et al.,* 2007; Pattussi *et al.,* 2007; Lawrence *et al.,* 2008; Barbato & Peres, 2009).

1.50.4 Negative binomial distributions for caries count data

Other authors have adopted similar types of methodologies to deal with 'over dispersed' data for which a single Poisson parameter is insufficient to describe a population e.g. that with an excess of zero counts (Ridout *et al.,* 1998; Bohning *et al.,* 1999; Lewsey *et al.,* 2000; Lewsey & Thomson, 2004; Mwalili *et al.,* 2008). Levin *et al.* (2009) adopted this type of complex statistical methodology to deal with their dmft count data. However, they adopted only simple Odds Ratios and Relative Risks for multiple paired SES groups' data from the cross-sectional SHBDEP/NDIP datasets to report change in dental inequalities from 1993-2003. Their results suggested that the odds of Scotland's five-year-olds having $d_3$mft>0 in DepCat 7 *versus* DepCat 1 appeared to diminish over time, whereas the Relative Risk of those children having additional carious teeth did not improve over time.

1.50.5 Drawbacks

Measurements of (dental) health inequality require: indicators to quantify health/morbidity, decisions about what groups or areas to compare and decisions on the most appropriate analysis to answer each research question. Policy makers do tend to require simple readily understood measures of health and socio-economic position. However, while the simple measures may be logically linked to the topic of investigation, they may answer only part of the question. Thus, comparison of the results of simple measures with more sophisticated measures of inequality has been advocated (Carr-Hill & Chalmers-Dixon, 2005; Cheng *et al.,* 2008).

1.51 Caries data, Lorenz and Gini curves

An early attempt to examine changes in the whole distribution of age-specific dental caries experience was undertaken by Nugent *et al.* (1996) who described dental inequalities among Scottish children by use of cumulative frequency curves. This was in spite of their reservations that due to the limitations of the DMFT index, the premise for the application of the Gini co-efficient calculation may not be met i.e. an equitable distribution of disease (Nugent *et al.,* 2002). Nonetheless, the Gini approach has been widely adopted in distributional studies from Europe and the Americas to quantify dental health inequality (e.g. Poulsen *et al.,* 2001; Tickle, 2002; Peres *et al.*, 2003; Tickle *et al.,* 2003; Antunes *et al.,* 2004; Macek *et al.,* 2004; Weyant *et al.,* 2004; Antunes *et al.,* 2005). Inequality in a population determined by the Gini-Coefficient relates to the degree to which dental disease is not uniformly distributed. A Co-efficient of 0 would occur in the event of perfect equality i.e. everyone had an identical level of disease irrespective of whether this is dmft=0 or dmft=20. 'Total inequality' would attract a Gini value of 1; i.e. when all the caries was concentrated in just one person (Armfield *et al.,* 2009). Although much has been published about the long-term declines in caries in a variety of countries, only a limited number of studies have documented changing inequalities in distribution of caries (e.g. Poulsen *et al.,* 2001; Bastos *et al.,* 2007; Armfield *et al.,* 2009). These research groups have reported increasing inequality measured by the Gini-Co-efficient/Lorenz curve in association with overall reductions in caries prevalence in the population and decreasing mean count values in those with dmft>0.

Further papers have used Gini-Coefficient/Index to describe significant associations between relative incomes inequality measured by this method and childhood and adult caries measured by both prevalence of DMFT=0 and count data (Pattussi *et al.,* 2001; Hobdell *et al.,* 2003).

1.52 Use of Concentration Index with oral health data

There are few examples of use of the Concentration Index (CI) with oral health data. Nevertheless, SES inequality in dental service utilization in European countries has been quantified by the use of the CI (Stoyanova, 2003; Koolman & van Doorslaer, 2004). Furthermore, the CI was adopted as one of the inequalities metrics in the previously noted study by Cheng *et al.* (2008) which modelled inequality in the prevalence of untreated caries in children in the USA. Perera & Ekanayake (2008) further modelled a variety of SES variables associated with dental caries prevalence with the CI. Contemporary studies from Australia report using CI with 'cumulative equivalised income' data and caries data from individual cross-sectional surveys to model SES-related trends (Do *et al.*, 2010). The graphic depiction of departure from the diagonal line of equity in illustrations of the Concentration Curve provides a more intuitive measure of inequality than the CI value itself. It is advised that with respect to oral health data, CI should be used in conjunction with SII and RII, respectively (Perera & Ekanayake, 2008; Cheng *et al.*, 2008), as the use of multiple summary tests of inequality has been previously justified by Mackenbach & Kunst (1997).

1.53 Slope Index of Inequality (SII) and caries data

There are limited examples of dental use of the SII. The USA National Centre for Health Statistics guidelines on measuring health disparities (Keppel *et al.*, 2005) were applied to the 2005 California Oral Health Needs Assessment Data for kindergarten and third graders in the aforementioned Cheng *et al.* (2008) analysis. Their studies used SII as one estimate of absolute inequalities in untreated caries prevalence (i.e. only the '*d*' component of dmft) according to SES ranking (along with other indices). The authors have made ‘open access software’ available for calculating SII and 95%CI. However, another contemporary research group (Perera & Eranayake, 2008) claims to be the first to adopt SII in oral health research. A publication has become available (Do *et al.*, 2010) describing age specific SES trends in children's caries morbidity, by use of the SII among other inequalities metrics.

1.54 Relative Index of Inequality (RII) and caries data

Cheng *et al.* (2008) make competing claims with the aforementioned authors Perera & Eranayake about being the first to demonstrate the relationship between caries prevalence, SES and school cluster-based SES by use of inequality indices rather than by ‘*mere*’ significance testing. Cheng *et al.* (2008) calculated the RII in comparison to the SII with a variety of simulated caries prevalences. Their conclusions recommend that both SII and RII be employed to compare geographic and longitudinal dental health inequalities.

1.55 Receiver operator characteristic curves (ROC) and caries

Receiver Operator Characteristic (ROC) plots are not technically tests of inequality at all, rather they illustrate the graphical relationship between sensitivity and specificity for a binary classification system (e.g. a two by two table) as the discrimination threshold varies. Nevertheless, they are useful, in that they can demonstrate the extent to which one variable is predicted by another and, in the case of inequalities research, can be helpful to assess the extent to which a health variable is determined by deprivation. Furthermore, successive ROC plots using consecutive cross-sectional data may be used to assess the extent to which the effect of deprivation is mitigated over time. A ROC plot may be considered to plot the fraction of 'true positives' against the fraction of 'false positives'. ROC plots have been applied in various longitudinal caries prediction studies, most commonly to examine the utility of clinical parameters e.g. microbial carriage (Radford *et al.,* 2000), prior caries experience (Steiner *et al.,*1992; van Palenstein Helderman *et al.,* 2001; Skeie *et al.,* 2006; Jeppesen & Foldsspang, 2006), and less frequently to assess the discriminatory potential of socio-demographic measures (Tagliaferro *et al.,* 2007; Almerich-Silla & Monteil-Company, 2007).

1.56 Population Attributable Risk (PAR) and oral health

A few studies have made use of the %PAR to estimate the effect size on populations with respect to a variety of exposures and oral health indicators. Published studies describe Population Attributable Risk in relation to i) caries (Pendrys, 1995; Moss *et al.,* 1999; Peres *et al.,* 2009), ii) fluorosis (Tomek *et al.,* 1984; Riordan, 1993; Pendrys, 2000; Do & Spencer, 2005) and iii) tooth loss (Holm, 1994). Although the %PAR does not appear to have been a very popular oral health inequality metric it, nonetheless, provides useful information with the potential to inform inequalities research.

1.57 The Significant Caries Index (SIC)

The SIC methodology (Bratthall, 2000) is advocated by collaborators of the WHO (WHO Oral Health Country/Area Profile Programme, undated) and relies on calculation of the mean dmft/DMFT score of the 33% of the population who have the poorest dental health. Detailed methodology for its calculation has been published (Nishi *et al.,* 2001). Although devised in association with monitoring towards the 2015 target for 12-year-olds to reach DMFT ≤ 3 (World Health Organization, 2009), this methodology has been adopted in deciduous dentition studies (e.g. Stecksen-Blicks *et al.,* 2006; Villalobos-Rodelo *et al.,* 2006; Armfield & Spencer, 2008) due to its ability to demonstrate more clearly the extent of disease in the tail of distributions (Nishi *et al.,* 2002; Antunes *et* *al.,* 2004; Ekman, 2006). The usefulness of SIC has been demonstrated further in describing longitudinal caries trends (Nishi *et al.,* 2002; Marthaler *et al.,* 2005; Stecksen-Blicks *et al.,* 2006) and child dental health inequality, as it has been described as being able to highlight inequalities (Pitts *et al.,* 2002; Almerich-Silla & Monteil-Company, 2007).

The methodology is recommended for use with communities at high risk of developing caries. Several alternative cut-off values i.e. 25%, 20% & 10% have been explored (Morgan *et al.,* 2005). For children in age-specific population sub-groups, the SIC ^{10} has been reported to have reached values as high as six to 10 times greater than that of the overall population mean (Australian Research Centre for Population Health, 2005; Armfield, 2005). Furthermore, the SIC has been able to reveal in vulnerable infant groups statistically significant trends which were reportedly obscured in earlier analyses (Stecksen-Blicks *et al.,* 2006).

In longitudinal comparisons of trends towards health improvement, Armfied and co-workers considered that, whilst the SIC did address the issue of what had happened in the tail-end of the caries distribution, it was only the concurrent use of Gini-Co-efficient which demonstrated that the totality of (deciduous) caries experience was being concentrated in increasingly smaller proportions of the population as dental health improved (Armfield & Spencer, 2009) i.e. inequality was increasing. Researchers are cautioned that, although SIC can overcome the problem of skewed data, other relevant information is lost by reliance on the SIC value, alone, which constrains full interpretation of the data (Campus *et al.,* 2003). The originator(s) clearly intended SIC be used in conjunction with, not in place of, the conventional indices. Together they can provide further clarity and ease of understanding by the dental profession, health authorities, decision makers and lay persons (Nishi *et al.,* 2002).

1.58 The Dental Health Inequality Index (DHII)

A Dental Health Inequality Index (DHII) which compares actual and theoretical caries distributions has been proposed by Nugent *et al.* (2002). They describe this measure as based on the ratio of the areas under the Lorenz curve for the actual caries distribution and that of a theoretical Poisson distribution which had the same mean DMFT value. Antunes and co-workers found that there was sufficient co-linearity between Gini and the DHII to render these indices interchangeable (Antunes *et al.,* 2004). After comparing use of DHII with other indices i.e. Gini and SIC, Paustian (2007) concurred and further concluded that inequality measures can supplement other disease measures in determining how to tailor disease prevention to a population. Moreover, measurement of (*dental*) health should in future use an appropriate reference line of equality (Paustian, 2007).

1.59 A further inequalities index appearing in the dental literature

A ‘symmetrised Theil index’ was recently described in attempts to design a measure to track change in dental health inequalities over time (Borrell & Talih, 2010). The original Theil Index has appeared previously. However, this form had not been described previously. The authors describe shortcomings in the capacity to identify *socio-demographic* inequalities and this would limit the test’s potential usefulness.

Chapter 2

2 The aims and objectives of this research

2.1 Rationale for this thesis

This thesis seeks to explore selected possible measures of health inequality for application with Scotland's caries data. The OHP programmes operating in Scotland and Glasgow since *circa* 2000 have already produced indications of dental health improvements in their five-year-old populations and in the light of this seemed to provide a suitable platform from which to explore the inequalities testing methodologies. Epidemiological trends had previously been monitored. However, it is necessary nowadays to demonstrate ways in which it is possible to look beyond simple epidemiological trend lines. This requires development of methodologies which will permit progress in the exploration of the inequalities aspects of these data. The most commonly applied inequalities measures have until now been limited to comparison of the extreme SES groups. Complex tests of inequality are required to fully understand the population dynamics of changes in inequality and take account what is happening in comparatively less disadvantaged nevertheless SES challenged groups. Furthermore, the availability of large cross-sectional caries datasets for Scotland and the individual NHS Board areas makes these data particularly suited to a study of caries epidemiology and inequalities in dental health, simultaneously, using *de facto* caries data sets covering a substantial period of time. Other research groupings with interest in the field of inequalities measurement have had to resort to simulated datasets (e.g. Cheng *et al.*, 2008). In Scotland, overall, it is reported that there was a period of "rapid decline" in caries prevalence and $d_3$mft burden over the five years preceding the 2008 NDIP Report for the age group (Merrett *et al.*, 2008). Similarly, examination of reports containing Glasgow caries data indicate that this geographic area was also observing changes in 5-year-olds' caries epidemiology (Blair *et al.*, 2006). However, as yet no comprehensive analysis has been carried out to explore the related inequalities dynamics. Inequalities may occur across whole population distributions or between subgroups identified by SES or other status e.g. geographic area of residence. In this study, the SHBDEP/NDIP data sets have permitted modelling of caries inequalities in each of these respects.

Furthermore, the foregoing review of Health Promotion, epidemiological methodology and health inequalities related literature etc. informs readers about the context and contemporary consensus about 'best-practice' relevant to this study of five-year-olds' caries epidemiological and inequalities trends. Moreover, this review has helped to further chrystallise the need to determine an appropriate framework with which to assess retrospective caries inequalities trends in Scotland and Glasgow for potential application onwards into the future.

For completeness, in the light of the literature review, the next chapter (Chapter 3) of this thesis will more fully describe the multiple intervention strands and complexity of the Health Promotion interventions which in part explain some of the changing environmental context to pre-five-year-olds' dental health, over the period of interest. Chapter 4 will proceed to focus on the epidemiological methodologies employed with respect to the five-year-olds' cross-sectional caries datasets for Scotland. These permitted examination of caries outcomes and longitudinal trends. The second Methods Chapter (Chapter 5) will later describe the methods selected to model any possible geographic and SES dental health inequalities which may exist in Scotland's five-year-old age group. The literature review suggests that it is very difficult to achieve improvements in (dental) health and at the same time make inroads towards improvement in dental health inequalities. It would thus seem remiss to have carried out caries inequalities testing without furnishing the 'richer-picture' of the changing environment and epidemiology made available to this research via the aforementioned case-studies.

2.2 The research questions

2.2.1 Caries outcomes at the NHS Scotland level

Q1. What are the longitudinal trends in five-year-olds' dental caries experience and the socio-economic dental caries inequalities across NHS Scotland between 1993-2007?
Null hypothesis 1: there is no change in dental caries experience or SES dental caries inequalities in Scotland as a whole during the period.

2.2.2 Caries outcomes at the NHS Scotland level, excluding Greater Glasgow (GGHB)

Q2. At the NHS Scotland level excluding NHS Greater Glasgow (GGHB), what are the trends in five-year-olds' dental caries experience and what are the socio-economic dental caries inequalities between 1993-2007?

Null hypothesis 2: there is no change in dental caries experience nor in dental caries inequalities of five-year-olds at the Scotland minus GGHB level, during this period.

Q3. If any change is apparent, is the direction, magnitude and timing the same as that occurring in Scotland as a whole?

Null hypothesis 3: There are no differences in dental carries experience or in dental caries inequalities with respect to direction, magnitude and timing comparing Scotland without GGHB to the whole of Scotland.

2.2.3 Caries outcomes at NHS GGHB level

Q4. What are the longitudinal trends in dental caries experience in five-year-olds in Greater Glasgow from 1993-2007, and do these differ by socio-economic group.
Null hypothesis 4: There is no evidence of any changes in dental caries experience among NHS Greater Glasgow five-year-olds across the time period 1993-2007.

2.2.4 Geographic and temporal relationships

Q5. What is the chronological relationship between changes in dental caries experience and dental caries inequalities in the five-year-old age group when NHS Scotland minus GGHB is compared to GGHB alone?
Null Hypothesis 5: There is no difference in timing of trends in dental caries experience and dental health inequalities in Scotland without GGHB compared to GGHB alone.

Q6. Does GGHB area have an excess burden of poor dental health in five-year-olds' ($d_3$mft>0) compared to the rest of Scotland i.e. is there evidence of geographic inequality in dental caries.
Null hypothesis 6: There is no difference in dental caries experience at Scotland level compared to GGHB. Therefore, there is no geographic inequality.

2.2.5 The utility of the tests for inequality

Q7. Compared to the standard metrics for assessing dental caries trends, outcomes and inequality, do the selected additional tests of health inequality and dental caries inequality which are identified in the literature provide additional understanding of whole population and socio-economic trend?

Null hypothesis 7: the selected additional tests for health inequality and dental caries inequality add nothing to understanding of dental health inequality.

Chapter 3

3 The environmental context: evolution of Dental Health Promotion programmes in Glasgow and Scotland

3.1 Introduction and context

In this thesis, caries data from the geographic area of Scotland and the subgroups Glasgow and the rest of Scotland (i.e. Not-Glasgow) will be used to investigate and model SES and geographic inequality in five-year-olds' dental health against a background of rapid changes in caries epidemiology over the later part of the period from 1993/04-2007/08.

The literature review indicates that health inequality outcomes are dictated to some extent by the nature and design of intervention programmes. Thus, the detail and complexity of the dental health improvement programmes which developed in Glasgow from 1996 and in Scotland from 2000 will now be outlined. These programmes gave rise to a very different paradigm from that which had operated previously in Scotland. This section will first use the Glasgow programme as a case-study example and will proceed to consider the evolving *Childsmile* programme. These case-studies will illustrate some of the difficulties exposed in the literature review related to study design / effectiveness / evaluation trade-offs in inequalities intervention / outcome research. Furthermore, these will provide the platform for the later caries epidemiology and inequalities trend analyses related to the dynamics arising from two 'real' dental health improvement contexts.

3.2 Background

A *Pre-Five-Year-Old Oral Health Gain Project* was commissioned by Greater Glasgow Health Board (GGHB) in 1996 as a response to the publication of *Scotland's Health A Challenge to Us All, The Oral Health Strategy for Scotland* (The Scottish Office, 1995). The author of this thesis was appointed as project leader and subsequently recruited Glasgow's first Oral Health Facilitator for the initial pilot district. A multidisciplinary project steering group scrutinised and endorsed the project leader's proposals for interventions in the pilot community. A detailed account of the resulting programme activities and short-term dental health outcomes has been described previously (Blair *et al.*, 2004 & 2006).

3.3 Aim and objectives

The overall aim of GGHB's locally-based *Pre-Five-Year-Old Oral Health Gain Project* was:

> "To inform future strategy for caries prevention among pre-five-year-olds living in socio-economically challenging life circumstances in GGHB."
> (Greater Glasgow Health Board, 1999).

3.3.1 Identification of a pilot intervention area

In 1994, Consultant Paediatricians from the Royal Hospital for Sick Children, Yorkhill, involved in child health and development outreach clinics into socio-economically deprived districts of Glasgow reported anecdotal observation of noticeably poorer dental health among young children residing in the Possilpark community, when compared to other similarly deprived districts (Greater Glasgow Health Board, 1999 & 2001). Resultant epidemiological studies among pre-school children within the district (examined by YB, early 1995, before any intervention programme was envisioned) confirmed the Paediatricians' subjective impression (Sweeney & Gelbier, 1999). The exceptionally high prevalence of severe dental caries e.g. at age 48-59 months, 17% with $d_3$mft=0 and mean $d_3$mft 5.9 (95% CI 5.1-6.8) justified the later selection of the G22 postcode sector (which included Possilpark) as the pilot intervention district (Blair *et al.*, 2004).

3.4 Initial dental health needs assessment

Formative work in the pilot community involved: a programme of dental health needs assessment, establishment of a widespread communications network and area-mapping of the local social, private and public services, amenities and infrastructure. This phase utilised information from the earlier caries epidemiology studies, later described by Sweeney & Gelbier (1999). Within an overall framework of 'Partnership Working', *de novo* work strands included quantitative questionnaires (Blair, 1997), focus groups, interviews with key contacts, briefing and debriefing of the local Community Health Project's lay health workers and volunteers and one-to-one discussions with local opinion formers and parents/carers (Blair, 2001).

3.4.1 Geographic profiling of community resources for health

Official sub-districts recognised by local government e.g. electoral wards, priority regeneration areas and '*community-felt*' neighbourhoods were identified and plotted onto maps alongside transport routes to food shops, pre-five services, medical/dental primary care services, community centres, libraries, churches, charitable and voluntary sector projects etc. and by these means potential settings for Oral Health Promotion were identified.

3.4.2 Demography

Further, contemporary resources e.g. *Possilpark initiative Area, Local Economic Digest* (Duncanson, 1994) and Ward Profiles 1995 (Hayes, 1996) informed the project about local and relative (compared to Glasgow averages) demographic factors of relevance e.g. gender balance, family structure, housing profile, education, provision of social support and benefits, employment, health related behaviours, morbidity, mortality and socio-economic composition of the area etc. and contributed to the formation of a '*rich-picture*' of locality-based information and understanding of the community's knowledge, skills, hopes and aspirations for their families, environment, education, health and well-being.

3.5 Study design

3.5.1 Translational research

The author (YB) developed and implemented the interventions and devised the monitoring arrangements and the evaluation strategy, within available resources. No ring-fenced funding was available for evaluation.

Interventions were based on translation, synthesis and integration of previous primary scientific research in the field of caries prevention, applied within an ecological Community Development-based framework.

3.5.2 An ecological whole population approach

The ecological study design evolved a complex superimposed matrix of novel Health Promotion interventions, which emanated from the *Scientific Basis of Dental Health Education* (Levine, 1996) and sought to involve the whole community in interventions aimed to improve the dental health of their cohort of pre-five-year olds (Blair, 2001). Implementation of the translational research proceeded in an incremental manner, at a pace acceptable to the community and was based on the following founding tenets: i) the Ottawa Charter for Health Promotion (WHO, 1986), ii) the Settings (Nutbeam, 1998a; Whitelaw *et al.,* 2001), iii) Community Development (Abelin, *et al.,* 1988; Cornwall & Jewkes, 1995; Ewles & Simnett, 1999; Pyett, 2002; Paulo, 2003; Baum *et* *al.,* 2006; Popay, 2006; Beresford, 2007) and iv) the Common Risk-Factor (Sheiham, 1995; Small, 2000; Department of Health, 2005a; Watt, 2007) approaches.

3.5.3 Matched and contrasting control populations

At the outset, two non-intervention areas were identified to act as controls. One control community comprised a socio-economically matched area located in the East-end of Glasgow containing the G33 postcode sector, whilst a contrasting comparatively affluent West-end control area was located in the G11 and G12 postcode sectors (Blair, 1997).

3.5.4 The recruitment of community partners

Within a 'Partnership Working' approach (Asthana *et al.,* 2002; Walter *et al.,* 2003), those who were recruited by the project leader to establish programme development, implementation and sustainability included local parents, carers and older siblings, community volunteers, lay representatives, the statutory agencies, charities, community projects, a food co-operative for the unemployed and the local business sector. Additionally, more formal collaborative relationships were established with local General Dental Practitioners and their staff, Health Visitors, the Community Dietician, Pharmacists, Medical Practitioners and practice staff and personnel from the pre-five nursery and school-based sectors (Greater Glasgow Health Board, 1999; Blair *et al.,* 2004).

3.5.5 The settings

A holistic whole-population approach was used within the initial programme in G22 (Possilpark) and latterly in the former matched control area (East-end). Some of the Health Promotion settings adopted included: the community, health centre and clinics, general medical and dental practices, schools, nurseries, pre-fives' groups and crèches, churches, community centres, health fairs, street markets, seminar days, opportunistic one-to-one situations, community projects, civic processions and libraries etc. extending into municipal spaces outside the district. Media publicity within and beyond the target district about community involvement in the above settings helped to develop the community's own confidence in their efforts and became a positive feedback-loop, which thereby reinforced and sustained the project activity.

3.5.6 Community Development

As Community Development (CD) has the potential to influence social and cultural factors within districts (Adams *et al.,* 2007) and both are determinants of health and wellbeing of residents (Baum & Palmer, 2002; Popay *et al.,* 2003), CD approaches were utilised to build community capacity. This provided an acceptable platform for skill-development in the pilot community. The OHP programme fairly quickly became recognised as a dynamic responsive community-based project, due to an early commitment from the staff to work within a common-risk factor approach and to share the community's own agendas. Salutogenic approaches and linking of healthful behaviours were supported and enabled by the relatively modest annual OHP budget of £10K per annum. A widespread range of non-stigmatising events and activities developed with the community achieved wide-reach into the district's *community-felt* neighbourhoods and groups. Many local residents identified themselves with local settings and geographic sub-districts.

3.5.6.1 To disseminate knowledge outside the professional domain

Baseline caries epidemiological findings from the dental health needs assessment described absolute and relative prevalence of $d_3$mft within the whole pilot area compared to contemporary published Glasgow averages. Previously these data would have been available only to oral health professionals. Sharing this information (and its interpretation) with the community motivated a district-wide desire to know how to prevent the excess dental morbidity experienced by their children. This was summarised by one resident with words to the following effect:

> "We always knew that kids' dental health (in Scotland) was really bad, but we didn't know that it was so much worse in Possil(park) than in other parts of Glasgow. This is terrible. People will think that we don't love our kids. What do they do in other places? We need to do something about this." (A mother in Possilpark, 1996)

3.5.6.2 To overcome fatalist beliefs

Previously in the area 'fatalist' feelings about children's dental health were widespread and the following sentiments were common community-held lay beliefs to explain children's poor dental health experience:

> "It is not my fault. There was nothing I could do about it. His (*her*) teeth were all bad when they grew in. I didn't have enough calcium when I was carrying him (*her*)" (Mothers in Possilpark, 1996)

> "I caught the pyorrhoea when I fell (*pregnant*) wae him (*her*). I had tae huv all ma own teeth out and I think it affected him (*her*) too." (Mothers in Possilpark, 1996)

> "Its just yer Donald if ye get good teeth or bad (teeth)." [Translation: Donald=Donald Duck=luck] (A Father in Possilpark, 1996)

Notwithstanding this, throughout the district a strong emotionally-influenced community momentum developed that something had to be done. However, at the outset the community were at a loss to know what they could do, and indeed should do, to support their children's dental health. They expressed lack of control, powerlessness and were of the belief that it would only be the actions of significant others (i.e. the dentist) which could make a difference to their children' dental health.

The single most important Community Development task undertaken was to educate and convince all those in regular day-to-day contact with infants and young children that the cumulative effect of small modifications in everyday living held the potential to bring about dental health improvement for rising cohorts.

3.5.6.3 To promote lay understanding of the scientific evidence-based consensus

To this end, copies of the *Scientific Basis of Dental Health Education* (Levine, 1996) and *Scotland's Health A Challenge to Us All, The Oral Health Strategy for Scotland* (The Scottish Office, 1995) were widely distributed to agencies and individuals throughout the district. Seminar days, group and one-to-one discussions explained the related scientific consensus, translated the science into everyday examples which could be readily understood and helped individuals and groups to identify potential areas for action in their daily lives. The potential, feasibility and acceptability of many small salutogenic modifications in local lifestyles and behaviour to contribute towards improved dental health outcomes were explored with the community.

3.5.6.4 To seed 'Partnership Working' in the community

Partnership Working (PW) was formally re-introduced to the NHS in Scotland as a method of avoiding conflicts associated with internal change (The Scottish Office, 1998) although its foundations are rooted early in the NHS (Scottish Government, 2008). In the foregoing context, the author of this thesis had received 'train the trainer' training in PW and had experience as part of a team delivering Organisational Development in NHS Greater Glasgow Primary Care Trust during the mid-1990s using the PW approach. However, PW is now widely recognised and endorsed for its potential contribution to capacity building and community planning (Scottish Executive, 2002). Thus, a discoursive participatory PW methodology was used throughout the OHP programme. It was adopted in recognition that the community were (*at least*) equal partners, to maintain flexibility and pragmatism, as it is characterised by a culture of information sharing, fully-informed participation, honesty, no hidden agendas, equal respect for all views and all participants during the process, the sharing of agendas and a recognition that mutuality, agreement, collaboration and shared ownership are the best (*only*) way to bring about (*any*) sustainable change.

3.5.6.5 To alter the dynamics of initiation of interventions

Nevertheless, in the initial stages the drivers for change were the OHP programme staff. However, as community self-confidence in their own ability to make decisions for their children's dental health increased, local people became more pro-active and increasingly used the staff as their 'touch-stones' and a potential source of funding and support for their own initiatives.

3.5.7 The Ottawa Charter

Following the principles of the Ottawa Charter for Health Promotion the community were sufficiently informed, enabled, empowered and motivated to eventually identify their own risk-reduction opportunities and to suggest modifications to community behaviours and working practices within the district. Several members of the local community emerged to become '*lay champions*' for oral health, transcending from co-operative collaborators to initiators and community advocates for (dental) health improvement. Notwithstanding this, their endorsement of the project's aims and objectives and of the *bona fides* of individual project staff was pivotal to community acceptance. The project leader subsequently managed the budget and staff which became the flexible resource of the community. Local people shared responsibility for their own community's (oral) health.

3.6 Examples of some selected translational '*evidence-based*' Dental Health Promotion interventions

Particular interventions cross-fertilised each other within the project. Many formed discrete salutogenic mini-programmes aimed to modify specific and general caries-risk by reducing risk-factors and promoting caries preventing-factors, from birth, by supporting '*translational activities*' i.e. the 'Baby Club' (*parenting class*); promotion of breast feeding; healthy weaning practice; use of a bi-daily smear of fluoride dentifrice 1000ppm F^- from the time of earliest eruption; the 'Ask for Sugar-free medicine' campaign; the 'Change-to-cup' scheme; promotion of 'safe' drinks i.e. plain milk and water; development and implementation of agreed snack and meal policies in childcare settings which aimed as far as possible to reduce frequency of consumption of non-milk extrinsic sugars (NMES); promotion of early dental registration and regular dental attendance via the 'Friendly Dentist Scheme'; sustained distribution of free NaF dentifrice (500ppm during 1996/97 rising to 1000ppm, routinely, from 1997) with age-appropriate toothbrushes for home use by infants and siblings and in other child-settings; regular daily tooth brushing programmes with adult supervision in nurseries and elementary schools; establishment of school Breakfast Clubs; free-fruit via regular distribution schemes; community food-tasting sessions; 'get-cooking classes'; arts and crafts activities themed on dental health and nutrition; community health fairs and deliberate cultivation of 'up-beat' positive local press and media coverage of oral health project activities etc. (Blair *et al.,* 2004).

3.7 Initial programme evaluation–process outcomes

There was uncertainty whether measurable dental health outcomes would be produced within the initial timeframe available (4 years). A wide variety of project activity and process measures were recorded, as advocated by other researchers (Croucher, 1997) and their nature was assessed against the principles within the Scientific Basis of Dental Health Education (Levine, 1996), the Ottawa Charter for Health Promotion (World Health Organisation, 1986) and the areas for action suggested by Sheiham (1995). These process-based outcomes were summarised by Greater Glasgow Health Board (1999) and Blair *et al.* (2004).

3.8 Active dissemination

3.8.1 Early dissemination-planned process

A first formal process and early outcomes Interim Report of the Pre-Five-Year-Old Oral Health Gain Project, Possilpark (Greater Glasgow Health Board, 1999) was substantially written by this author (YB) and submitted on behalf of the steering group to NHS Greater Glasgow Health Board for its formal consideration, as part of the required process to secure ongoing funding. Over and above, the epidemiological results following two-years of interventions were designed to show whether there was any change in morbidity compared to baseline.

3.8.2 Further process at the community level

A community event was held in Possilpark to mark publication of the final four-year pilot project report and to disseminate it simultaneously within the pilot district and to

GGHB. An experienced Nursery Head Teacher was given the opportunity to address the assembled stakeholders:

> "…….before the project started all the children had no (*anterior*) teeth or their teeth were all black. Now the (*nursery*) children have nice teeth…………" (Forrest, 2001).

The endorsement of such influential people from within the local community to an audience with included the Chairman of the NHS Primary Care Trust, helped to create and sustain the favourable climate for the extension of the interventions.

3.8.3 Early dissemination-unplanned process

Positive messages about the widespread acceptability, community involvement and epidemiological outcomes after just two years in the G22 pilot district's pre-five-year olds' were disseminated by the Phase 1 study community to the matched control area via Glasgow's lay activist networks e.g. the *Healthy Cities* network (Mittlemark, 2001; Breuer, 2002; Planum, 2002). This encouraged advocates in the matched control area to commence informal health promoting activities, themselves, and to actively lobby GGHB for the same resources as allocated to the original pilot area's community.

3.9 A phase-2 intervention study is commissioned (the political decision to abolish the control area)

The representations of activists from the matched control population combined with the first project report, which outlined early outcomes, persuaded a formal Greater Glasgow NHS Board meeting to officially abolish the East-end G33 district's status as the matched control area from early 1999, on the grounds that it would be unethical to further withhold (*beneficial*) interventions from this matched SES population (Blair *et al.*, 2004 & 2006). Political pressures of this type are not unknown (Sanson-Fisher *et al.*, 2007). The project leader interviewed and recruited the second Oral Health Facilitator (initially, on a seconded basis from the Community Dental Service) to similarly engage in Community Development, under supervision, in this phase-2 project intervention district.

3.10 Caries Epidemiology: evaluation (at small area level)

Throughout the *Pre-Five-Year-Old Oral Health Gain Project,* and later, caries epidemiology studies were undertaken in the initial intervention and control areas. This involved specially commissioned studies amongst pre-five-year-olds, until 1999/2000, which have been published previously (Sweeney & Gelbier, 1999; Blair *et al.*, 2004).

Furthermore, the routine biennial SHBDEP and NDIP programmes produced caries prevalence information for Glasgow's five-year-olds. Data extracts for specific postcode sectors of interest provided further information about the age group's epidemiology (Blair *et al.,* 2006). These studies were essential components of a final formal project report presented to the NHS Board on expiry of the GGHB pilot '*project*' funding (Greater Glasgow Health Board, 2001).

3.11 Influencing strategy to ensure intermediate sustainability

3.11.1 Local

In 1999/2000, representations and evidence of infants' temporal caries trends in the pilot intervention districts compared to the P1 five-year-olds' trends in Glasgow, as a whole, over the study period were presented by this author and the Consultants in Dental Public Health. Together, they successfully influenced a review of the Community Dental Service in NHS Greater Glasgow (Greater Glasgow Primary Care NHS Trust, 2000) chaired by a high profile Professor of Public Health, with an international reputation.

In turn, the report of this review group persuaded GGHB that the strategy developed by the *Pre-Five-Year-Old Oral Health Gain Project* had the potential to bring about improvements in infants' dental health beyond the geographic boundaries of the pilot G22 (North Glasgow) and G33 (East-end) districts. Oral Health Action Teams (OHATs) were to be newly created and were the selected vehicle to '*roll-out'* project interventions to cover eventually the whole geographic area of Greater Glasgow NHS Board.

3.12 Creation of the Oral Health Action Teams (OHATs)

Each geographic unit of primary care administration in the GGHB area (i.e. Local Health Care Co-operatives, LHCC, n=16) was funded via an implementation plan (Greater Glasgow Primary Care NHS Trust, 2000) to establish an Oral Health Action Team (OHAT) to extend the programme methodology. The initial priority was to extend to all of the remaining severely deprived neighbourhoods (GGHB, 2001 DepCat 7 population *c.* n=287,600 p.a., birth rate *c.* 3450 p.a.), prioritised by SES deprivation and the respective magnitudes of the LHCC's resident child populations. Thereafter, the OHAT model extended to encompass all LHCCs in the GGHB area. By 2001/2002 the majority the DepCat 7 neighbourhoods in GGHB had an active OHAT, with final implementation of the programme-roll-out completed to remaining LHCCs (total OHATs, n=15) by 2003/2004 (NHS Greater Glasgow, 2005).

3.13 Longer term assessment of OHATs outcomes

The author (YB) collaboratively conducted two formal evaluations to assess the ongoing Health Promotion strategy (NHS Greater Glasgow, 2005; Blair *et al.,* 2006). The complex evaluation framework originally posited by Nutbeam (1998b) and subsequently adapted for Oral Health Promotion programmes by Watt *et al.* (2001) was adopted.

3.14 Further occurrences which safeguarded sustainability

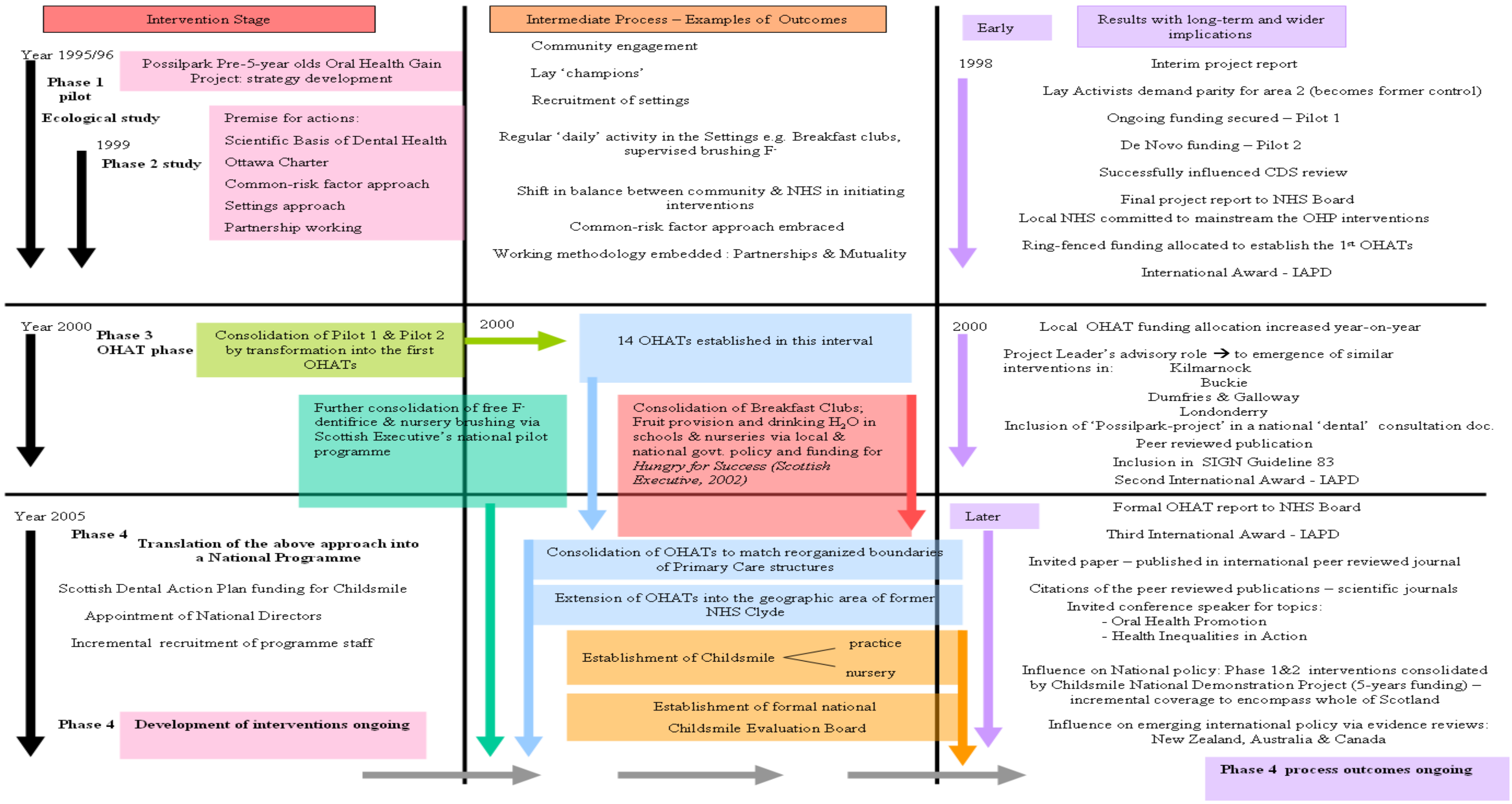
3.14.1 Local

The above OHAT (2005) evaluation report (substantially prepared by the author) was submitted by the Monitoring and Evaluation Subgroup of the OHAT Steering Group to Glasgow's NHS Board and was subsequently published and distributed to other NHS organisations (NHS Greater Glasgow, 2005). Figure 3-1 illustrates the programme processes and further narrative description follows. Following a reorganisation of the NHS in Scotland (April, 2006), the OHATs process continues to be operational in GGHB. To this day, OHATs continue to operate via the units of primary care administration which replaced the LHCCs i.e. the Community Health (*and Social Care*) Partnerships (CH(C)Ps, initially, n=10, now n=7, following a further reorganisation) encompassing the geographic area of former NHSGG and the Clyde part of former NHS Argyll & Clyde.

3.14.2 National

The author (YB) responded to the Scottish Government's consultation exercise in 2002 following publication of *Towards Better Oral Health in Children* (Scottish Executive, 2002a) outlining the approaches and health outcomes that were temporally associated with implementation of Oral Health Promotion in Glasgow. The resultant 'Scottish Dental Action Plan' (Scottish Executive, 2005b) and the consequent *Childsmile* programme, through its *Childsmile* Core and *Childsmile* Practice activities has carried forward, and further built upon the ethos and interventions developed within the original Pre-Five-Year-Old Oral Health Gain Project (colloquially known as the Possilpark Project) e.g. through the novel skill mix, and the staged interventions described on the *Childsmile* website (Accessed 20/07/2010: http://www.child-smile.org.uk) and via both universal and directed population distributions across Scotland of 1000ppm fluoride dentifrice, and supervised toothbrushing programmes (Macpherson *et al.*, 2008; Shaw *et al.*, 2009; Macpherson *et al.*, 2010).

Figure 3-1: Process map showing intervention stage, intermediate outcomes and results with longer term and wider implications



3.14.2.1 High-level endorsement

The Chief Dental Officer for Scotland commented:

> "……the community-based, Possil Park programme; what we are looking at here is community-based support or development-based programmes. These types of programmes have worked extremely well in the pilot sites."
> (Watkins, 2004).

This was an important step towards ensuring sustainability, as at the time, there were powerful professional lobbying groups still advocating 'medical model' approaches to solve the general caries problem across Scotland's child population.

3.14.2.2 Incorporation into a Scottish Evidence Review

A later endorsement, which continues to be influential, emanates from inclusion of the peer reviewed paper (Blair *et al.*, 2004) in the recommendations contained in the NHS Quality Improvement Scotland Report, SIGN 83, *Prevention and management of dental decay in the pre-school child* (Scottish Intercollegiate Guidelines Network, 2005).

3.14.2.3 Incorporation into *Childsmile*

In addition, the published methodologies in the 2004 and 2006 scientific papers have been specifically endorsed as being components of NHS Scotland's *Childsmile* National Demonstration Programme forming part of the:

> "well documented evidence-base and history to the development of the particular interventions which comprise *Childsmile*" (Shaw *et al.*, 2009).

These types of approval by policy makers, peers and authoritative bodies are particularly important during the ongoing competitive processes for NHS resource allocation.

3.14.3 External critical appraisal

The author (YB) has regularly acceded to requests to provide further information on this OHP work to colleagues overseas. The '*Possilpark*' type of approach appears to be considered promising by policy makers further afield, in evidence reviews related to promoting oral health carried out in e.g. Canada (BC Ministry of Health, 2006), New Zealand (Ministry of Health, 2008) and Australia (Satur *et al*., 2010). It will be important to continue to publish ongoing findings in the international literature. It has not yet been necessary to reference the international support to secure Scottish funding for the

Scottish OHP programmes' continuation, to date. However, in the face of contemporary financial pressures, it may well become important in the future. The advantages of having external critical appraisal and peer review have been described (Bailar & Patterson, 1985; Kassirer & Campion, 1994; Scottish Intercollegiate Guidelines Network, 2004).

3.14.4 Developments further afield

The pilot work for the national prevention programme which preceded *Childsmile* was substantially influenced by the community level interventions described earlier in this chapter and the evaluations of temporal caries epidemiological outcomes in Glasgow's pre-five and five-year-olds. The success of the national toothbrushing pilot programme funded from 2000 and with lead-time established from 2001/02 in various regions of Scotland, gave policy makers and funders sufficient confidence to consider that other aspects of the Glasgow '*Possilpark project'* had potential to contribute to Scotland's national strategy for dental health improvement. Full funding for the *Childsmile* Programme commenced from 2006, for a five year period, in the first instance. This has led to expansion of Community Development, Ottawa Charter and Partnership Working as the underpinning ethos of Scotland's national OHP programme. At the time of writing, Scottish Government funding for the national *Childsmile* programme development, implementation and evaluation continues unabated.

3.15 The *Childsmile* Programme (Scotland's National Oral Health Demonstration Programme)

The development of National Health Demonstration Projects (NHDPs) in Scotland commenced following publication of a White Paper *Towards a Healthier Scotland* (The Scottish Executive, 1999). The Scottish Executive provided funding, initially, for a pilot programme to establish and evaluate a national programme: a) to distribute free fluoride toothpaste and brushes to all eight-month-old children in Scotland, b) to undertake sustained targeted distributions to high-risk children aged one-to three years of age and c) to implement daily supervised nursery toothbrushing programmes in pre-fives establishments (Naven & Macpherson, 2006). From 2005, child dental health was formally added to the portfolio of topics supported for NHDPs. The purpose of the NHDPs was to act as a test-bed for interventions and to become established as a learning resource for Scotland, by combining best evidence on existing good practice with innovation. Funding for the *Childsmile* programme was initiated by publication of the '*Scottish Dental Action Plan'* (Scottish Executive, 2005b) with the aims of improving oral health of children, reducing inequalities in dental health and in access to dental services by adoption of a new paradigm of anticipatory care and OHP from infancy (Macpherson *et al.*, 2010).

The above free F^- dentifrice distribution and supported nursery toothbrushing programmes progressed to become known as the *Childsmile Core Programme*. This is the universal OHP intervention which provides the national nursery and school toothbrushing programmes for all children up to age six years across Scotland (Macpherson *et al.*, 2010). From 2006, two further *Childsmile* demonstration programmes were established, one in the East of Scotland and one in the West (Macpherson *et al.*, 2010). The West programme was established to target children from birth for OHP in General Dental Practice (GDP), Salaried GDP and community settings. The East programme aimed to deliver additional clinical prevention (fluoride varnish applications) via Salaried Services and was aimed at children of three years of age, and above, attending prioritised targeted nursery and primary school settings. Programmes were expected to evolve in response to monitoring, evaluation and community feedback. In 2008, these programmes were redefined as four interconnected elements to deliver both targeted and universal population based approaches. The four elements are known as: *Childsmile Practice*, *Childsmile Nursery*, *Childsmile School* and *Childsmile Core*. These elements were rolled out across Scotland from the following year to provide fully integrated OHP to support children from infancy and each will be described further (Macpherson *et al.*, 2010).

3.15.1 Childsmile Practice

The published aims for Childsmile Practice were initially a) to build formal links between primary dental care services and public health nurses/health visitors (HVs); b) to raise parents' awareness to support development of good oral health behaviours for their children and c) to promote the provision of OHP and clinical prevention in the GDP setting (Macpherson *et al.*, 2010).

During the initial demonstration phase HVs used a *'Caries Risk Assessment Protocol'* with families to assist in identification of infants aged 11 days to eight weeks-old, who were considered at increased risk of developing caries [this type of HV assessment had previously been a component of a caries prediction model explored in Dundee (MacRitchie *et al.*, 2011)]. Subject to parental consent, families of these 'at-risk' infants were referred by their HV to Dental Health Support Workers (DHSWs) who form part of the *Childsmile* extended skills workforce. The *Childsmile* programme developed an intervention framework for identified points in children's life-course with all appropriate OHP laid out in a '*Care Manual*' specially prepared for the DHSWs and novel Extended Duties Dental Nurses (EDDNs). The DHSWs liaise closely with HV colleagues and visit a child's home soon after birth. They are key to providing a focused community-based OHP service, customised to the needs of the child and family.

As appropriate, parents are facilitated to attend primary care dental practice where extended duties *Childsmile* trained EDDNs deliver OHP advice to parents commencing from the point when their child is *circa* three months old. Depending on family circumstances, for the *'hard to reach'* the OHP may alternatively be delivered by the novel skill-mix (DHSWs) in the home setting. Since 2006, *Childsmile* explicitly commences with a HV mediated introduction to *Childsmile* in the family setting a few days *'from birth'* and has the ability to vary the intensity of interventions and settings for *Childsmile* programme delivery according to the needs of individual children (Scottish Dental Clinical Effectiveness Programme, 2010; Macpherson *et al.*, 2010). Furthermore the DHSWs link families to other community activities as part of a '*common risk factor'* approach e.g. weaning fairs, cooking on a budget and food co-operatives.

All GDP practices in *Childsmile* areas are invited to join the programme and those who accept are provided with central support i.e. guidance, training and finance. *Childsmile Practice* payments, over and above NHS payments, cover day-release of staff, training costs, backfill, travel etc. Furthermore, an enhanced capitation payment is payable for each *Childsmile* child registered. The DHSWs encourage families to attend GDP services when the child is about six-months-old, with recall appointments at not less than six monthly intervals. *Childsmile* sessions with the EDDN include dietary advice, toothbrushing demonstration and clinical prevention, as appropriate. Families with greater need receive longer or more frequent appointments and fluoride varnish applied by the *Childsmile* EDDN.

3.15.2 Childsmile Nursery and School

Childsmile Nursery and *Childsmile School* provide clinical preventive interventions in priority nurseries and schools i.e. the 20% of nurseries and primary schools with the highest proportion of children living in the most deprived local quintile of postcode areas, identified by SIMD (2009). These programme elements aim a) to improve the oral health of children who would benefit most from preventive care, b) to promote awareness about sound oral health to help bring about positive behaviour change in children and c) to facilitate those in most need of further dental care to receive it. To this end, Salaried Service's EDDNs apply twice yearly fluoride varnish (FV) in these settings. Systematic reviews suggest FV therapy is effective in preventing caries (Marinho *et al.*, 2003b; Petersson *et al.*, 2004). Furthermore, additional F^- from FV, over and above that from dentifrice, is considered to confer additional anti-caries benefit compared to F^- from dentifrice alone (Whelton & O'Mullane, 2001; Marinho *et al.*, 2009). Children in these settings are further helped to become registered with a dentist where they may receive two additional applications of FV per annum. It is the school and nursery settings which are thus targeted in this programme element and all attending children are offered the FV intervention. These *Childsmile* elements are supported by a robust basic medical history taking and consent process.

3.15.3 Childsmile Core

The *Childsmile Core* element represents the Scottish Executive's National toothpaste/toothbrushing scheme described earlier. This now involves every child in Scotland receiving toothpaste/toothbrush packs on at least six occasions during their first five years, along with the offer of free daily supervised toothbrushing for every three- and four-year-old attending nursery in Scotland. Moreover, this toothbrushing programme is available to P1 and P2 children in SES disadvantaged areas in each NHS Board area. National standards govern this activity and a national procurement of supplies is in place to support *Childsmile Core*.

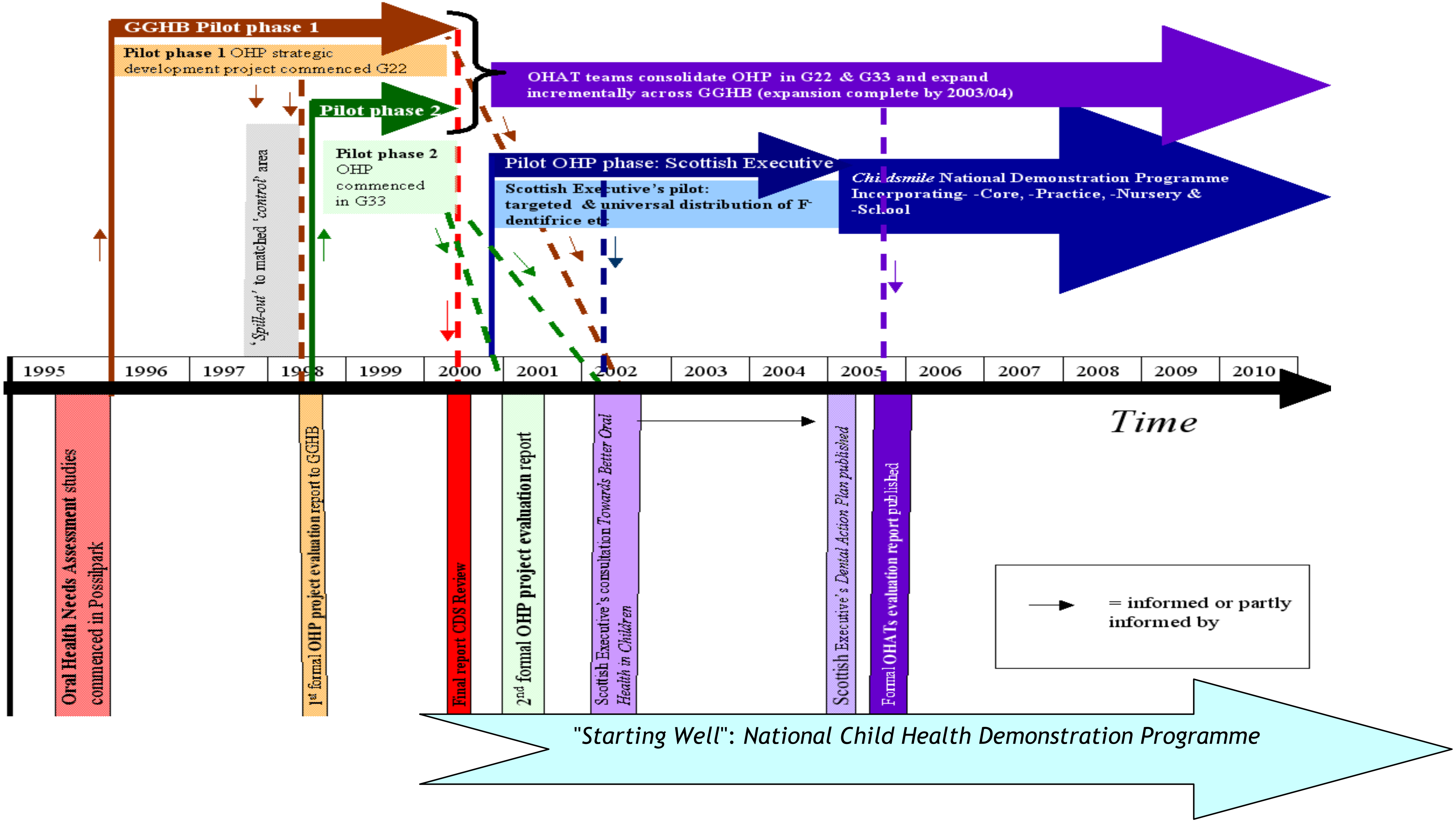
3.15.4 On-going development of Childsmile

To date, evolution of the four programme elements continues, as new child cohorts are enrolled. An important modification has been that the *Childsmile Practice* element has now become a universal programme component, with all new-born children being offered enrolment into the programme at the statutory first visit from their Health Visitor. Nevertheless, the intensity of OHP interventions is varied to meet the needs of individual *Childsmile* children, with those most '*at risk*' receiving the most intensive support (i.e. '*proportionate universalism*'). The expansion of staff recruitment and their development is supported nationally. Furthermore, the *Childsmile Care Manual* has been reviewed and revised and E-informatics developments, monitoring, evaluation and website development continue apace.

3.16 Conclusion to this chapter

The socio-political and geographic contexts contributing to this thesis is unusually complex. This chapter began by outlining the establishment of NHS Glasgow's original strategic development project, prior to the subsequent programme of development in Glasgow (effectively a progression of incremental process evaluations). From 2000, the Scottish Executive (latterly the Scottish Government) formalised and supported extension and development of many aspects of the earlier NHS GGHB *Possilpark Project*. The *Childsmile* resource streams for Glasgow are complementary to the funding streams to CHPs to support their local OHAT activities. It will possibly be helpful for readers to view the illustration in Figure 3-2, which shows the relative timings of some of the various events and the inherent complexities, to the extent that they can be readily shown. Within some small areas e.g. Possilpark, Glasgow, further sub-strata of interventions occurred and these have already been more fully described. This type of deliberate multi-layering has since been advocated (e.g. Marmot *et al.*, 2010).

Figure 3-2: Time-line illustrating the commencement and over-layering of respective OHP intervention programmes initiated in Glasgow (GGHB) and in Scotland



3.16.1 Caveat

Coinciding with the publication of Scotland's *'Oral Health Strategy*' (The Scottish Office, 1995), '*pump-priming'* funding was injected into all NHS Board areas to improve children's dental health. In this section there has been great emphasis on the OHP developments in Glasgow between 1995 and 2005. However, it must be acknowledged here that there were novel concurrent Dental Health Improvement programmes in the other NHS Board areas e.g. in Lanarkshire a nursery toothbrushing programme commenced from *circa* 1996 and in Tayside NHS Board (TNHSB) area: a) a substantial proportion of the NHS Board area's 1993-1994 birth cohort were recruited into the Dundee Caries Risk Model (DCRM) programme for pre-school children (Ballantyne-MacRitchie, 2000; Ballantyne-MacRitchie, 2011); b) there may have been trickle-down (commencing in 1997) from a targeted supervised five-year-olds' fluoride toothbrushing RCT with 1000ppm F^- in SES deprived schools (Pine *et al*., 2000; Curnow *et al*., 2002) and c) the 'GETCaPPP' *Generalisable Evidence-Based Targeted Caries Prevention for Pre-School Children by Integrated Primary Care Teams* (Pitts *et al*., 2005) was implemented from 1999. In common with the GGHB programme, community empowerment was a feature of the TNHSB toothbrushing project. However, reportedly, that work did not simultaneously embrace the *'common risk factor approach' (*Pine, 2004). Nevertheless, these were the precursors to the Tayside Oral Health Strategy i.e. an integrated NHS OHP programme implemented from 2002 (Heggie *et al*., 2000; Merrett, 2005). With the exception of these projects and those in three disparate small geographic areas, which had made approaches to the *Possilpark* project team for information and to seek support to set up similarly structured OHP to that in GGHB, for the most part, other programmes in Scotland were rooted in more conventional DHE, prior to the initiation of *Childsmile*. The projects which 'seeded' from the *Possilpark* programme were, namely, the Buckie, Kilmarnock and Dumfries and Galloway OHP programmes. There is nothing in Scotland of which the GGHB team are aware, beyond the above programmes which developed independently along similar lines. Nevertheless, as already suggested, the *Childsmile* Pilot and the *Childsmile* NHDP began to fund and disseminate a new paradigm for Scotland from 2000 and 2006, respectively.

3.16.2 Forthcoming methods chapters

In the two methodological chapters which follow there will be respective descriptions of: i) the epidemiological methodology used in the dental health outcomes assessments, prior to ii) a description of the tests of dental health inequalities applied to the dental health outcomes data.

Chapter 4

4 Caries Epidemiology (Methods 1)

4.1 Background to the five-year-olds' caries data (Glasgow and Scotland 1987-2011)

4.1.1 The author's involvement

The author has had lengthy experience and direct involvement in the SHBDEP and NDIP programmes in Greater Glasgow, having participated as a trained and calibrated examiner in the first SHBDEP survey (1987) and maintained regular '*hands-on*' involvement in dental surveys to the present date. Furthermore, notwithstanding the above, the author accepted the role of NDIP Co-ordinator for the NHS Board, commencing related additional duties from the first NDIP survey in 2002. This role has involved determining annually the caries survey samples, training staff dental teams, ensuring inter-examiner clinical standardisation, local preparation of teams for the national training and calibration exercise, local supervision of the programme's clinical governance, collation and data-cleaning of the NHS Greater Glasgow (and successor organisation) caries datasets and their submission to the Information & Statistics Division, NHS National Services Scotland. Furthermore, there is a requirement to contribute to local epidemiology planning, analysis and interpretation.

4.1.2 The sample selection methodologies

In order to identify suitable successive random samples, SHBDEP guidelines laid out a two stage sampling technique (Pine *et al.*, 1997a). However, sampling methodology was modified with the introduction of the NDIP programme and is now based on random school-based cluster samples in the year groups of interest (NDIP Protocol and Implementation Group, 2003).

4.1.3 Quality standards and protocols applicable to SHBDEP and NDIP caries data collections

4.1.3.1 Calibration

Annual training and calibration ensures that there is 'substantial agreement' (Landers & Koch, 1977) with respect to inter-examiner reliability of caries diagnosis at the d_3 level. Only those dental examination teams who meet the required standard for inter-examiner agreement for both presence and absence of D_3/d_3 experience, in the relevant age group, are permitted inclusion in respective years' SHBDEP & NDIP surveys.

Using standardised examination conditions and lighting sources, dental examination teams are trained with reference to a standardised training-pack (Mitropoulos *et al.*, 1992) and calibrated at Scottish level for each cross-sectional survey to ensure substantial consistency over time and across geographic areas (Watkins & Pitts, 1994). Intra-examiner reliability at surveys is assessed by dental inspection repeated after an interval. Around 1:10 subjects are re-examined later on the same day. Findings are subsequently compared.

Notwithstanding this, the BASCD caries diagnostic criteria were amended in 1992 to reflect changes in the nature of caries lesions (Pitts *et al.*, 1996). Prior to this, caries at D_3/d_3 level was recorded only from the point at which cavitation occurred. However, after this date a further category of D_3/d_3 was introduced, permitting examiners to include a score for 'visual caries' when there was clear visual evidence that caries did extend into the dentine.

At each survey, the stratified and randomly selected SHBDEP/NDIP schools in the NHS Board area are randomly allocated within the annual pool of calibrated dental teams.

4.1.3.2 Stratified random cluster sampling of survey subjects

At the level of each NHS Board area in Scotland, stratified random cluster samples of children (school class-based) and informed negative consent aim to produce representative samples of children from which to draw population inferences at NHS Board and national levels.

Data from the SHBDEP and NDIP epidemiological programmes adhere to the recommended methodologies a) of the British Association for the Study of Community Dentistry (BASCD) for survey sampling (Pine *et al.*, 1997a), b) of a framework of agreed standards for applying caries diagnostic criteria (Pitts *et al.*, 1997) and c) for the conduct of dental caries epidemiological surveys by only trained examiners, calibrated for the age group immediately prior to each year's survey (Pine *et al.*, 1997b).

4.1.3.3 The principle of 'negative consent'

The parent information letter supplied to all parents and legal guardians of children subjected to SHBDEP and NDIP dental inspections up to 2009/10, via their school, is explicit with respect to reassurances that only anonymised aggregated data will be processed. The letter is in effect a ‘negative consent letter’, in that it invites parents /legal guardians to positively respond to the school or Community Dental Service only in the circumstance that they do not wish their child to participate. Thus, SHBDEP and NDIP conform with the requirements of the NHS Service (Scotland) Act (HMSO, 1996), and the Education (Scotland) Act (HMSO, 1980) in the conduct of these surveys. The further steps recently outlined for use in other parts of the of the UK i.e. positive consent (Monaghan & Morgan, 2009) are not required and their epidemiological consequences (Dyer *et al.*, 2008; Monaghan *et al.*, 2011) are thus avoided. Furthermore, as both SHBDEP and NDIP form part of NHS Scotland’s routine data collection for monitoring and evaluation of services, it is not necessary to obtain ethical approval for secondary analysis of SHBDEP/NDIP anonymised aggregated data, as in this study. Nevertheless, the most recent (2010/11) version of the NDIP parent information letter now refers to possible future data uses e.g. record linkage.

4.1.3.4 Contemporary standards for data security

Over the period of SHBDEP and NDIP programmes, data collection standards and data security have developed on an ongoing basis. From an initial paper-based data collection system, by 2002/03, NDIP had implemented direct data entry onto unencrypted laptop computers, originally running Dental Survey Plus 2 software with data transfers via floppy discs or data-sticks. This early procedure has been superseded by custom written NDIP software that is currently at version NDIPv4. Contemporary standards (2009) for data security in NHSGGC include fully encrypted NDIP laptops with password access restricted to identified NDIP personnel from NHS Greater Glasgow and Clyde (NHSGGC). No unencrypted portable devices are used for NDIP. All data transfers are carried out to, and from, secure folders on secure network drives running on the NHSGGC IT network. Data are backed-up nightly by NDIP teams onto the network, with further back-up *nocte* at the remote Scottish NHS’s data warehouse in Livingston. NDIP data are the subject of contemporary NHSGGC information governance protocols within NHSGGC and NDIP staff here receive annual training and *ad hoc* updates with respect to data-security and developments, in the light of the Data Protection Act (1998). Furthermore, NHSGGC staff are required to formally sign, with a witness, a personal data protection undertaking prior to their initial involvement with any personal information of children associated with the NDIP programme (this will become an annual requirement following recent recommendations by the Scottish Dental Epidemiology Co-ordinating Committee (SDECC).

4.1.4 Use of postcode data to determine SES

Commencing in 1993, postcode sector of child's home address has been routinely collected along with child's forename, surname and date of birth. This permitted the Carstairs Index to be applied to caries data in the form of DepCat weighted septile categories (McLoone, 2004). More recently, full postcode data has been gathered to permit identification of the child's home SIMD datazone. A paper by the Measuring Deprivation Subgroup (2004) for the ISD Geography, Population, Census and Deprivation Group recommends the use of 2001 Carstairs scores for analyses of postcode-sector data from 1991 onwards. The data which are the subject of this thesis have therefore used the Carstairs score from the 2001 Census to derive DepCat (septiles) applicable to the home postcode sector of caries survey subjects (deprivation quintile & decile have also been appended to the database for potential use in future analyses). This is necessary to give continuity of SES index throughout the period 1993/94 to 2007/08.

4.2 The study design for the inequalities research

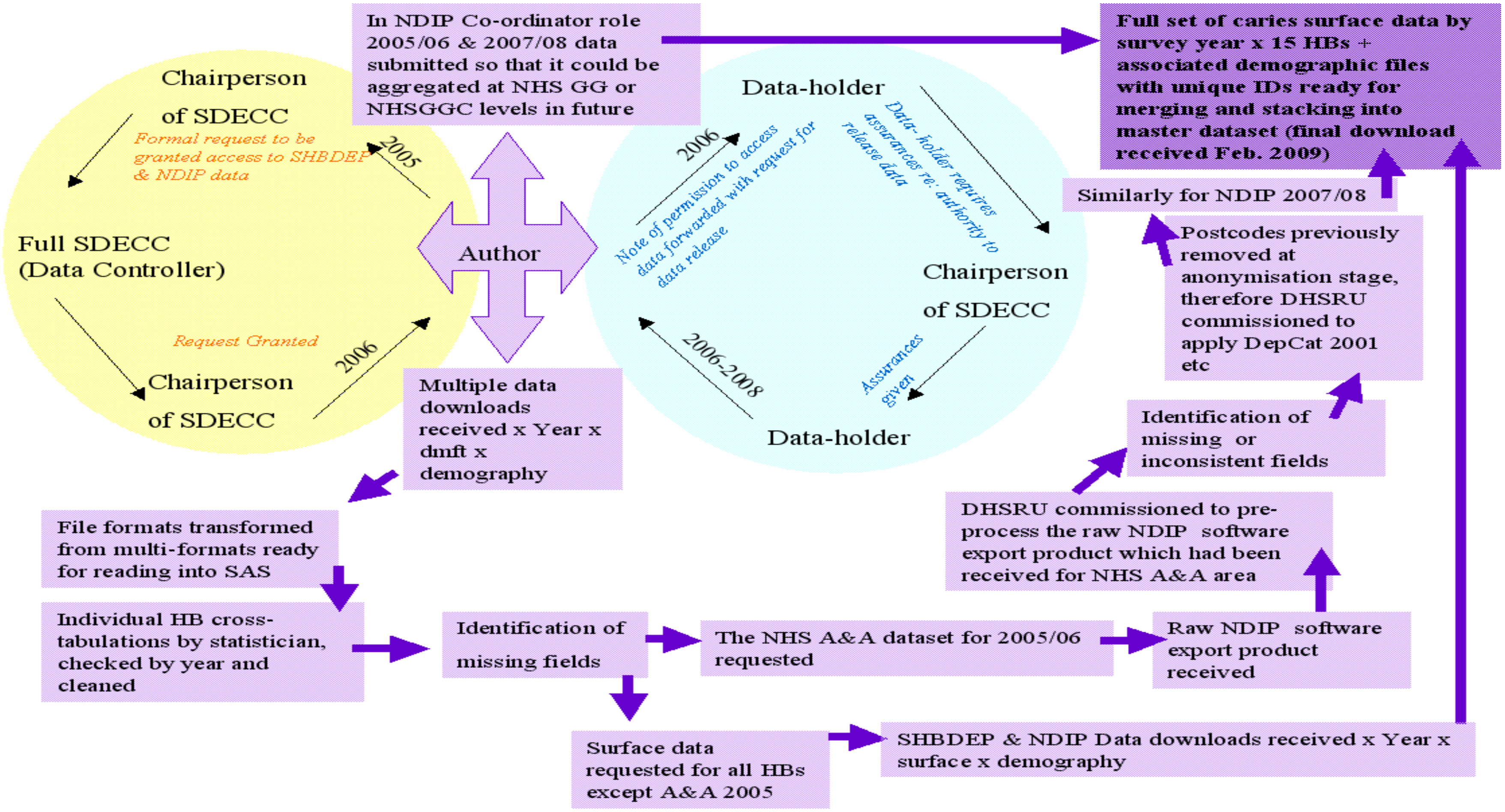
4.2.1 Secondary analysis of SHBDEP/NDIP data

This epidemiological study aimed to perform a secondary investigation of Scottish five-year-olds' historic caries datasets to assess temporal trends over the period 1993/94 to 2007/08. Cross-sectional ecological assessment at eight time points over the interval elicited longitudinal caries trends at three levels, namely, 1) GGHB area, 2) the remainder of NHS Scotland and 3) Scotland as a whole. Analyses were undertaken to assess temporal trends in caries epidemiology over the period both prior to, and since, implementation of the previously described OHAT and Scottish Executive pilot programmes.

4.2.2 The epidemiological process

The flow diagram illustrated in Figure 4-1 indicates some of the many stages involved in obtaining appropriately formatted, compatible and comparable data from the cross-sectional national surveys and the preparation of the large aggregated complex dataset used in this study.

Figure 4-1: Flow diagram showing stages and duration of the data retrieval, data processing and preparation into a master five-year-old children's caries dataset by tooth surface



4.2.3 Rationale

The SHBDEP data prior to 1993/94 contained no indication of subjects' SES. Thus, research for this thesis focused on data from this date forward. The very large caries dataset resulting from aggregation of Scotland's data from eight successive cross-sectional five-year-olds' caries surveys permitted an exploration of selected potential tests of dental health SES inequalities. The ability to deconstruct these data by geographic area and SES of subjects, over time, allowed tests to be assessed for their potential future routine use with Scottish caries data. The study design was a secondary analysis of caries data collected at eight cross-sectional SHBDEP/NDIP caries surveys commencing in 1993/94. Thus, in addition to investigating SES dental health inequalities in the age group, examination of geographic dental health and (dental) health inequalities trends in the GGHB area, the Not-Glasgow area and their potential respective impacts on trends across the combined area of Scotland, as a whole, could be examined. These data permitted comparisons of cross-sectional caries prevalence and related trends in geographic and SES dental health inequalities.

The socio-demographic make-up of the GGHB population is very different from the SES distribution and relative population density in the rest of Scotland. Moreover, the resulting differences in the GGHB area's statistical averages for general health morbidity and mortality compared to those of other areas e.g. the rest of Scotland and the UK, are generally held to be a conventional wisdom. [N.B. These general health trends were described in the literature review].

However, little was known about the extent of dental health differentials between GGHB and the rest of Scotland's (age specific) population, as Scotland's caries databases had never been dismantled and analysed in this way, prior to this thesis. There was no evidence to indicate whether cross-sectional dental health prevalence and SES inequalities showed similar (dental) health disadvantages associated with residence in GGHB and, if so, whether there are any trends to increasing or decreasing differences.

Moreover, at the outset little was known about the potential tests for use in the assessment of caries inequalities in Scotland. By becoming familiar with the caries epidemiology and the inequalities prevalence and trends through performing the above analyses it was hoped that this research would be able to inform recommendations as to which of the tests of health inequality appearing in the literature are suitable for use with Scotland's caries data.

4.2.4 Data request to the 'Data-Holder''

Immediately after the chairperson of the Scottish Dental Epidemiology Co-ordinating committee authorised the author (YB) to receive the datasets, a data request was submitted to the Dental Health Services Research Unit (DHSRU), University of Dundee. The Data-Holder was the senior statistician for DHSRU and no data were released until the statistician had independently verified that SDECC fulfilled the role of the Data Controller (within the terms of the Data Protection Act, 1998) on behalf of all the Scottish Health Boards. Following verification, multiple datasets were released incrementally over an extended period, as her time permitted.

4.2.5 Retrieval of Scotland's five-year-olds' caries datasets

Caries data retrieved for this survey from the national 'Data Holder' were transmitted anonymously for each individual in each SHBDEP/NDIP year with specific survey subject ID numbers and the NHS Board area of their school's location appended.

Files containing subject identification numbers and demographic information of corresponding individuals e.g. survey year, age, DepCat (2001) of home postcode sector and NHS Board area were transmitted separately and the individual files were transferred to the University of Glasgow's secure password protected data drive. Access to this drive is restricted to the author of this thesis and the Consultant Epidemiologist. Subject ID number, year and NHS Board area were used for record-linkage in the assembly of the master dataset for this study. Contemporary information governance standards according to the University of Glasgow, Dental Public Health Unit's protocol (2009) were applied.

4.2.5.1 The nature of the original data provided

Initial data provided comprised of dt, mt and ft data, fully pre-processed at subject level within selected years. The separate files obtained for individual survey years were in a variety of file formats.

4.2.6 Request for data at surface level

Having taken into consideration the work of Gilthorpe (Gilthorpe & Cunningham, 2000; Gilthorpe *et al.,* 2000; Lewsey *et al.,* 2000) and the reported enhanced potential for statistical analyses of clustered data, nested within subjects, a further request for the raw, coded caries data at individual tooth surface level was made by the author to the Data-Holder.

4.2.6.1 Transfer of surface level data

Tooth surface level datasets for Scottish five-year-olds were subsequently received in multiple individual file downloads for the years 1987/98, 1998/90,1991/92, 1993/94, 1995/96, 1997/98, 1999/00, 2002/03, 2003/04, 2005/06 (with the exception of NHS Ayrshire and Arran Board Area) and 2007/08, in varying file formats.

In addition, separate files were received for each caries data year containing related information for each subject e.g. NHS Board area of school attended, subjects' age at date of examination and for 1993/94 data onwards, the DepCat (2001) of postcode sector of residence.

4.2.6.2 Additional file request

On preliminary data checking it was found that the original download of the Scottish data for 2005/06 did not include that of the NHS Ayrshire and Arran Board Area. Following a further request to DHSRU these data were later located in the raw Excel export format from NDIP survey software. In order that uniform methodology was applied and comparability of data maintained throughout, the University of Glasgow commissioned DHSRU to further pre-process this dataset using their standard methodology. Subsequently, a comparable pair of tooth surface and corresponding demographic data files were received.

The first data file was received on 29/05/2007 and the final data transfer from the 'Data-Holder' occurred on 6/2/2009. Overall, a total of 36 emails had been received containing multiple database attachments/downloads from the total of 64 exchanges of email correspondence between the 'Data-Holder' and the author which were pertinent to this thesis.

4.2.7 Transfer and storage of data obtained for this research

Following receipt of individual data files by the author, these anonymised files were converted into SAS format and transferred to the Consultant Epidemiologist in accordance with prevalent contemporary standards.

4.2.8 Identification and data-linkage

Data-linkage between the caries surface-level datasets and the demographic information datasets was achieved by use of linking subject identification number, year and Board area by concatenation. A unique identifier applicable only within this research was thus created for each caries data subject.

4.3 Assessments of data quality and consistency

Since no SES information was available prior to 1993/94 and the convention for dealing with non-cavitated lesions had altered in that year's data collection, and henceforth with respect to previous years' data, it was decided to restrict this thesis to an analysis of the years: 1993/94, 1995/96, 1997/98, 1999/00, 2002/03, 2003/04, 2005/06 and 2007/08 which are fully comparable with respect to the caries diagnostic criteria applied, the data fields collected and their subsequent treatment.

4.4 Application of a socio-economic index

Due to the confidentiality undertaking contained within the parent information ('*negative-consent*') letter, the full postcode information of subjects from other NHS Board areas was not made available to the author (YB). It was not possible therefore to assign deprivation indices arising from the 2001 Census 'in-house'. Nonetheless, as the original postcode sector data of historic datasets were retained by the 'Data-Holder' at DHSRU, their statistician was commissioned to further append the specified DepCat (2001) and in addition the quintile and decile (for potential future use) to each year's demographic file.

4.5 Compilation of a master database

The majority of the data cleaning, cross-tabulations and compilation of the master dataset was carried out in 2007/2008, which corresponded to the most recent NDIP five-year-olds' survey. On receipt of the last data download in February 2009, pre-processed in exactly the same way as the earlier data, the master dataset for analyses was complied and the data fully re-checked for consistency by cross-tabulations prior to commencement of any analysis.

Programming was undertaken collaboratively with the author contributing expertise in cariology and dental survey methodology and a Consultant Epidemiologist providing expertise in software programming and statistical analysis.

4.6 Selection of denominator populations

As indications from a Senior Information Analyst at the Greater Glasgow and Clyde NHS Board suggested that the birth rates, proportions of births by DepCat and the resultant five-year-old age cohorts were relatively stable within the varying SES groups over the time 1993 to 2008, a request was made for the respective numbers and proportions in the five-year-old population by DepCat at the 2001 Census at each of the proposed levels for data analysis i.e. those who were resident in Glasgow (former GGHB area), in Scotland outwith Glasgow and in Scotland as a whole, respectively. Conveniently, 2001 was also approximately at the mid-point of the available cross-sectional surveys. The Health Informatics team of Greater Glasgow and Clyde NHS Board provided these data at the author's request. Interaction tests were performed on the full caries datasets and these demographic data permitted subsequent weighting by SES e.g. population weighted means with (95%CI) in addition to unweighted analyses.

4.7 Survey analyses

The percentage of children with $d_3$mft=0 and $d_3$mft>0 and the mean d_3t, mt and ft were ascertained by recoding and analysing surface $d_3$mft data originally coded according to BASCD conventions. All analyses were carried out using SAS version 9.1 (SAS, Cary, NC) and raw summary statistics were produced for each geographic and SES level. Preliminary survey analyses was carried out using the SURVEYMEANS procedure with later weighting/adjustment for SES, age and gender as appropriate.

4.8 Statistical analyses

Moreover, logistic regression models used $d_3$mft, age, gender, DepCat, survey year and status as a resident in Glasgow as independent explanatory variables for $d_3$mft>0. Adjusted Odds Ratios and 95% Confidence Intervals (95%CI) for $d_3$mft>0 were ascertained by logistic procedures.

Testing for statistical significances of trends in $d_3$mft, over time, in the respective SES categories of five-year-olds and in the geographic areas was by Meta-analysis using linear regression analyses and the differences attributable to the geographic area of residence and/or year were assessed by Generalised Linear Modelling (GLM) procedures. Changes in the underlying distribution of $d_3$mft scores e.g. by year and within each of the areas were determined using Wilcoxon tests.

4.9 Maintenance of the historic geographic boundaries

Restructuring of NHS Scotland (2006), resulted in the merger of NHS Greater Glasgow with a substantial portion of the former geographic area and population of NHS Argyll & Clyde, to create a new entity. Throughout this analyses the original geographic boundaries of NHS Greater Glasgow (GGHB) have been maintained, as the author acting in the role of NDIP Co-ordinator compiled and submitted the caries datasets for the new entity in such a way that they could be analysed to reflect either the new or historic geographic boundaries. For the purpose of this thesis the geographic area comprising the Scottish land-mass and associated islands outwith the area defined above as Glasgow (GGHB) will be referred to as 'Not-Glasgow'.

4.10 Interrogation

The master database was subsequently interrogated by the Consultant Epidemiologist according to the author's pre-determined analysis plan. This schedule was designed to address the research questions related to caries epidemiology and to explore and examine the performance and potential of an array of selected inequalities tests for use with caries datasets. The selected inequalities tests will be described in the forthcoming Methods chapter of the thesis.

4.10.1 Preservation of the subjects throughout

All respective subjects, from each year, at the levels of Scotland, Glasgow and Not-Glasgow and within each deprivation category are included in the caries survey analysis and the later inequalities analysis. Complete caries data and NHS Board area are held for all subjects (inclusion criteria). In this study, no relevant child's data was excluded from analyses with the exception of e.g. relatively few children who could not be included in the respective logistic regression analyses due to missing information on age, gender or DepCat (2001). Where no note of exclusions is recorded in the results sections, all subjects have been included in the analysis.

4.11 Limitations of the epidemiological analyses

It is beyond the scope of this research to undertake direct comparisons of interventions and comparisons of temporal outcomes in caries epidemiological trends in Glasgow compared to the rest of Scotland. This is due in most part to the dearth of information on OHP interventions, intensity and timing etc. in the rest of Scotland outwith Glasgow.

Thus, the aim is therefore to examine the epidemiological trends within each of the geographic areas.

Chapter 5

5 Descriptive epidemiology (Methods 2)

5.1 Selected tests of inequality

Critical examination of the literature describing tests of inequality revealed that there is no overall consensus on the appropriateness of particular individual tests or models for examining dental health inequality.

The analysis plan for point prevalence estimation of inequality in dental health and trend, between areas, which has been developed for this thesis will therefore focus on a variety of the previously published tests of inequality appearing in the international literature. The author's selection is listed in Table 5-1, with annotation as to the source of recommendation for each from the following reviews: Regidor, 2004a; Regidor, 2004b; Carr-Hill & Chalmers-Dixon, 2005 (for *South East England Public Health Observatory)*; American Centres for Disease Control (Kepple *et al.*, 2005); Munoz-Arroyo & Sutton, 2007 (*for the Scottish Public Health Observatory*) and the report by the Scottish Government, 2008 (Health Analytical Services Division, '*Long-Term Monitoring of Health Inequalities, First Report on headline Indicators-September 2008).* Moreover, the ROC analysis has been included on the prospective list of tests to be carried out due to its ability to measure sensitivity and specificity of a diagnostic outcome ($d_3$mft>0) to the 'test' variable 'deprivation' when measured on an interval scale (Metz, 1978) along with the Significant Caries Index (SIC), as it has been reported as a specific test of dental health inequality (Bratthall, 2000) which has been adopted by the WHO (2009).

Table 5-1 outlines the inequality tests applied to the caries outcomes data. Extrapolating the prevalence at each SES and geographic level to the respective denominator population permits assessment of the scale of the problem at each geographic level. The recent *Marmot Review* (Marmot *et al.*, 2010) authors believe that this is a very important consideration with respect to (dental) health inequalities.

Table 5-1: The selected tests of health inequality and additional statistical tests to be used in the assessment of dental health inequalities in relation to this thesis and their respective documentary sources

	Selected conventional tests of inequality	Miscellaneous other selected summary indicators of inequality
Simple	* * $ # *Absolute range (top *vs.* bottom) * * # Relative range	* Significant Caries Index (SIC) Receiver Operator Characteristic Plot (ROC) * Odds ratios (*for* $d_3mft>0$)
Complex	* * # Population Attributable Risk (PAR) * * # * Slope Index of Inequality (SII) * * $ # * Relative Index of Inequality (RII) * * # * Concentration Curve/Index (CI) * CI x 75=> % redistribution required to remove health difference $ * * Scale (the extent of the problem) # * Gini coefficient	
	$ Scottish Government: Long-term Monitoring of Health Inequalities. First Report on Headline Indicators, September 2008	* ScotPHO 2007: Measuring Socio-Economic Inequalities in Health- a Practical Guide. Munoz-Arroyo & Sutton, 2007
	# Sepho: The Public Health Observatory Handbook of Inequalities Measurement. Carr-Hill & Chalmers-Dixon, 2005	*CDC: Methodological Issues in Measuring Health Disparities, Centres for Disease Control and Prevention, National Centre for Health Statistics. Keppel, Pamuk *et al.*, 2005
	*WHO Oral Health Country/Area Profile Programme (undated)	* Regidor, 2004a & 2004b: Measures of Health Inequalities: Part 1; and Measures of Health Inequalities Part **2.**

5.2 The '*simple*' tests of dental health inequality

The absolute and relative range of inequality are generally considered to be the simple tests of inequality and are often referred to, respectively, as 'simple absolute inequality' and 'simple relative inequality' in published literature. The absolute range of inequality was assessed by calculating differences in mean and prevalence scores for $d_3$mft in SES group extremes within, and between, the selected geographic levels. On the other hand, relative range of inequality was assessed by computation of ratios of the values in the most extremely deprived SES districts divided by the values in the relatively most affluent socio-economic comparator and likewise for the geographic areas.

5.3 Summary of the selected complex tests of inequality included in this thesis

The preceding table outlines the inequality tests applied to the caries data contained in the master dataset complied for this research. Extrapolating the prevalence at each SES and geographic level to the respective denominator population provides an estimation of the' scale of the problem' at each geographic level.

5.4 Preparation for the measurement of complex dental health inequality

After the academic supervisor had agreed the above schedule of complex tests proposed by the author, the Consultant Epidemiologist carried out appropriate software programming using SAS version 9.1 (SAS, Cary, NC).

5.5 Validation of local inequality testing procedures

The Consultant Epidemiologist tested all locally written programming for each complex test of inequality applied. The respective outcomes from each type of inequality test were validated by importing previously published datasets and testing the local analytical programmes' outcomes against the results of previously peer reviewed and published studies within the scientific literature. The papers utilised to validate each of the inequalities tests are listed in Appendix 1. These papers generally did not include calculation of 95% Confidence Intervals. The local programming for each test was successfully validated by the Consultant Epidemiologist to the satisfaction of the author for all complex tests of inequality adopted in this thesis. The validated methodologies were used to generate the inequalities data-points presented in this thesis. Data-points from each of the inequalities tests were subjected to Meta-analysis to make statistical inferences.

The master dataset compiled previously for the dental health outcomes assessment was subsequently imported and the locally programmed procedures for the following tests of inequality were applied.

5.5.1 Gini coefficient

The Gini-coefficient was calculated from the cumulative distribution of $d_3$mft scores plotted against the cumulative unranked population and computation of the ratio of the resultant area that lies between the line of equality and the Lorenz curve divided by the total area under the line of equality for each geographic level, at each cross-sectional survey. These Gini Coefficients give a measure of the distribution of $d_3$mft scores across the whole population at each of the geographic levels, irrespective of SES. Values closer to 1 indicate higher levels of inequality.

5.5.2 Concentration Curve

The Concentration Curves were obtained by plotting cumulative persons with morbidity (using their $d_3$mft score) against cumulative population ranked by SES Index (DepCat 2001). The x axis ranks the cumulative percentage of the sample by their DepCat and the y axis the cumulative percentage of the distribution of $d_3$mft scores. The test was originally devised to assess the relationships of variables to income inequality. Whilst the convention for plotting income inequality is to rank from poorest to wealthiest (i.e. increasing values for income), the DepCat Index, as used in this study, conversely rises as deprivation increases. The result is that Concentration Curves generated from DepCat data will lie below the line of equity (i.e. the 45^{o} line on a graph running from the bottom left corner of a graph to the top right corner) indicating that there is a direct association between this rising DepCat score and relatively poorer dental health i.e. the additional disproportionate burden is found in the poorer DepCat group who have the higher DepCat score values, as DepCat measures relative deprivation, not income.

5.5.3 The Concentration Index

The Concentration Index (CI) is derived from the above Concentration Curve. The CI is calculated from twice the area between the Concentration Curve and the line of equity (i.e. the 45^{o} line on a graph running from the bottom left corner of a graph to the top right corner). In the case where there is no SES-based relationship with $d_3$mft score the value would be zero as the CI would overlie the 45^{o} line. The greater the area between the curve and the diagonal, the greater is the systematic disproportional concentration of $d_3$mft score according to SES. The greater the departure of the curve from the diagonal, the greater the area between it and the 45^{o} line. The convention in this test is that ascending affluence is plotted on the x-axis. However, DepCat score increased as deprivation, not affluence increases. Therefore, the Concentration curve will lie below the diagonal in this computation and the higher the value of the CI, the greater the concentration of $d_3$mft among the relatively deprived DepCat groups.

5.5.4 Concentration Index (CI) and Koolman & Doorslaer's transformation

The results of the transformation obtained by multiplying CI by 75 (as has been advocated by Koolman & van Doorslaer, 2004) aids interpretation of CI and this was carried out.

5.5.5 Slope Index of Inequality (SII)

The Slope Index of Inequality (SII) was calculated by first ordering the $d_3$mft scores within each DepCat category from the lowest score to the highest in a cumulative distribution. Each DepCat category was then ranked from lowest to highest and given a score based on the midpoint value of its range within the distribution. The linear regression line was then fitted using weighted least-squares, with weights apportioned according to the population proportion in each SES category (Keppel *et al.*, 2005).

5.5.6 Relative Index of Inequality (RII)

The Relative Index of Inequality (RII) is an alternative relative version of the SII and was calculated from the SII following statistical transformation. It is expressed as the odds for prevalence estimated for the lowest SES group in a hierarchy (*DepCat 7*) divided by the odds for prevalence in the highest (*DepCat 1*) group (Regidor, 2004b). Although this gives a relatively intuitive interpretation for those familiar with Odds Ratios (Keppel *et al.*, 2005), it must nevertheless not be interpreted as an Odds Ratio, as it is not a measure of association (Regidor, 2004b).

5.5.7 Population Attributable Risk (PAR)

In this research the %PAR measured the proportion of $d_3$mft>0 which was attributable to the variable ‘exposure to deprivation’ (measured by DepCat) and which could be eliminated in the hypothetical circumstances that the whole population of P1s was unexposed to deprivation i.e. the assumption being that this is the case in the relatively unexposed DepCat 1 group (DepCat 1 group represents the reference group). This metric is calculated to reflect respective population sizes, therefore the larger the group with high prevalence, the greater is the potential for improvement in overall population prevalence.

5.6 Miscellaneous other selected summary statistical indicators of inequality

5.6.1 SIC

The values pertaining to the mean $d_3$mft of the worst affected tertile (SIC) and decile (SIC^{10}) were calculated using the methodology for SIC originally proposed by Bratthall (2000) and the SIC^{10} modification suggested by Morgan *et al. (*2005).

5.6.2 Odds Ratios

Odds Ratios are tests of association and not strictly tests of inequality. They are nevertheless useful, as the Odds Ratio is computed from the odds of disease in exposed (to the variable of interest) persons compared to the odds in unexposed persons.

The Odds Ratios and corresponding 95% confidence intervals (95%CI) for presence of $d_3$mft>0 were mathematically modelled by logistic regression analysis carried out in SAS version 9.1 (SAS, Cary, NC) by survey geographic and SES sub-groups.

Analysis was subsequently carried out for each survey year at the levels Scotland, Glasgow and Not-Glasgow. The logistic regression analyses mutually adjusted for the identified potential confounders age, sex, DepCat and 'status as a resident in Glasgow', as appropriate.

5.6.3 Receiver Operator Characteristics Plot (ROC)

In order to assess the ability of the selected deprivation index (DepCat 2001) to accurately discriminate between those with $d_3$mft>0 and those without, the sensitivity and specificity of every subject's data value was calculated by logistic regression and plotted, at each cross-sectional survey for each geographic area, to produce respective ROC plots.

5.7 Assessment of the 'scale of the problem'

The demographic datasets for the five-year-old P1 group resident in Scotland, Glasgow and Not-Glasgow received from the Health Informatics team at Greater Glasgow and Glasgow and Clyde NHS Board were used to calculate the absolute numbers and relative numbers of five-year-olds affected by $d_3$mft in geographic areas and SES groups in order to give dimension to the 'scale of the problem' as advocated (Marmot, 2010).

5.8 Statistical testing of inequalities trends

Trends in inequalities were assessed by Meta-analysis using GLM procedures.

Chapter 6

6 Population level dental health at five years of age over the period 1993/94-2007/08 (Results 1)

6.1 Introduction

This chapter will describe the epidemiological findings from the secondary analysis of the SHBDEP and NDIP data. The inequalities outcomes are described in the next chapter.

6.2 The denominator population

The use of DepCat scores in planning and analysis may involve the use of postcode sector scores applied at the Scottish level or within individual Health Board areas. Throughout this thesis the use of the term 'DepCat' applies to Carstairs score applied at the whole of Scotland level. The demographic distribution of five-year-old children by Scottish DepCat of residence in the geographic areas Scotland, Glasgow and Not-Glasgow at the 2001 Census can be seen in Table 6-1.

Table 6-1: The denominator populations of five-year-old children in Scotland, Glasgow and Not-Glasgow at the 2001 Census by DepCat of home postcode

	2001 Census							
Area	**DepCat 1**	**DepCat 2**	**DepCat 3**	**DepCat 4**	**DepCat 5**	**DepCat 6**	**DepCat 7**	Total five-year-old population
Scotland **(n=)**	3957	8103	12607	14562	8459	6734	4331	**58753 (100%)**
Glasgow (n=)	562	1314	986	1337	934	1651	3155	**9939 (17%)**
Not-Glasgow (n=)	3395	6789	11621	13225	7525	5083	1176	**48814 (83%)**

6.3 Summary statistics from successive surveys

The data in Table 6-1 served as the denominator population of five-year-old children at each of the geographic levels throughout this analysis. A total of eight comparable stratified random cross-sectional datasets from five-year-old caries epidemiology surveys over the period 1993/94 (T1) to 2007/08 (T8) were available for inclusion in this analysis. The numbers of subjects, the DepCat of their postcodes of residence and their sampling probability in parenthesis at the respective SHBDEP/NDIP surveys is shown in Table 6-2 for the relevant years, at each of the geographic levels.

Table 6-2: Number of five-year-old children involved in SHBDEP/NDIP surveys (sampling probability) for whom a complete caries data set is available at the geographic levels: Scotland, Glasgow and not-Glasgow by DepCat (2001) of home postcode in 1993/94, 1995/96, 1997/98, 1999/00, 2002/03, 2003/04, 2005/06 and 2007/08

YB= regular calibrated SHBDEP examiner for P1 surveys | YB = NDIP Co-ordinator for GGHB P1 surveys

Area		DepCat (2001)							
	SHBDEP/NDIP Survey Year	DepCat 1, n=	DepCat 2, n=	DepCat 3, n=	DepCat 4, n=	DepCat 5, n=	DepCat 6, n=	DepCat 7, n=	Total survey sample size =
Scotland	1993/04	218(0.06)	477(0.06)	1353(0.11)	1142(0.08)	798(0.09)	593(0.09)	497(0.11)	**5078**
	1995/96	262((0.07)	659(0.08)	1510(0.12)	1591(0.11)	815(0.10)	710(0.11)	693(0.16)	**6240**
	1997/98	376(0.10)	674(0.08)	1584(0.13)	1624(0.11)	881(0.10)	7430.11)	702(0.16)	**6584**
	1999/00	374(0.09)	943(0.12)	1884(0.15)	1674(0.11)	791(0.09)	621(0.09)	494(0.11)	**6781**
	2002/03	287(0.07)	977(0.12)	2228(0.18)	2644(0.18)	1477(0.17)	1123(0.17)	1011(0.23)	**9747**
	2003/04	496(0.13)	1478(0.18)	2455(0.19)	2393(0.16)	1447(0.17)	1361(0.20)	1326(0.31)	**10956**
	2005/06	619(0.16)	1480(0.18)	2522(0.20)	2947(0.20)	1301(0.15)	1083(0.16)	993(0.23)	**10945**
	2007/08	672(0.17)	1549(0.19)	2550(0.20)	2687(0.18)	1950(0.23)	1676(0.25)	983(0.23)	**12067**
	Total Scotland sample size T^1 to T^8	**3304**	**8237**	**16086**	**16702**	**9460**	**7910**	**6699**	**68398**
Glasgow	1993/04	19(0.03)	33(0.03)	65(0.07)	97(0.07)	70(0.07)	159(0.10)	397(0.13)	**840**
	1995/96	90(0.16)	225(0.17)	138(0.14)	195(0.15)	106(0.11)	309(0.19)	586(0.19)	**1649**
	1997/98	78(0.14)	135(0.10)	128(0.13)	174(0.13)	130(0.14)	245(0.15)	575(0.18)	**1465**
	1999/00	93(0.17)	133(0.10)	91(0.09)	122(0.09)	83(0.09)	163(0.10)	398(0.13)	**1083**
	2002/03	41(0.07)	192(0.15)	225(0.23)	371(0.28)	255(0.27)	334(0.20)	814(0.26)	**2232**
	2003/04	146(0.26)	628(0.48)	443(0.45)	587(0.44)	435(0.47)	799(0.48)	1225(0.39)	**4263**
	2005/06	293(0.52)	428(0.33)	349(0.35)	580(0.43)	284(0.30)	433(0.26)	853(0.27)	**3220**
	2007/08	332(0.59)	246(0.19)	360(0.37)	246(0.18)	537(0.57)	915(0.55)	786(0.25)	**3422**
	Total Glasgow sample size T^1 to T^8	**1092**	**2020**	**1799**	**2372**	**1900**	**3357**	**5634**	**18174**
Not-Glasgow	1993/04	199(0.06)	444(0.07)	1288(0.11)	1045(0.08)	728(0.10)	434(0.09)	100(0.09)	**4238**
	1995/96	172(0.05)	434(0.06)	1372(0.12)	1396(0.11)	709(0.09)	401(0.08)	107(0.09)	**4591**
	1997/98	298(0.09)	539(0.08)	1456(0.13)	1450(0.11)	751(0.10)	498(0.10)	127(0.11)	**5119**
	1999/00	281(0.08)	810(0.12)	1793(0.15)	1552(0.12)	708(0.09)	458(0.09)	96(0.08)	**5698**
	2002/03	246(0.07)	785(0.12)	2003(0.17)	2273(0.17)	1222(0.16)	789(0.16)	197(0.17)	**7515**
	2003/04	350(0.10)	850(0.13)	2012(0.17)	1806(0.14)	1012(0.13)	562(0.11)	101(0.09)	**6693**
	2005/06	326(0.10)	1052(0.15)	2173(0.19)	2367(0.18)	1017(0.14)	650(0.13)	140(0.12)	**7725**
	2007/08	340(0.10)	1303(0.19)	2190(0.19)	2441(0.18)	1413(0.19)	761(0.15)	197(0.17)	**8645**
	Total Not-Glasgow sample size T^1 to T^8	**2212**	**6217**	**14287**	**14330**	**7560**	**4553**	**1065**	**50224**

Complete datasets containing surface level data for individual teeth scored according to BASCD criteria were available for an overall total of 68,398 five-year-old children over the study period. The mean age (SD) and gender of subjects at each cross-sectional survey are shown in Table 6-3. Overall, 44 subjects were missing information on gender. This was comprised of 11 and 33 missing fields, respectively, from Glasgow and Not-Glasgow.

Table 6-3: The mean age (SD) in years and gender of subjects at eight successive cross-sectional five-year-old caries epidemiology surveys at the geographic levels Scotland, Glasgow and Not-Glasgow, from 1993/94-2007/08

Year	1993/94	1995/96	1997/98	1999/00	2001/02	2002/03	2004/05	2007/08
Scotland								
Mean age (yrs) (SD)	5.3 (0.3)	5.3 (0.3)	5.3 (0.3)	5.3 (0.3)	5.5 (0.3)	5.5 (0.3)	5.5 (0.3)	5.5 (0.4)
Gender M% (F%)	51.6 (48.4)	51.2 (48.8)	51.2 (48.8)	51.0 (49.0)	50.3 (49.7)	52.0 (48)	51.9 (48.1)	51.3 (48.7)
Glasgow								
Mean age (yrs) (SD)	5.2 (0.3)	5.2 (0.3)	5.2 (0.3)	5.2 (0.3)	5.6 (0.3)	5.5 (0.3)	5.5 (0.3)	5.5 (0.4)
Gender M% (F%)	51.1 (49.9)	52.5 (47.5)	50.5 (49.5)	51.1 (48.9)	49.5 (50.5)	52.2 (47.8)	51.3 (48.7)	50.4 (49.6)
Not-Glasgow								
Mean age (yrs) (SD)	5.3 (0.3)	5.3 (0.3)	5.3 (0.3)	5.3 (0.3)	5.5 (0.3)	5.5 (0.3)	5.5 (0.3)	5.5 (0.4)
Gender M% (F%)	51.8 (48.2)	50.7 (49.3)	51.4 (48.6)	51.0 (49.0)	50.6 (49.4)	51.9 (48.1)	52.1 (47.9)	51.6 (48.4)

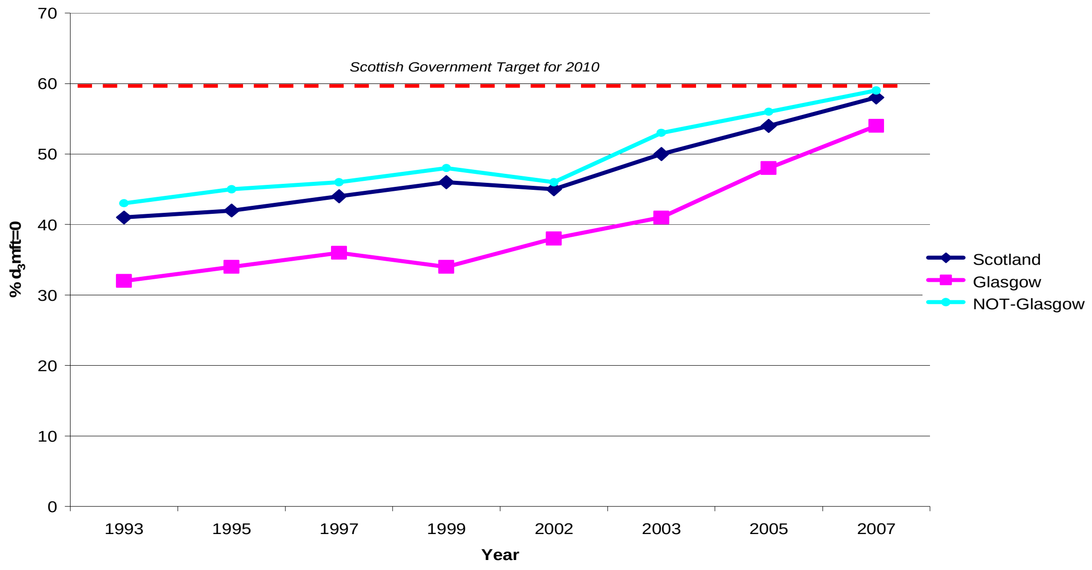
6.4 Trends in % of five-year-old children with obvious experience of caries into dentine (weighted for DepCat)

The overall values for % $d_3$mft=0 (95%CI), weighted for DepCat, are shown for each survey year in Table 6-4 at each of the geographic levels. Longitudinal trends showing progress towards the 'Scottish Target', by which 60% of five-year-olds should have $d_3$mft=0 by 2010, may be studied in Figure 6-1.

Table 6-4: The overall percentages of P1 children with $d_3$mft=0 (95%CI) weighted for DepCat

	1993	1995	1997	1999	2002	2003	2005	2007
Scotland weighted % $d_3$mft =0 (95%CI)	41.1 (39.8-42.3)	42.5 (41.3-43.6)	44.4 (43.2-45.5)	45.5 (44.4-46.6)	44.9 (44.0-45.9)	49.6 (48.8-50.0)	54.5 (53.6-55.3)	58.3 (57.5-59.1)
Glasgow weighted % $d_3$mft =0 (95%CI)	31.8 (28.2-35.1)	33.8 (31.7-35.8)	35.6 (33.3-37.8)	34.1 (31.6-36.6)	38.1 (36.2-40.0)	41.5 (40.4-42.6)	47.7 (46.3-49.1)	56.0 (55.0-57.0)
Not-Glasgow weighted % $d_3$mft =0 (95%CI)	42.9 (41.6-44.4)	44.6 (43.2-46.0)	46.3 (45.0-47.6)	47.8 (46.6-49.0)	46.4 (45.4-47.5)	52.6 (51.5-53.7)	56.0 (55.0-57.0)	58.8 (57.8-59.7)

Figure 6-1: Scotland, Glasgow and Not-Glasgow: longitudinal trends in the % of five-year-old children with $d_3mft=0$ (weighed for DepCat)



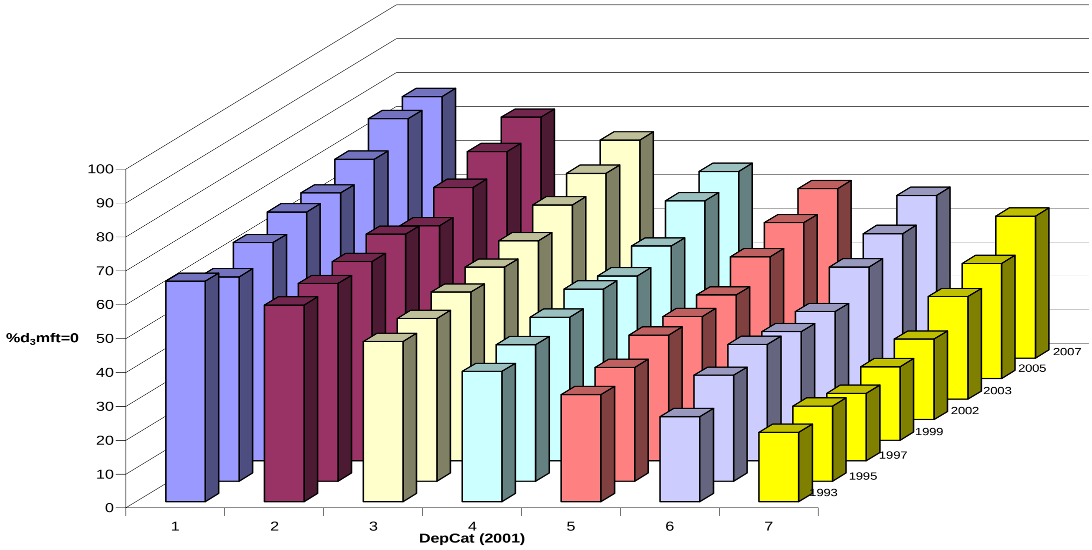
Whilst Glasgow consistently has smaller overall proportions of five-year-old infants with $d_3mft=0$ than Not-Glasgow, it appears that during the later intervals a faster rate of improvement commenced in Glasgow than previously. The overall magnitude of improvement is greater in Glasgow (i.e. 24 percentage points, 76%) than in Not-Glasgow (i.e. 16 percentage points, 37%). With the exception of the 1999/00 data-point in Glasgow and 2002/03 in the rest of Scotland, the trend towards improvement was occurring throughout the study interval from 1993/94. No separation of the 95%CIs was evident in Glasgow until 2002. However, in Scotland as a whole there was significant improvement compared to 1993, as early as 1997.

6.5 Trends in percentages of five-year-olds with $d_3mft=0$ by DepCat and year

6.5.1 Scotland

The percentages of children with $d_3mft=0$ in each SES group in Scotland, by year, are illustrated in Figure 6-2. Over the interval of study, there is a generalised trend towards increasing proportions of children with $d_3mft=0$ across the whole DepCat spectrum.

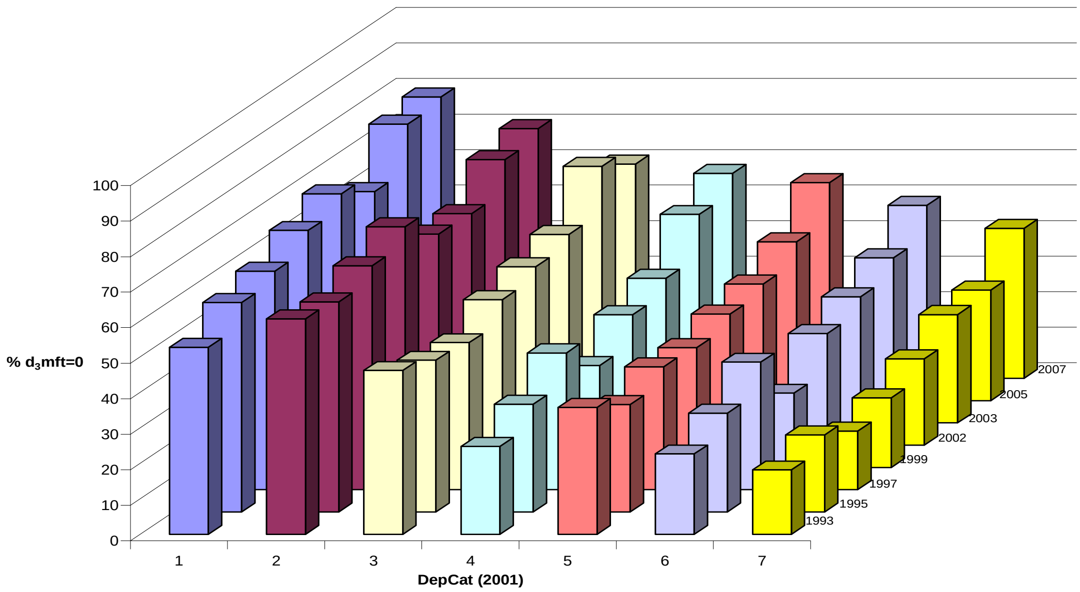
Figure 6-2: The % of five-year-olds with $d_3mft=0$ in each DepCat in Scotland, by survey year, 1993-2007



Glasgow

The trends in percentages of children with $d_3mft=0$ in Glasgow are shown in Figure 6-3 and are less smooth than in Scotland as a whole. Indications of improvement are most notable during later intervals. Although not in evidence prior to this, in 2007/08, Glasgow's percentages of five-year-old children with $d_3mft=0$ exceed those of the rest of Scotland for all SES groups with the exception of those resident in DepCat 2 and DepCat 3 districts. However, this is the product of just the most recent cross-sectional dataset and would require to be confirmed with future data. Nevertheless, by 2007/08 the comparatively deprived SES groups have made considerable progress towards the government target, while the most affluent groups have met or exceeded this.

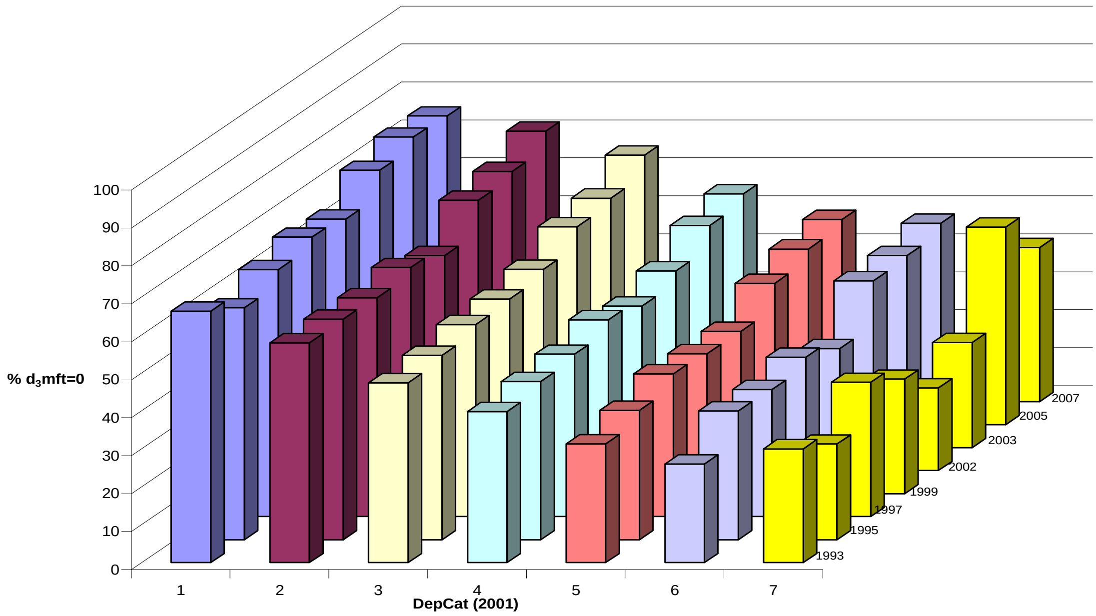
Figure 6-3: The % of five-year-olds with $d_3mft=0$ in each DepCat in Glasgow, by survey year, 1993-2007



6.5.2 *The rest of Scotland, Not Glasgow*

Figure 6-4 illustrates the trends in percentages of children with $d_3mft=0$ in the remainder of Scotland, outwith Glasgow, by SES and year. There is a generalised trend to improvement in % $d_3mft=0$ across all SES categories. The SES affluent groups have also exceeded the government target. While the SES deprived groups have some way to go. There has nonetheless been substantial progress latterly. The data underlying Figures 6-2 to 6-4 and their respective 95% CIs may be viewed in Appendix 2.

Figure 6-4: The % of five-year-olds with $d_3mft=0$ in each DepCat in Not-Glasgow by survey year: 1993-2007



6.5.3 *The adjusted Odds Ratios for d3mft>0, compared to 1993/94, in each geographic area*

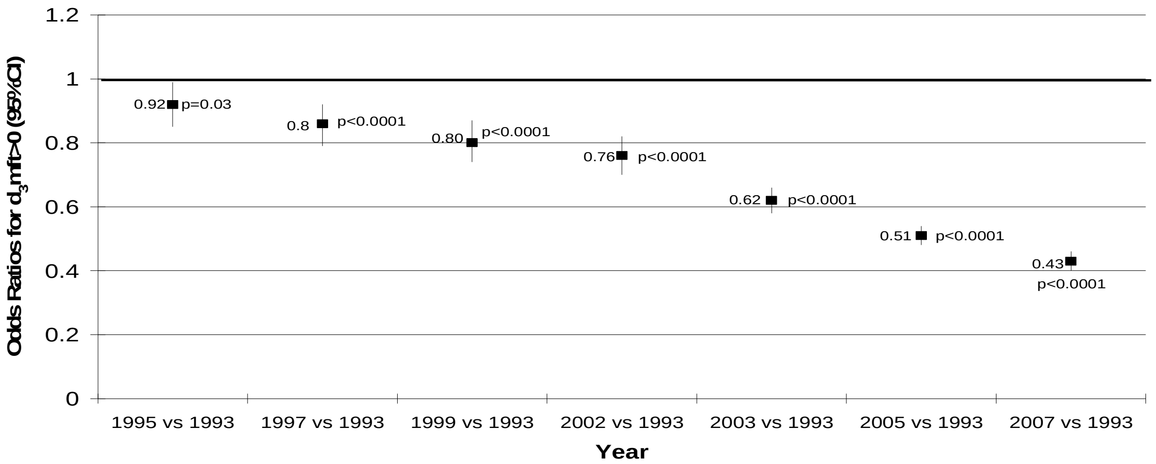
Regression studies indicated that age ($p<0.0001$), sex ($p=0.0007$), DepCat ($p<0.0001$) and status as a resident in Glasgow ($p=0.0045$) all had the potential to modify effects for $d_3mft>0$ in five-year-old Scottish children. Odds-Ratios (OR) for $d_3mft>0$ (adjusted for age, sex and DepCat) were calculated in comparison to 1993/94, as the reference year. Of the total number of subjects, n=68,398, the observations from 1356 subjects were excluded from the following analyses of 'year effects' due to missing values for one or more variables and reported results are based on n=67,042 observations.

6.5.3.1 Scotland

The adjusted (age, sex & DepCat) OR (95%CI) values for $d_3mft>0$, p values (compared to 1993/94) and trends within Scotland as a whole are illustrated in Figure 6-5. A significant steady downward trend is evident throughout the period of study. By

2007/08, the OR (95%CI) for $d_3mft>0$ reached a value of 0.43 (0.40-0.46) compared to the baseline year 1993/94.

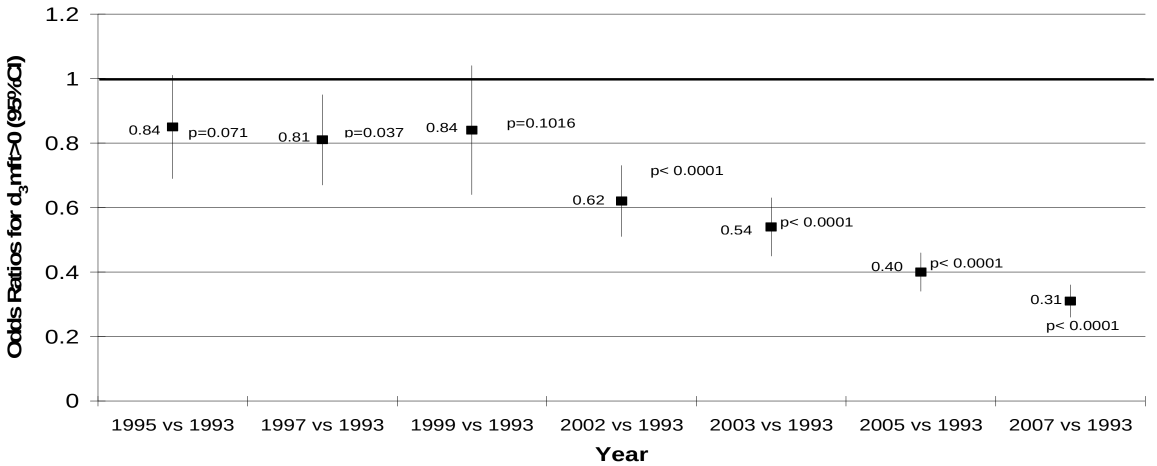
Figure 6-5: The adjusted (age, sex & DepCat) Odds Ratio estimates (Wald 95% CI) and Chi Squared p values for five-year-old children with $d_3mft>0$ in Scotland from 1995/96 to 2007/08 compared to the baseline reference year 1993/94



6.5.3.2 Glasgow

Data similar to that shown above for Scotland are illustrated for Glasgow in Figure 6-6. The adjusted (age, sex & DepCat) ORs for $d_3mft>0$ improved significantly over the period from baseline to T8. However, in the early years a plateau is apparent with no statistically significant improvement in the ORs for $d_3mft>0$ from 1993/94 to 1999/00. Over the later period, there was evidence of a trend towards significant improvement in ORs for $d_3mft>0$. By T8 the OR for $d_3mft>0$ had reached a value of 0.31 (95%CI 0.26-0.38) when compared to the 1993/94 baseline year.

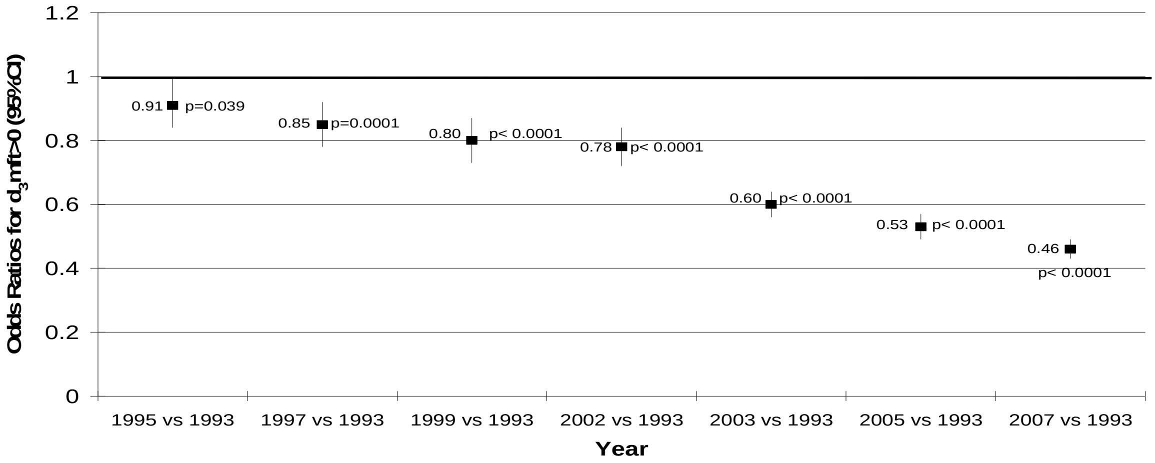
Figure 6-6: Adjusted (age, sex & DepCat) Odds Ratio estimates (Wald 95% CI) and Chi Squared p values for five-year-old children with $d_3mft>0$ in Glasgow from 1995/96 to 2007/08 compared to the reference year 1993/94



6.5.3.3 Not-Glasgow

Data illustrated in Figure 6-7 show that in the rest of Scotland, outwith Glasgow, there were indications of a more general trend in adjusted ORs (95%CIs) over the whole interval from T1.The adjusted OR for $d_3$mft>0 in this geographic area, compared to 1993/94, achieved a value of 0.46 (95%CI 0.43-0.50) by T8.

Figure 6-7: Adjusted (age, sex & DepCat) Odds Ratio estimates (Wald 95% CI) and Chi Squared p values for five-year-old children with $d_3$mft>0 in Not-Glasgow from 1995/96 to 2007/08 compared to the reference year 1993



6.5.4 Overall Odds Ratios (adjusted for age, sex and DepCat) for $d_3$mft>0 compared to 1999/00, in each geographic area

The 1999/00 year is about the mid-point in the cross-sectional datasets and is also the time from which the aforementioned OHP intervention programmes became established. Thus, the trends before and after this date were compared, with 1999/00 as an alternative reference date in regression analyses. The overall Odds Ratios (adjusted for age, sex and DepCat) for $d_3$mft>0 in Scotland, Glasgow and Not-Glasgow in each caries survey year, compared to 1999/00, from logistic procedures are shown in Table 6-5. The ORs for $d_3$mft>0 improved significantly by 1999/00 when compared to the earliest survey year. However, in Scotland as a whole and in the geographic subgroups the magnitude of reduction in ORs for $d_3$mft>0 was greater in the period after 1999/00. The respective differences in ORs from T1 to T4 and from T4 to T8 were 24% and 37% in Scotland, 33% and 57% in Glasgow and 22% and 34% in Not-Glasgow.

Table 6-5: The overall (adjusted for age, sex & DepCat) Odds Ratios (95%CI) and p values for difference in %$d_3$mft>0 in Scotland, Glasgow and Not-Glasgow in 1993/94, 1995/96, 1997/98, 2002/03, 2003/04, 2005/06 & 2007/08 compared to 1999/00

Year	Scotland		Glasgow		Not-Glasgow	
	Odds ratio (95%CI) for $d_3$mft>0 versus 1999/00	P VALUE	Odds ratio for $d_3$mft>0 versus 1999/00	P VALUE	Odds ratio for $d_3$mft>0 versus 1999/00	P VALUE
1993/94	1.31 (1.22-1.42)	p<0.0001	1.49 (1.22-1.82)	p<0.0001	1.29 (1.19-1.40)	p<0.0001
1995/96	1.23 (1.15-1.32)	p<0.0001	1.04 (0.88-1.22)	N/S	1.20 (1.11-1.30)	p<0.0001
1997/98	1.13 (1.06-1.21)	P<0.001	1.06 (0.90-1.25)	N/S	1.10 (1.02-1.19)	p<0.02
1999/00	OR =1.00 (Reference year)					
2002/03	1.14 (1.07-1.21)	p<0.0001	0.95 (0.82-1.11)	N/S	1.13 (1.06-1.22)	P<0.001
2003/04	0.91 (0.86-0.97)	p<0.01	0.73 (0.64-0.84)	p<0.0001	0.84 (0.69-0.89)	p<0.0001
2005/06	0.72 (0.68-0.77)	p<0.0001	0.51 (0.44-0.59)	p<0.0001	0.74 (0.69-0.79)	p<0.0001
2007/08	0.63 (0.60-0.67)	p<0.0001	0.43 (0.37-0.50)	p<0.0001	0.66 (0.62-0.71)	p<0.0001

6.5.5 The Odds Ratios (adjusted by age and sex) for $d_3$mft>0, by year, compared to 1999/00, in each DepCat

The results of the analysis of the ORs for $d_3$mft>0 (adjusted for age & sex) in the discrete DepCat communities in the three geographic areas are shown for each survey year in Tables 6-6, 6-7 and 6-8. In the period from 1993/94, when compared to 1999/00, there is evidence of significant improvements in the OR (95%CI) for $d_3$mft>0 in Scotland and Not-Glasgow in respective DepCat 4, 5 and 6 communities. However, during this time in Glasgow, only the DepCat 4 community improved their position and this did not reach significance. Nevertheless, during the later period from 1999/00 onwards, a pattern of significant overall improvements in the ORs (95%CI) in five-year-olds may be observed in the respective geographic areas. This trend became increasingly consistent across the DepCat categories in the later survey years.

6.5.5.1 Scotland

Table 6-6: Adjusted Odds Ratios (Wald 95%CI) and p values for $d_3mft>0$ in each DepCat category in Scotland following the logistic procedure. Study years are compared to 1999/00. Values highlighted in bold reached statistical significance at the level p<0.05

Area	Year v 1999/00	1993/94		1995/96		1997/98		2002/03		2003/04		2005/06		2007/08	
	DepCat	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for d3mft>0	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE
Scotland	1	1.11 0.78-1.57	N/S	1.36 0.98-1.89	N/S	1.4 0.85-1.55	N/S	1.02 0.74-1.41	N/S	0.85 0.64-1.14	N/S	0.63 0.47-0.83	p=0.001	0.61 0.46-0.81	p<0.001
	2	1.12 0.89-1.40	N/S	1.10 0.90-1.35	N/S	1.09 0.89-1.33	N/S	1.16 0.96-1.39	N/S	0.93 0.78-1.10	N/S	0.76 0.64-0.90	p=0.002	0.63 0.53-0.74	p<0.0001
	3	1.16 1.01-1.34	N/S	1.13 0.99-1.29	N/S	1.05 0.92-1.20	N/S	0.94 0.83-1.06	N/S	0.78 0.69-0.88	p<0.0001	0.68 0.60-0.77	p<0.0001	0.58 0.51-0.65	p<0.0001
	4	1.28 1.10-1.50	p<0.002	1.19 1.04-1.37	p<0.02	1.09 0.95-1.26	N/S	1.09 0.96-1.23	N/S	0.98 0.87-1.12	N/S	0.73 0.64-0.82	p<0.0001	0.66 0.58-0.74	p<0.0001
	5	1.24 1.01-1.53	p<0.05	1.38 0.93-1.40	N/S	0.97 0.80-1.19	N/S	0.99 0.83-1.19	N/S	0.79 0.66-0.95	p<0.05	0.68 0.56-0.81	p<0.0001	0.58 0.49-0.68	p<0.0001
	6	1.40 1.09-1.81	p<0.01	1.04 0.82-1.31	N/S	0.90 0.72-1.13	N/S	1.01 0.82-1.24	N/S	0.73 0.60-0.90	p<0.01	0.63 0.51-0.77	p<0.0001	0.51 0.42-0.62	p<0.0001
	7	1.07 0.79-1.45	N/S	0.97 0.73-1.28	N/S	1.11 0.83-1.47	N/S	0.88 0.68-1.14	N/S	0.64 0.50-0.81	p<0.001	0.54 0.42-0.69	p<0.0001	0.38 0.30-0.49	p<0.0001

1999/00 reference year
OR = 1.0

6.5.5.2 Glasgow

Table 6-7: Adjusted Odds Ratios (Wald 95%CI) and p values for $d_3mft>0$ in each DepCat category in Glasgow following the logistic procedure. Study years are compared to 1999/00. Values highlighted in bold reached statistical significance at the level $p<0.05$

Area	Year *v* 1999/00	1993/94		1995/96		1997/98		2002/03		2003/04		2005/06		2007/08	
	DepCat	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE
Glasgow	1	1.80 0.66-4.88	N/S	1.40 0.76-2.55	N/S	1.25 0.67-2.32	N/S	0.82 0.37-1.84	N/S	1.07 0.62-1.86	N/S	0.57 0.34-0.95	p<0.05	0.52 0.32-0.87	p<0.05
	2	1.36 0.62-2.99	N/S	1.44 0.92-2.27	N/S	1.23 0.74-2.04	N/S	1.43 0.90-2.28	N/S	1.46 0.98-2.17	N/S	1.00 0.66-1.52	N/S	0.88 0.56-1.39	N/S
	3	1.04 0.55-1.92	N/S	1.20 0.70-2.04	N/S	1.27 0.74-2.18	N/S	0.89 0.54-1.45	N/S	0.79 0.50-1.25	N/S	0.46 0.29-0.74	p=0.001	0.59 0.37-0.94	p<0.05
	4	1.22 0.67-2.24	N/S	0.93 0.56-1.52	N/S	0.64 0.39-1.06	N/S	0.69 0.44-1.08	N/S	0.59 0.38-0.90	p<0.05	0.36 0.24-0.56	p<0.0001	0.30 0.18-0.47	p<0.0001
	5	0.92 0.47-1.79	N/S	1.18 0.64-2.18	N/S	0.96 0.54-1.72	N/S	0.87 0.52-1.47	N/S	0.79 0.48-1.30	N/S	0.63 0.38-1.05	N/S	0.42 0.26-0.67	p=0.0004
	6	0.90 0.53-1.53	N/S	0.68 0.44-1.07	N/S	0.47 0.30-0.74	p=0.001	0.58 0.37-0.91	p<0.05	0.48 0.32-0.72	p<0.001	0.39 0.26-0.60	p<0.0001	0.28 0.19-0.41	p<0.0001
	7	1.10 0.77-1.57	N/S	0.88 0.64-1.21	N/S	1.23 0.88-1.71	N/S	0.76 0.56-1.02	N/S	0.56 0.42-0.73	p<0.0001	0.54 0.41-0.72	p<0.0001	0.33 0.25-0.44	p<0.0001

1999/00 reference year
OR = 1.0

6.5.5.3 Not-Glasgow

Table 6-8: Adjusted Odds Ratios (Wald 95%CI) and p values for $d_3mft>0$ in each DepCat category in Not-Glasgow following the logistic procedure. Study years are compared to 1999/00. Values highlighted in bold reached statistical significance at the level p<0.05

Area	Year v 1999/00	1993/94		1995/96		1997/98		2002/03		2003/04		2005/06		2007/08	
	DepCat	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE	Odds Ratio (95%CI)] for $d_3mft>0$	P VALUE
Not Glasgow	1	1.06 0.72-1.56	N/S	1.33 0.90-1.98	N/S	1.12 0.79-1.58	N/S	1.06 0.74-1.53	N/S	0.77 0.54-1.08	N/S	0.67 0.47-0.95	p<0.05	0.68 0.48-0.97	p<.0.05
	2	1.08 0.85-1.36	N/S	1.07 0.84-1.35	N/S	1.08 0.87-1.35	N/S	1.13 0.92-1.38	N/S	0.79 0.65-0.96	p=0.02	0.74 0.61-0.89	p<0.05	0.60 0.49-0.72	p=0.002
	3	1.17 1.02-1.35	N/S	1.11 0.97-1.28	N/S	1.03 0.90-1.18	N/S	0.93 0.82-1.6	N/S	0.76 0.66-0.86	p<0.0001	0.71 0.63-0.81	p<0.0001	0.57 0.50-0.64	p<0.0001
	4	1.28 1.09-1.50	p=0.002	1.18 1.02-1.37	p<0.05	1.13 0.98-1.03	N/S	1.10 0.97-1.26	N/S	0.97 0.84-1.11	N/S	0.76 0.67-0.87	p<0.0001	0.70 0.61-0.79	p<0.0001
	5	1.28 1.03-1.59	p<.0.05	1.13 0.91-1.40	N/S	0.97 0.76-1.20	N/S	1.01 0.83-1.22	N/S	0.77 0.63-0.93	p<0.01	0.68 0.56-0.82	p<0.0001	0.63 0.53-0.76	p<0.0001
	6	1.60 1.20-2.13	p<0.01	1.10 0.83-1.45	N/S	1.12 0.86-1.46	N/S	1.19 0.93-1.51	N/S	0.72 0.56-0.92	p=0.01	0.70 0.55-0.89	p<0.01	0.63 0.50-0.80	p=0.0002
	7	1.01 0.55-1.86	N/S	1.28 0.69-2.37	N/S	0.79 0.48-1.39	N/S	1.55 0.89-2.69	N/S	1.13 0.61-2.09	N/S	0.40 0.23-0.69	p=0.001	0.63 0.38-1.06	N/S

1999/00 reference year
OR = 1.0

6.6 Trends in overall survey mean $d_3$mft (weighted for DepCat) in the three geographic areas

Data illustrated in Figure 6-8 show the trends in overall mean $d_3$mft (95%CI) weighted by DepCat, for the five-year-old population at each time point in the respective geographic areas. The mean values and 95%CIs are shown in Table 6-9. The weighted mean $d_3$mft (95%CI) was significantly greater in Glasgow, compared to the Not-Glasgow geographic area at each of the cross-sectional surveys. The trends are towards reducing overall mean $d_3$mft scores in each of the areas.

Figure 6-8: The overall weighted (by DepCat) mean $d_3$mft (95%CI) for five-year-olds at each time point T1 to T8 in the three geographic areas

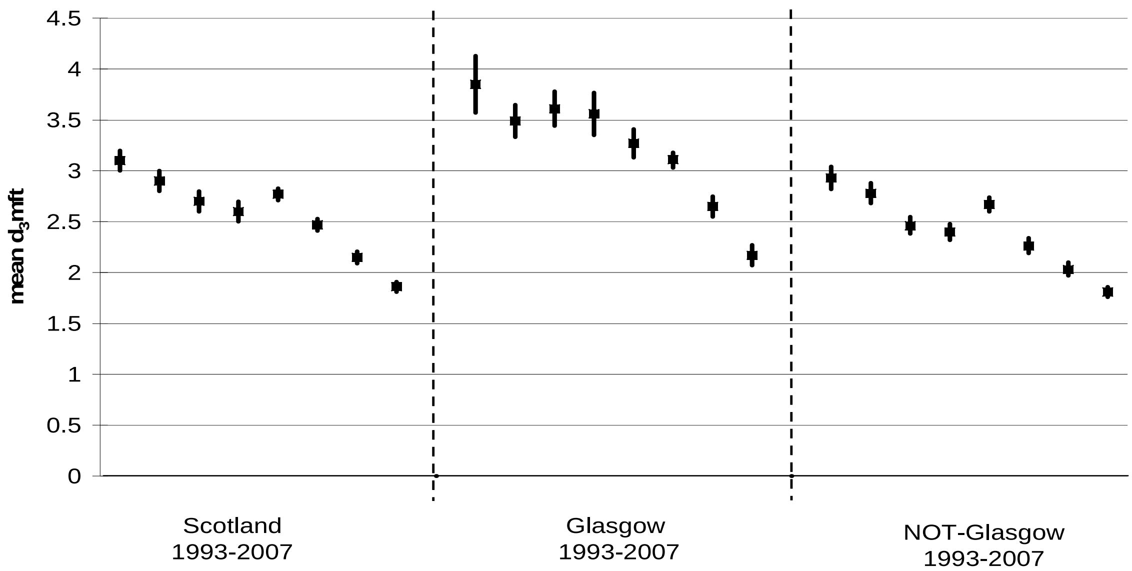


Table 6-9: The overall weighted (by DepCat) mean $d_3$mft (95%CI) in Scotland, Glasgow and Not-Glasgow at successive surveys from T1 to T8

	1993	1995	1997	1999	2002	2003	2005	2007
Scotland weighted mean $d_3$mft (95%CI)	3.1 (3.0-3.2)	2.9 (2.8-3.0)	2.7 (2.6-2.8)	2.6 (2.5-2.7)	2.8 (2.7-2.8)	2.5 (2.4-2.5)	2.2 (2.1-2.2)	1.9 (1.8-1.9)
Glasgow weighted mean $d_3$mft (95%CI)	3.8 (3.6-4.1)	3.5 (3.3-3.5)	3.6 (3.4-3.8)	3.6 (3.4-3.8)	3.3 (3.1-3.4)	3.1 (3.0-3.2)	2.7 (2.6-2.8)	2.2 (2.1-2.3)
Not-Glasgow weighted mean $d_3$mft (95%CI)	2.9 (2.8-3.0)	2.8 (2.7-2.9)	2.5 (2.4-2.5)	2.4 (2.3-2.5)	2.7 (2.6-2.7)	2.3 (2.2-2.3)	2.0 (2.0-2.1)	1.8 (1.8-1.9)

6.7 Trends in mean $d_3$mft by DepCat and year

6.7.1 Scotland

Data for Scotland illustrated in Figure 6-9 indicates that during each cross-sectional survey there was a marked SES gradient in the five-year-old population's burden of $d_3$mft, with a direct relationship apparent between disadvantage and extent of caries morbidity. Mean $d_3$mft decreased over the interval T1 to T8 within each SES category. The mean $d_3$mft of Scotland's DepCat 1 and DepCat 7 communities' children reduced, respectively, from 1.3 (95%CI 0.9-1.6) to 0.7 (95%CI 0.6-0.9) and from 5.0 (95%CI 4.6-5.4) to 3.1 (95%CI 2.9-3.4). Thus, in the extreme SES groups the respective absolute reductions were 0.6 and 1.9 $d_3$mft. The significances of differences from the 1999/00 values, when this year is used as the reference year appear in Table 6-10.

Figure 6-9: Mean $d_3$mft of Scotland's P1 children in each DepCat category by year: 1993-2007

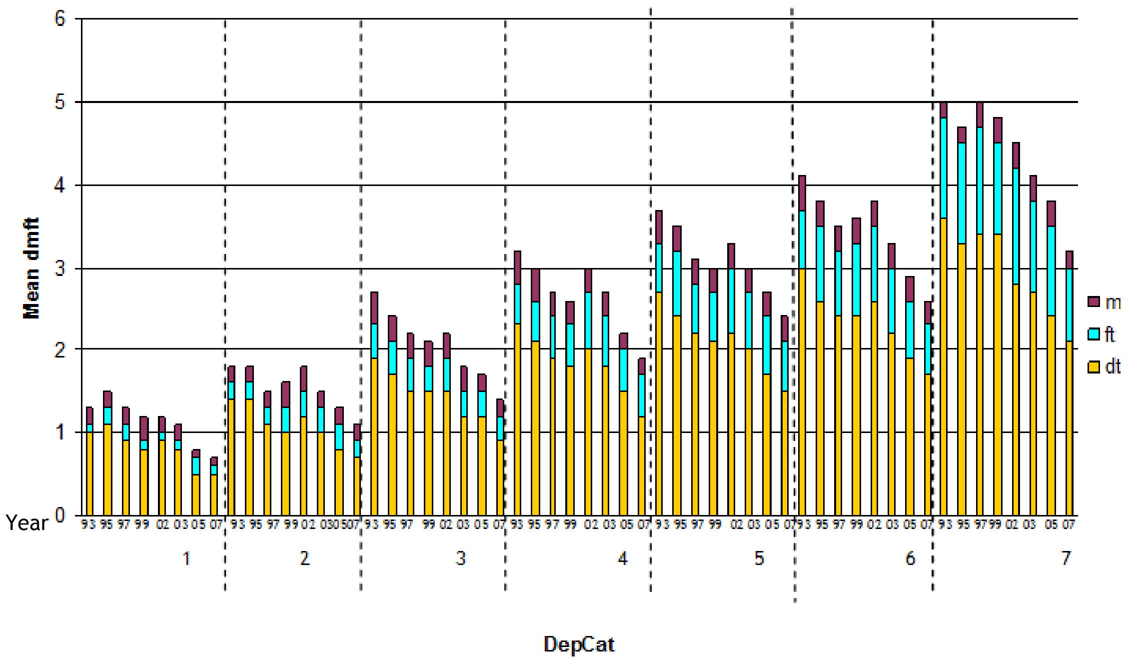


Table 6-10: The Wilcoxon test p values for distribution of data underlying the mean $d_3$mft scores in Scotland by DepCat and year, compared to 1999/00 [bold shading indicates p<0.05]

	Year	1993/94 P VALUE	1995/96 P VALUE	1997/98 P VALUE	2002/03 P VALUE	2003/04 P VALUE	2005/06 P VALUE	2007/08 P VALUE
Scotland *v* 1999/00	DepCat 1	0.596	0.065	0.397	0.911	0.353	p=0.002	p<0.001
	DepCat 2	0.146	0.107	0.351	p=0.045	0.658	p=0.004	p<0.001
	DepCat 3	p=0.001	p=0.034	0.464	0.510	p<0.001	p<0.001	p<0.001
	DepCat 4	p<0.001	p<0.001	0.267	p=0.006	0.597	p<0.001	p<0.001
	DepCat 5	p<0.001	0.056	0.810	0.137	0.179	p<0.001	p<0.001
	DepCat 6	p=0.039	0.275	0.314	0.418	0.056	p<0.001	p<0.001
	DepCat 7	0.456	0.830	0.270	0.428	p=0.004	p<0.001	p<0.001

Although there is some evidence of improvement by 1999/00, compared to early years in DepCat 3, 4, 5, & 6, it was not until 2005/06 that a consistent and statistically significant improvement occurred across the whole DepCat spectrum simultaneously.

6.7.2 Glasgow

Similar trends were observed in the Glasgow geographic area over the corresponding period and these are illustrated in Figure 6-10. The associated significances for year differences, compared to the 1999/00 reference year, are shown in Table 6-11.

Figure 6-10: Mean $d_3$mft of Glasgow's P1 children in each DepCat category by year: 1993-2007

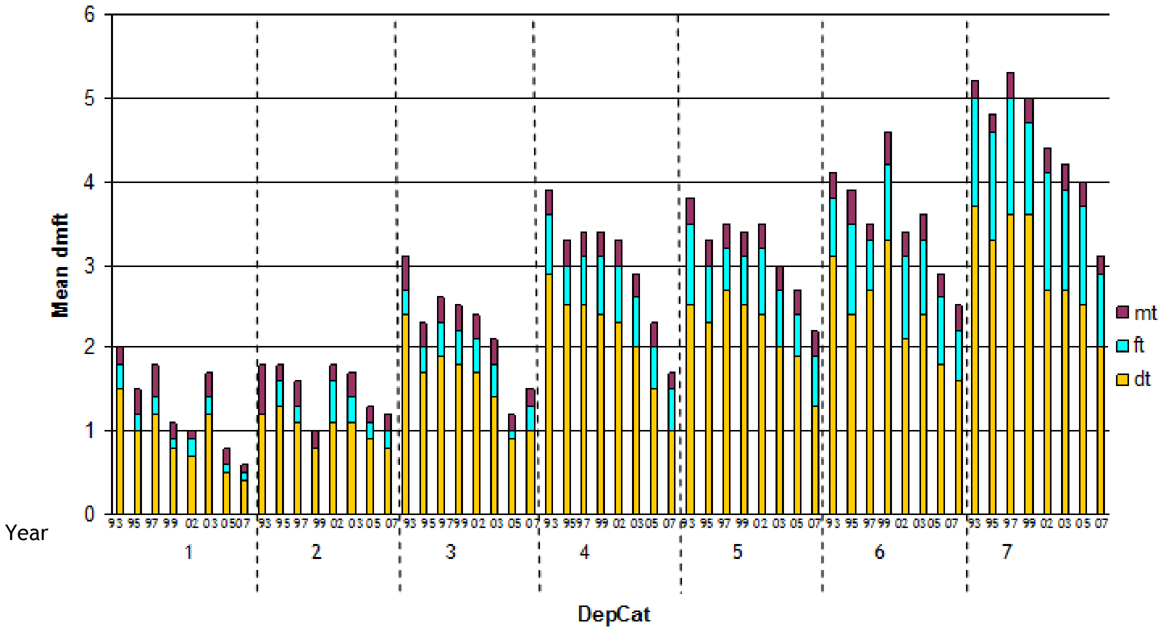


Table 6-11: The Wilcoxon test p values for distribution of data underlying the $d_3$mft scores in Glasgow by DepCat and year, compared to 1999/00 [bold shading indicates p<0.05]

	Year	1993/94 P VALUE	1995/96 P VALUE	1997/98 P VALUE	2002/03 P VALUE	2003/04 P VALUE	2005/06 P VALUE	2007/08 P VALUE
Glasgow *v* 1999/00	DepCat 1	0.195	0.211	0.320	0.558	0.451	p=0.034	p=0.009
	DepCat 2	0.243	p=0.031	0.178	p=0.043	p=0.019	0.666	0.866
	DepCat 3	0.504	0.734	0.392	0.931	0.379	p<0.001	p=0.015
	DepCat 4	0.281	0.793	0.473	0.377	0.107	p<0.001	p<0.001
	DepCat 5	0.949	0.9905	0.890	0.868	0.235	p=0.072	p<0.001
	DepCat 6	0.338	0.116	p=0.002	p=0.002	p=0.002	p<0.001	p<0.001
	DepCat 7	0.579	0.846	0.139	0.086	p<0.001	p<0.001	p<0.001

In 1993/94, both the mean $d_3$mft for DepCat 1 children and DepCat 7 children in Glasgow were poorer than the means for Scotland as a whole with respective values of 2.0 (95%CI 0.5-3.5) and 5.2 (95%CI 4.7-5.6). However, by 2007/08, the mean $d_3$mft values of the extreme SES groups were similar i.e. 0.6 (95%CI 0.5-0.8) and 3.1 (95%CI

2.8-3.4) respectively. With the exception of DepCat 2, convincing improvements did not occur across the DepCat spectrum until the later two survey years.

6.7.3 The rest of Scotland, Not-Glasgow

The trends in the rest of Scotland, Not-Glasgow, can be seen in Figure 6-11. Respective mean $d_3$mft values for DepCats 1 & 7 in 1993/94 and 2007/08 were 1.2 (95%CI 0.9-1.6) and 4.5 (95%CI 3.5-5.4) at T1 and latterly 0.9 (95%CI 0.6-1.1) and 3.3 (95%CI 2.7-3.8). Data in Table 6-12 indicate the associated p values compared to 1999/00, as the reference year.

Figure 6-11: Mean $d_3$mft of Not-Glasgow's P1 children in each DepCat category by year: 1993-2007

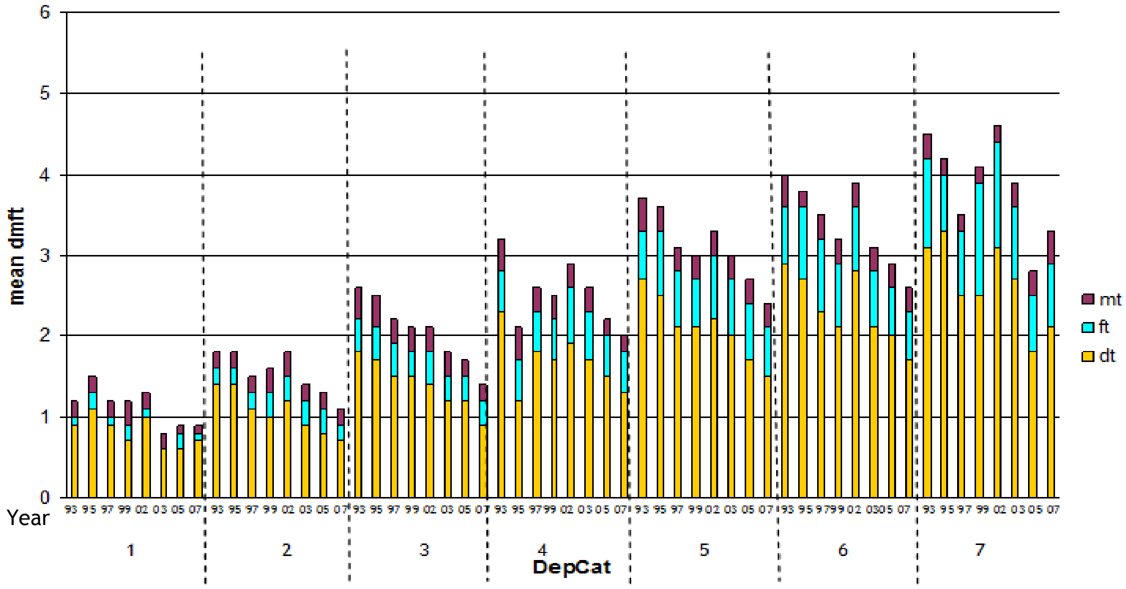


Table 6-12: The Wilcoxon test p values for distribution of data underlying the raw $d_3$mft scores in Not-Glasgow by DepCat and year, compared to 1999/00 [bold shading indicates p<0.05]

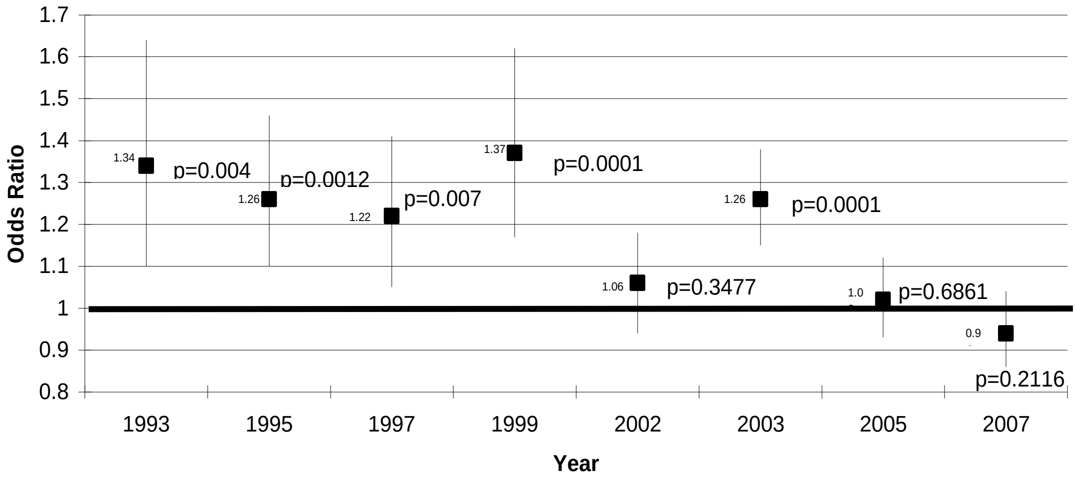
	Year	1993/94 P VALUE	1995/96 P VALUE	1997/98 P VALUE	2002/03 P VALUE	2003/04 P VALUE	2005/06 P VALUE	2007/08 P VALUE
Not-Glasgow *v* 1999/00	DepCat 1	0.824	0.179	0.628	0.734	0.099	p=0.032	p=0.033
	DepCat 2	0.347	0.287	0.569	0.158	p=0.042	p=0.002	p<0.001
	DepCat 3	p=0.002	p=0.043	0.703	0.422	p<0.001	p<0.001	p<0.001
	DepCat 4	p<0.001	p=0.001	0.225	p=0.005	0.897	p<0.001	p<0.001
	DepCat 5	p<0.001	p=0.046	0.817	0.114	0.226	p=0.002	p<0.001
	DepCat 6	p=0.004	0.124	0.540	p=0.006	0.064	p=0.037	p<0.001
	DepCat 7	0.560	0.511	0.436	0.095	0.920	p=0.006	p=0.115

Statistically significant improvements in mean d_3mft scores were observed in several SES groups by 1999/00, compared to before. However, it was not until the later period from 2005/06 onward that consistent improvements occurred across the SES spectrum.

6.8 Odds Ratios (adjusted for age, sex & DepCat) for $d_3mft>0$ in Glasgow compared to the rest of Scotland, from 1993/94 to 2007/08

Odds Ratios were computed to assess whether there was any indication of systematic detriment to five-year-olds' dental health associated with their residence in Glasgow. The results can be seen in Figure 6-12 which illustrates the ORs, Wald 95%CI (adjusted for age, sex and DepCat) for $d_3mft>0$ of five-year-olds residing in Glasgow, compared to those in the remainder of Scotland at each of the cross-sectional surveys, based on n=67,042 observations. A very significant unfavourable and consistent, so-called '*Glasgow Effect*' on five-year-olds' dental health outcomes is evident, until 2002/03, over and above that of SES deprivation. Compared to peers from the rest of Scotland, initially, Glasgow five-year-olds had an increased likelihood (odds) of having $d_3mft>0$. However, from 1999/00 onwards, the apparent Glasgow geographic detriment to P1s dental health diminished. By the later times there is no evidence of significant difference in the odds of $d_3mft>0$ occurring in Glasgow P1s, compared to the children from the rest of Scotland.

Figure 6-12: Odds Ratio (Wald 95%CI) adjusted by age, sex & DepCat for $d_3mft>0$ for five-year-old children resident in Glasgow compared to Not-Glasgow over the period 1993-2007



There is a clear statistically significant excess of five-year-old children with $d_3mft>0$ associated with living in Glasgow at all time points, up to, and including, 1999/00 ($p<0.01$, at each cross-sectional survey after adjusting by DepCat to remove the confounding effect of deprivation). Moreover, over and above, when compared to baseline (1993/94), this '*Glasgow effect*' appears to have been mitigated and substantially decreased by 2005 ($p<0.0001$), and beyond. After this time there no longer remained any significant difference in ORs for five-year-old $d_3mft>0$ associated with living in Glasgow, compared to the rest of Scotland.

6.9 Other effects

The relationship between the '*Glasgow effect*' and simultaneous SES deprivation assessed by DepCat score was explored. There was a further statistically significant detrimental effect on some five-year-old Glasgow children's dental health, over and above that described as the '*Glasgow effect*'. This further effect was directly associated with residence in both DepCat 4 and DepCat 7 communities, Chi-Square values 10.5990 (p=0.0011) and 14.3205 (p=0.0002), respectively.

6.9.1 Some factors associated with $d_3mft>0$ effects in Scottish five-year-old children

The results of logistic procedures to explore the relative effects of the variables age, sex, DepCat and *'status as a resident in Glasgow'* on the $d_3mft>0$ of Scotland's five-year-old children, by year, are shown in Table 6-13. Of the variables explored, age and DepCat were significantly associated with $d_3mft>0$. Although age was significantly associated with $d_3mft>0$, in Scotland, Table 6-3 showed that the difference in mean age of subjects over the cross-sectional surveys did not exceed a maximum of 0.2 years, overall. DepCat score had the greatest, most highly statistically significant and consistent association with $d_3mft>0$. Moreover, up to and including 1999/00 there was evidence of a consistent association between residence in Glasgow and $d_3mft>0$ in the age group. However, in 2002/03, 2005/06 and 2007/08 this earlier association was no longer apparent.

Table 6-13: The Chi Square values and p values from logistic regression analysis of the effects of age, sex, DepCat and 'status as a resident in Glasgow' on five-year-old Scottish children's dental health ($d_3mft>0$), T1 to T8

	Age effect		**Gender effect**		**DepCat effect**		**Effect of residence in Glasgow**	
Year	**p value**	**Chi-Square value (Wald)**	**p value**	**Chi-Square value (Wald)**	**p value**	**Chi-Square value (Wald)**	**p value**	**Chi-Square value (Wald)**
1993/94	p<0.0001	15.7573	N/S	1.588	p<0.0001	232.3452	p=0.0045	8.0587
1995/96	p<0.0102	6.5955	N/S	0.2915	p<0.0001	253.003	p=0.0012	10.4482
1997/98	p<0.0001	22.7013	N/S	0.0247	p<0.0001	280.2915	p=0.0079	7.0553
1999/00	p=0.0004	12.7341	N/S	0.0057	p<0.0001	301.0612	p<0.0001	14.5642
2002/03	p=0.0013	10.4078	N/S	2.3273	p<0.0001	393.8286	N/S	0.8817
2003/04	p<0.0001	33.7403	p=0.005	7.8889	p<0.0001	437.6177	p<0.0001	24.3886
2005/06	p<0.0001	38.0125	p=0.0066	7.3794	p<0.0001	483.126	N/S	0.1633
2007/08	p<0.0001	93.24	N/S	0.0428	p<0.0001	448.4167	N/S	1.5605

Chapter 7

7 Inequalities outcomes (Results 2)

7.1 Introduction

The results of the various previously validated tests of inequality which were applied to the master caries dataset are described and illustrated in the following sections.

7.2 Simple tests of dental health inequality

7.2.1 Absolute and relative geographic dental health inequality

Comparing five-year-old Glasgow children with children from the remainder of Scotland, the simple trends in both absolute and relative inequality in the values for weighted mean $d_3$mft and % of children with $d_3$mft>0 may be examined in Table 7-1. Whilst these data suggest that absolute inequality for both indices has reduced substantially, overall, across the period, with respect to both weighted mean $d_3$mft and % $d_3$mft>0, there is little evidence of convincing decreases in relative inequality. There are indications that both absolute and relative geographic inequality in the five-year-old population burden of $d_3$mft and its prevalence increased in the late 1990s, peaking in 1999/00 and decreasing thereafter.

Table 7-1: Simple absolute and relative geographic inequality in weighted $d_3$mft and % $d_3$mft>0 between Glasgow and the remainder of Scotland at geographic level

Inequality: **Glasgow *vs.* Not-Glasgow**	**Year**							
	1993/94	1995/96	1997/98	1999/00	2002/03	2003/04	2005/06	2007/08
For weighted mean $d_3$mft, absolute inequality =	0.92	0.71	1.15	1.16	0.6	0.85	0.62	0.36
For weighted mean $d_3$mft, relative inequality=	1.3	1.26	1.47	1.48	1.2	1.38	1.31	1.2
For weighted % $d_3$mft>0 absolute inequality =	11	11	10	14	8	12	8	5
For weighted % $d_3$mft>0 relative inequality =	1.19	1.2	1.19	1.27	1.15	1.26	1.18	1.12

7.2.2 Simple absolute and relative SES related dental health inequality

7.2.2.1 Prevalence of $d_3$mft>0

Following the recommendations of Keppel *et al.* (2005), the simple absolute and simple relative SES inequality in prevalence of $d_3$mft>0 at each of the geographic levels in each survey year are shown in Table 7-2 using a morbidity measure ($d_3$mft>0) rather than a measure of health ($d_3$mft=0).

Table 7-2: The simple absolute and relative inequality in %$d_3$mft>0, comparing five-year-old children in DepCat 7*vs.*DepCat 1 communities within each of the geographic levels: Scotland, Glasgow and Not-Glasgow at successive surveys, 1993/94 to 2007/08

Geographic area		Scotland		Glasgow		Not-Glasgow	
		Simple SES inequality in % $d_3$mft>0					
YEAR		Absolute	Relative	Absolute	Relative	Absolute	Relative
1993		44.6	2.28	34.5	1.73	36.3	2.08
1995		38.1	1.96	37.2	1.9	35.9	1.92
1997		44.5	2.25	45	2.17	29.7	1.85
1999		45.7	2.4	47.1	2.41	37.4	2.15
2002		43.1	2.3	46.4	2.58	44.5	2.32
2003		40.5	2.39	34.6	1.99	45.4	2.69
2005		42.7	2.83	46.7	3.1	23.7	1.97
2007		35.3	2.54	37	2.78	34.7	2.4
From Meta-analysis of trend in the years 1993 to 2007	p value	N/S	$p<0.05$	N/S	$p<0.02$	N/S	N/S
	R^2 value		R^2=0.55		R^2=0.66		

At baseline (1993/94), Glasgow had the lowest simple absolute and relative SES inequality in five-year-old percentage of children with $d_3$mft>0, due to the substantially poorer dental health experience in the Glasgow DepCat 1 community compared to the rest of Scotland. However, by 2007/08, although the prevalence of $d_3$mft>0 was by then lower in Glasgow than in the rest of Scotland at both the extremes of the SES spectrum, both the simple absolute and simple relative SES inequality had increased. The increase in simple relative inequality was significant in Scotland as a whole and in Glasgow ($p<0.05$, R^2 value = 0.55; $p<0.02$, R^2 value = 0.66, respectively). No consistent trend in simple absolute inequality was evident in the geographic areas over the period.

7.2.2.2 Mean $d_3$mft

Table 7-3 shows the absolute and relative SES inequality in mean $d_3$mft score between the extreme SES groups (DepCat 1=reference group) at baseline and in 2007/08. While absolute inequality has decreased to a similar level in all of the geographic areas, relative inequality in $d_3$mft has increased. This trend has been most marked in Glasgow due to the magnitude of the proportional improvement in the mean $d_3$mft of the resident DepCat 1 group, from baseline, compared to that in the DepCat 7 community. Meta-analyses by regression of trends indicates that in Scotland as a whole there was a significant improvement in simple absolute SES inequality in mean $d_3$mft ($p<0.02$, R-squared value 0.66) which was simultaneous with an increase in simple relative inequality, which just failed to reach significance ($p=0.055$).

Table 7-3: The simple absolute and relative inequality in mean $d_3$mft scores comparing five-year-old children in DepCat 7*vs.*DepCat 1 communities within each of the geographic levels: Scotland, Glasgow and Not-Glasgow at successive surveys, 1993/94 and 2007/08

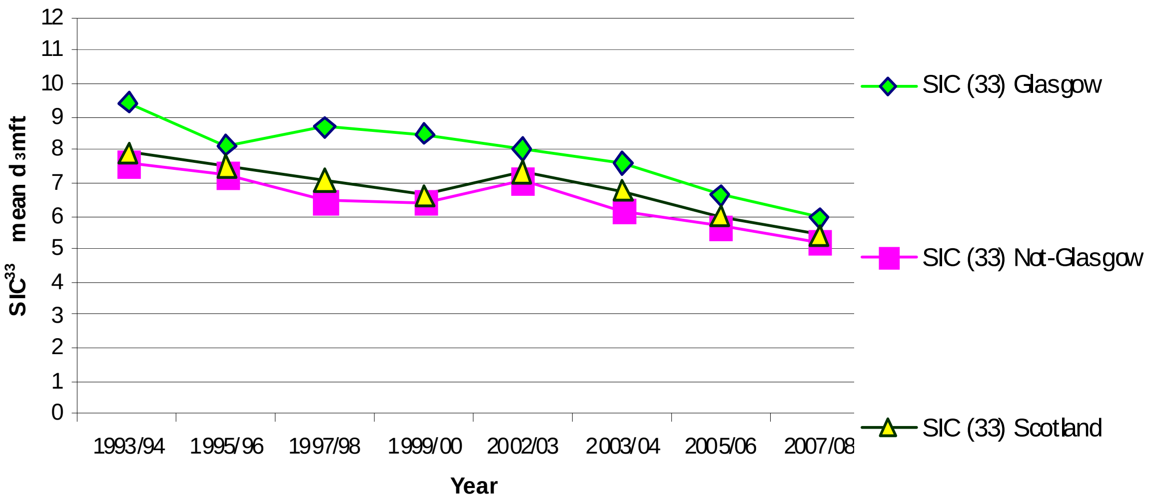
Geographic area		Scotland		Glasgow		Not-Glasgow	
		Simple SES inequality in mean $d_3$mft score					
YEAR		Absolute	Relative	Absolute	Relative	Absolute	Relative
1993		3.7	3.85	3.2	2.6	3.3	3.75
1995		3.2	3.13	3.3	3.2	2.7	2.8
1997		3.7	3.85	3.5	2.9	2.3	2.9
1999		3.6	4	3.9	4.54	2.9	3.4
2002		3.3	3.75	3.4	4.4	3.3	3.54
2003		3	3.71	2.5	2.47	3.5	4.88
2005		3	4.75	3.2	5	1.9	3.11
2007		2.5	4.57	2.4	5.16	2.4	3.66
From Meta-analysis of trend in the years 1993 to 2007	p value	p<0.02	p<0.055	N/S	p<0.062	N/S	N/S
	R^2 value	R^2=0.66	R^2=0.48		R^2=0.46		

7.2.3 Significant Caries Index (SIC and SIC[10])

7.2.3.1 SIC

The SIC values derived from the mean $d_3$mft of the worst affected third of the five-year-old populations are illustrated in Figure 7-1, at each cross-sectional survey, for the three geographic areas of interest, respectively. In all three geographic areas, the trends have been for SIC to diminish significantly (p<0.01, respectively).

Figure 7-1: Respective SIC values for five-year-old infants in Scotland, Glasgow and Not-Glasgow and over the period 1993/94 to 2007/08



Moreover, the amplitude of the gap between the SIC for Glasgow five-year-old children and those residing in the remainder of Scotland has decreased over time, indicating that by this measure inequality between the geographic areas has decreased significantly [a Meta-analysis using the Generalised Linear Model (GLM) procedure indicated that there was a significant difference in trend ($p<0.0001$) over the period and evidence of a year effect ($p<0.0001$) and an interaction between year and geographic area ($p<0.0001$)].

Over the interval from 1993/94, geographic inequality in the SIC value between Glasgow and the rest of Scotland decreased from 1.81 to 0.71 $d_3$mft for absolute inequality and from 1.24 to 1.14 for relative inequality. The results of Meta-analysis (Regression Procedure) of data from the eight surveys indicate that the respective R-Square values for the SIC in Scotland, Glasgow and Not-Glasgow are 0.77 ($p<0.005$), 0.83 ($p<0.002$) and 0.76 ($p<0.005$).

7.2.3.2 The SIC^{10} (which may be interpreted as a simple absolute / relative measure or a complex absolute measure)

The mean $d_3$mft of the SIC^{10} for all deciles of the five-year-old populations are illustrated for Scotland (in Figure 7-2), Glasgow (Figure 7-3) and Not-Glasgow (Figure 7-4). Depending on how the SIC^{10} is interpreted, it may be used to give a simple absolute or a simple relative measure of inequality (i.e. the mean $d_3$mft of the worst affected decile, compared to that with the best dental health). The SIC^{10} may also be viewed as a measure of complex absolute inequality i.e. by examination of the whole SIC^{10} distribution.

Figure 7-2: Scotland: SIC^{10} values for five-year-old population deciles over the period from 1993/94 to 2007/08

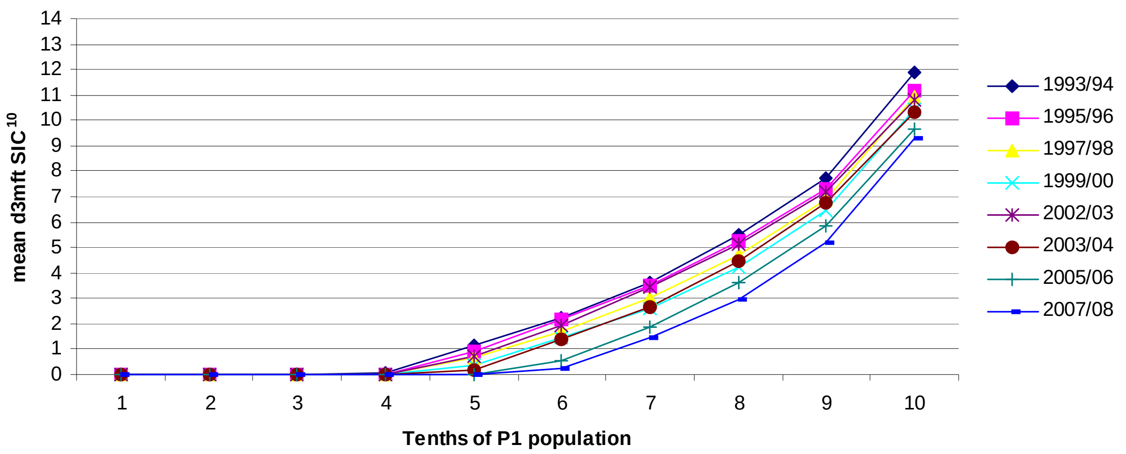


Figure 7-3: Glasgow: SIC[10] values for five-year-old population deciles over the period from 1993/94 to 2007/08

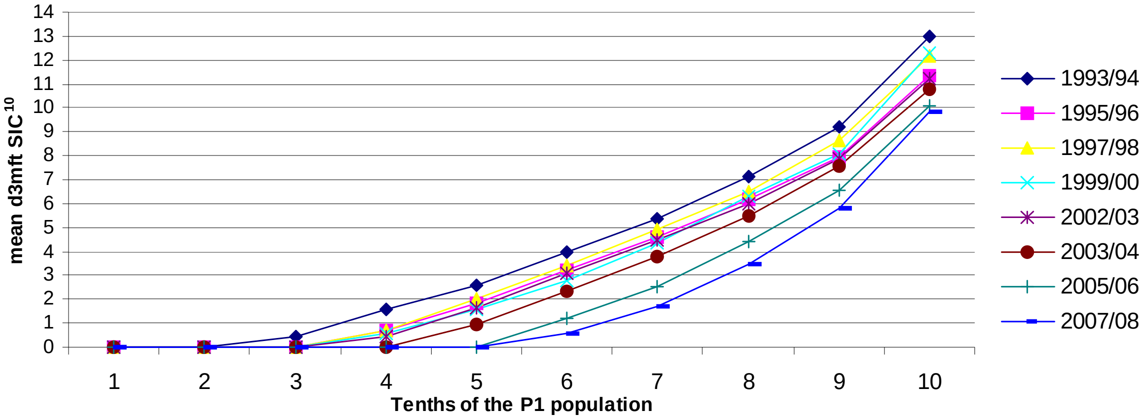
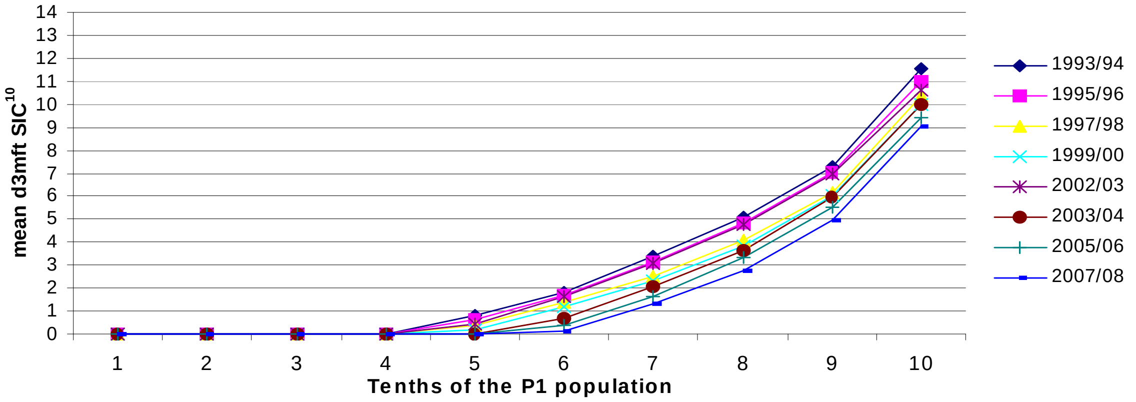


Figure 7-4: Not-Glasgow: SIC[10] values for five-year-old population deciles over the period from 1993/94 to 2007/08



Prior to 2005/06, the substantial majority of the Glasgow five-year-old population had $d_3mft>0$ experience. The SIC^{10} profile of Glasgow five-year-old children improved considerably in the later years compared to baseline (1993/94), even in the worst affected deciles, where gains amount to decreases in the order of three to four d_3mf teeth.

In Glasgow, the SIC^{10} deteriorated from 1995/96 to 1999/00 and in the remainder of Scotland in 2002/03. The results of simple tests of inequality indicate that from baseline (1993/94) to 2007/08, geographic inequalities between the worst SIC^{10} decile from Glasgow and that of the rest of Scotland, Not-Glasgow, decreased. The respective absolute and relative geographic inequalities in 1993/94 were 1.34 and 1.12 and by 2007/08 they were 0.81 and 1.01 (the value 1.00 would indicate no relative geographic inequality in SIC^{10} existed).

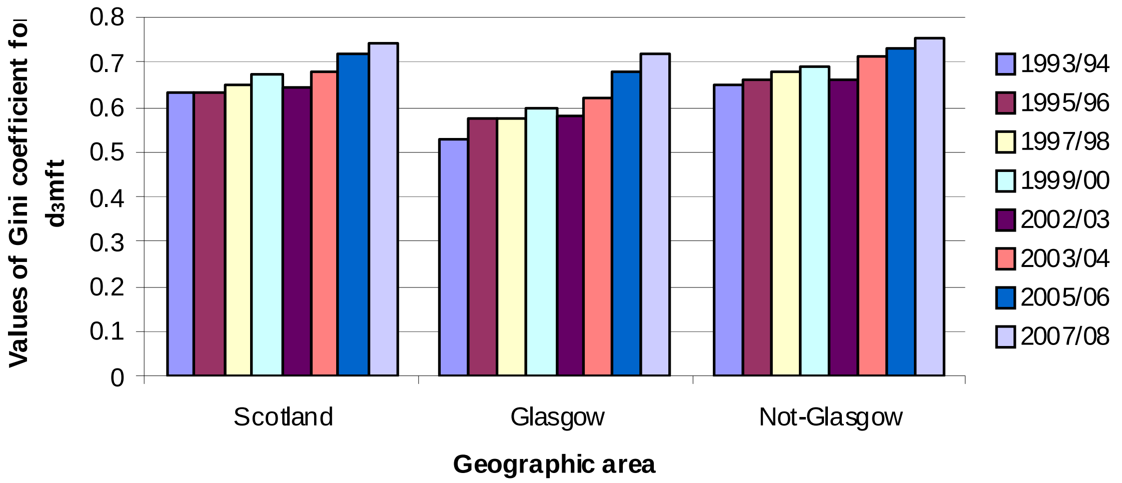
The differences in the distribution of the d_3mft data underlying the SIC^{10}, compared to 1999/00 as the reference year, was statistically significant (Wilcoxon tests, $p<0.001$, respectively) in all three of the geographic areas in 1993/94, 2005/06 and 2007/08, and inconsistent at the other time points.

7.3 Complex tests of dental health inequality

7.3.1 Gini coefficient

The value of the Gini Coefficients at each cross-sectional survey are illustrated in Figure 7-5. N.B. a value of 0 conforms to perfect equality, whilst a value of 1 denotes perfect inequality. This metric suggests that at all time points the Gini coefficient values indicate that inequality in the whole population distribution of $d_3$mft scores is less in Glasgow than in the remainder of Scotland [N.B. the lower the inequality in $d_3$mft measured by Gini Coefficient, the greater is the prevalence and caries burden]. Furthermore, inequality measured by Gini-coefficient for the distribution of $d_3$mft among the whole population of five-year-old children, unranked by SES, within each of the geographic areas, is indicative of increasing whole population inequality over successive surveys, irrespective of SES. The increase by this measure has been most marked in Glasgow. Meta-analysis of the Gini-coefficient results over the period from 1993/94 indicates that the increases have been significant in Scotland, Glasgow and Not-Glasgow over the whole period 1993/94 to 2007/08 ($p<0.01$, R-Squared value 0.76, 0.83 & 0.75, for each respectively). Comparison of the Gini-coefficient trends in Glasgow with the Not-Glasgow area (reference group) by use of a GLM procedure indicates that differences in Gini coefficient were associated with geographic area ($p<0.001$) and year ($p<0.0001$) and that there was significant interaction between geographic area and year ($p<0.0001$).

Figure 7-5: Values of the Gini coefficient for $d_3$mft of five-year-olds resident in Scotland, Glasgow and Not-Glasgow and at each cross-sectional survey from 1993/94 to 2007/08



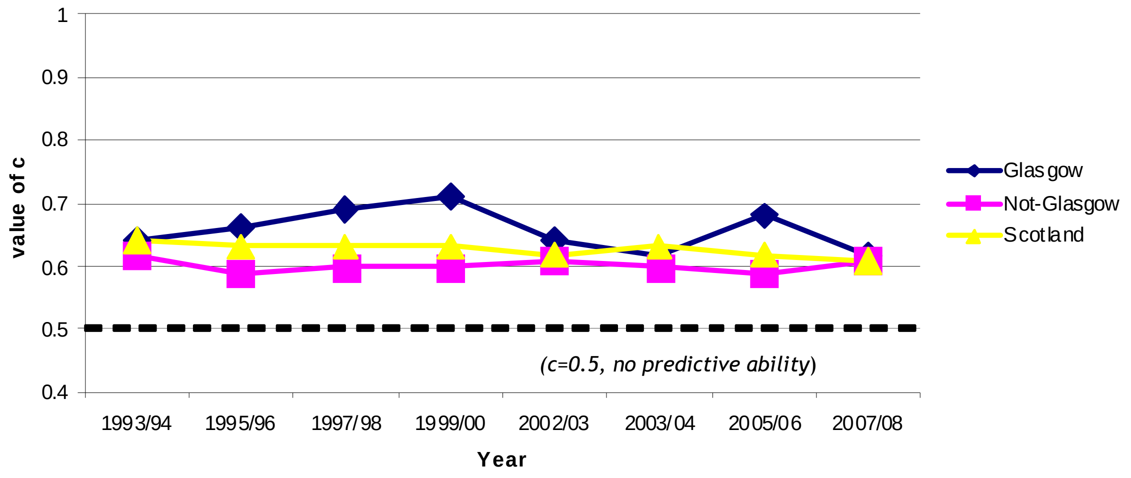
7.3.2 The SIC[10]

In common with the Gini coefficient, the SIC[10] distributions plot $d_3$mft scores of individuals in the population in question without reference to SES. The full SIC[10] distributions for these caries data have already been illustrated in an earlier section (see Figures 7-2 to 7-4) and may be considered to demonstrate complex absolute inequality.

7.3.3 Receiver Operator Characteristic Plots (ROC) and the value of c

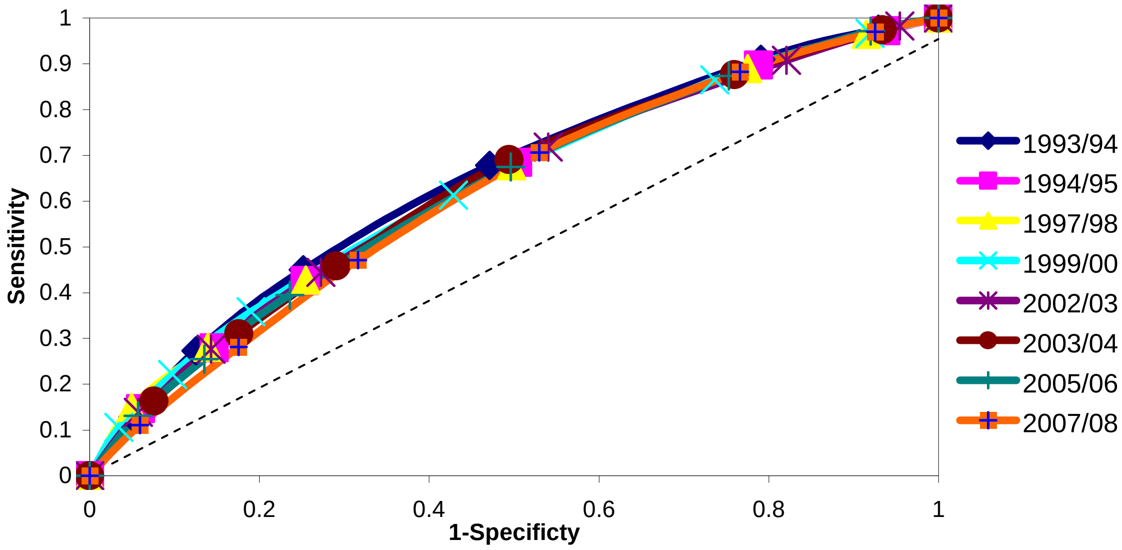
With respect to ROC plots and the value of c, i.e. the area under the ROC curve, these give an assessment of the ability of a diagnostic test in medicine to predict an outcome (Altman & Bland, 1994). In this case the ability of deprivation (DepCat, 2001), to predict an outcome (i.e. $d_3$mft>0) is measured. A c value of 0.5 indicates no predicative ability i.e. correspondence with the diagonal, whereas a value of 1 would indicate that all decay is 'explained' by DepCat category. The trends in the values of c from logistic regression of DepCat 2001 and $d_3$mft>0 from 1993/94-2007/08 in each of the geographic levels are illustrated in Figure 7-6.

Figure 7-6: From logistic regression, the trends in the value of c for the ability of DepCat 2001 scores to predict $d_3$mft>0 in Scotland, Glasgow and Not- Glasgow over the period 1993/94 to 2007/08



The resultant ROC curves for DepCat 2001 and $d_3$mft>0 at the successive cross-sectional surveys have been plotted separately for the three geographic areas of interest. The ROC plots for Scotland are illustrated in Figure 7-7.

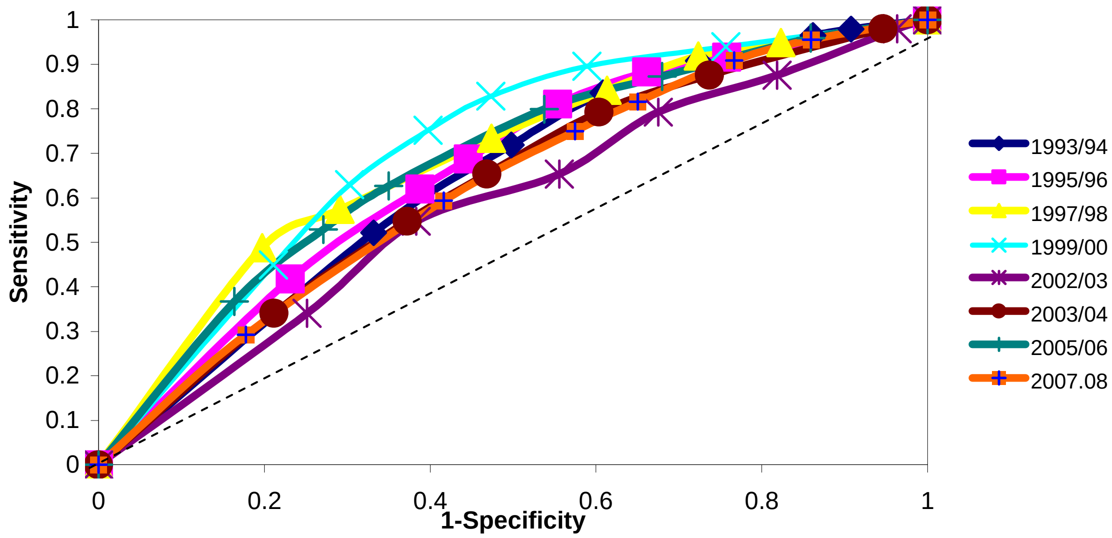
Figure 7-7: Time series ROC plots for five-year-olds' $d_3mft>0$ and deprivation (DepCat, 2001) in Scotland from 1993/94 to 2007/08



The closer the ROC plot to the diagonal line (c value =0.5) the less is the predictive potential of the explanatory variable for the outcome of interest. Conversely, the greater the bend in the curve upwards and to the left and top of the chart, the greater is the association (and predictive potential) of DepCat 2001, in this instance, for $d_3mft>0$. This succession of ROC plots was remarkably consistent over time.

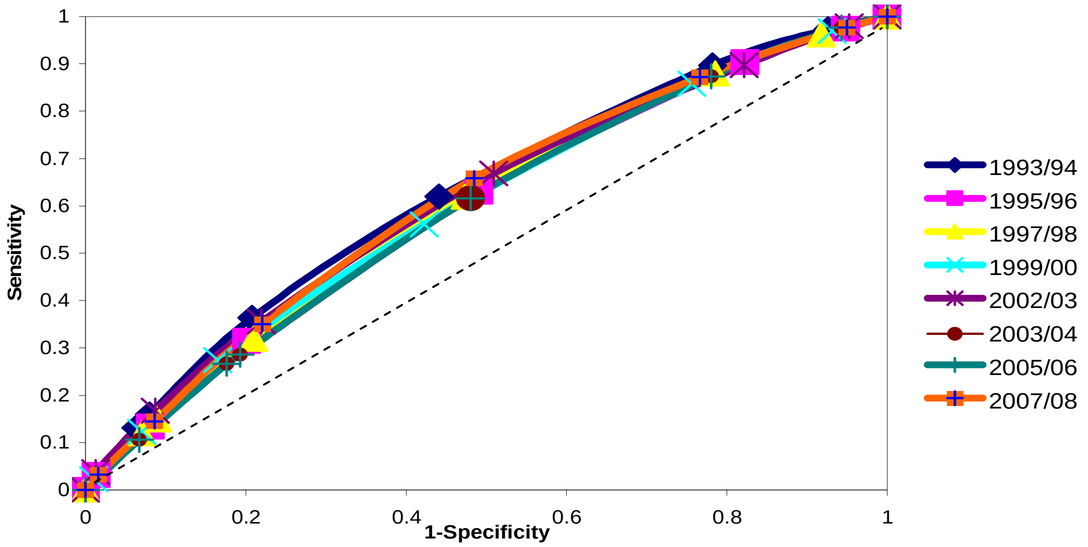
However, the successive ROC plots for Glasgow P1 children's $d_3mft>0$ and SES deprivation (Figure 7-8) fluctuated quite markedly. The relationship between deprivation and d_3mft was maximal in Glasgow in 1999/00, suggesting deterioration in equality, when compared to the earlier surveys.

Figure 7-8: Time series ROC plots for five-year-olds' $d_3mft>0$ and Deprivation (DepCat, 2001) in Glasgow from 1993/94 to 2007/08



Similar to the behaviour of the ROC plots for Scotland at the successive cross-sectional surveys, in Not-Glasgow (see Figure 7-9) ROC plots were remarkably consistently over time.

Figure 7-9: Time series ROC plots for five-year-olds' $d_3$mft>0 and Deprivation (DepCat, 2001) Not-Glasgow from 1993/94 to 2007/08



The value of c has slowly and slightly decreased from 0.64 to 0.61 over the entire interval from 1993/94 in Scotland as a whole (R-square value 0.76, $p<0.005$). Furthermore, a GLM procedure, using Not-Glasgow as the reference group, indicated that there was a significant difference in the c values in Glasgow, which was independent of year ($p<0.001$).

7.3.4 Concentration Curves

Successive Concentration Curves (CC) are illustrated for the cross-sectional surveys in each of the three geographic areas in Figures 7-10, 7-11 and 7-12. The greater the departure of the CC from 0 (the diagonal), the greater is the disproportionality of distribution.

In this case, as ascending values of DepCat on the x-axis indicate increasing deprivation, rather than increasing affluence (the more usual convention in the field of incomes inequality), the negative values (from the curve lying below the diagonal in this analysis) indicate that the excess morbidity is associated with increasing deprivation. The Concentration Curve indicates that P1s with $d_3$mft scores increasingly greater than 0 are concentrated among the poor SES groups.

Figure 7-10: The Concentration Curves for five-year-olds' $d_3$mft>0 and DepCat, 2001 in Scotland over the period 1993/94-2007/08

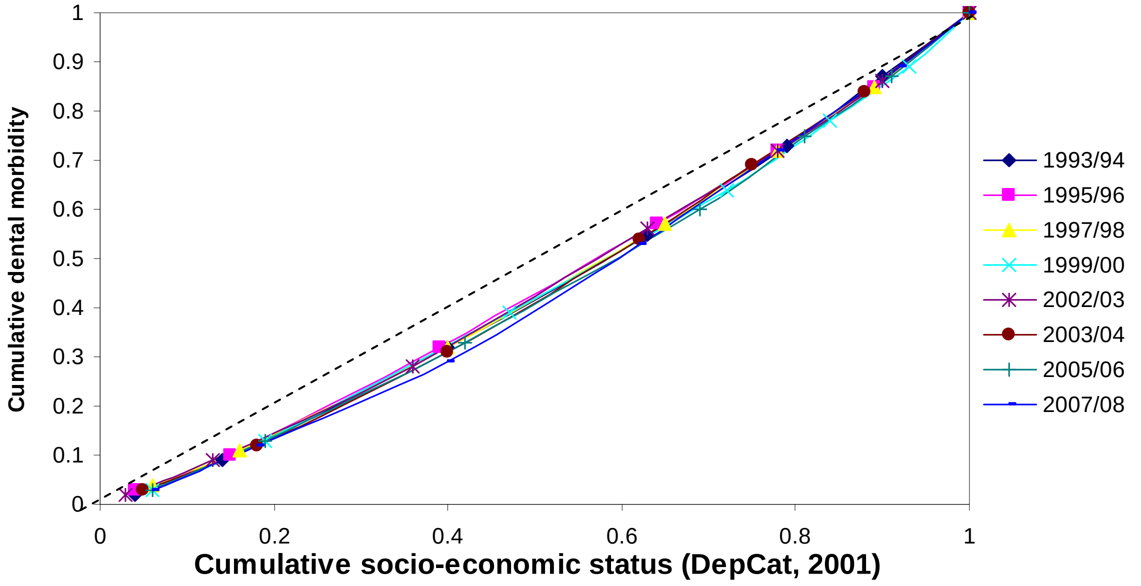


Figure 7-11: The Concentration Curves for five-year-olds' $d_3$mft>0 and DepCat, 2001 in Glasgow over the period 1993/94-2007/08

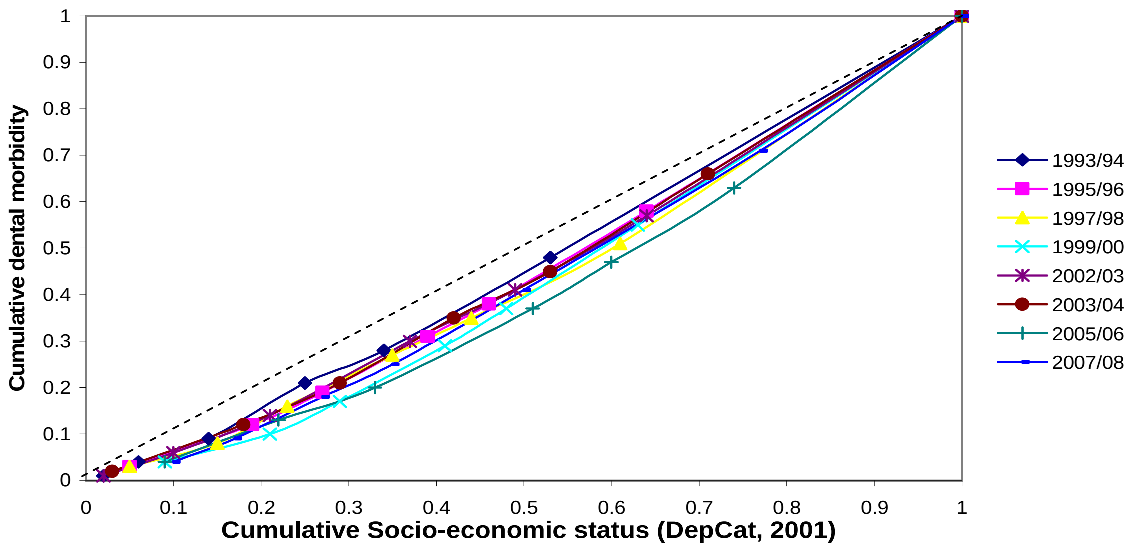
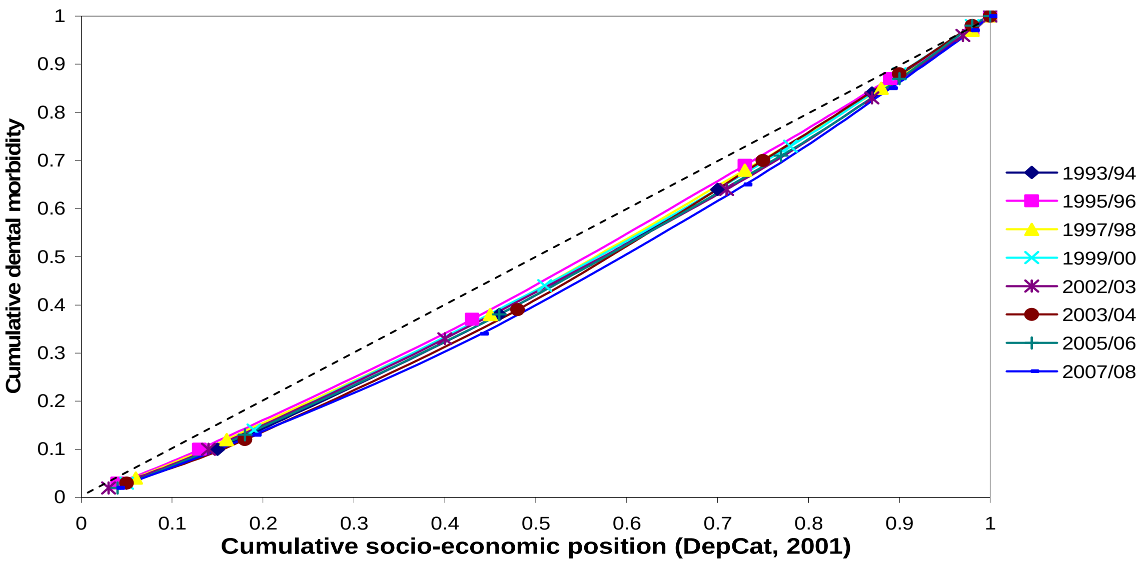


Figure 7-12: The Concentration Curves for five-year-olds' $d_3$mft>0 and DepCat, 2001 in Not-Glasgow over the period 1993/94-2007/08



7.3.4.1 Concentration Index (CI)

Corresponding Concentration Index (CI) values, denoting twice the area between the Concentration Curve and the line of equality, were calculated for each area and time. However, they are not shown, as values of CI are not intuitive, difficult to understand and add nothing to this thesis. For these reasons they will not be presented. However, their transformed values are presented in the following paragraph.

7.3.4.2 Koolman & Doorslaer's (2004) transformation of CI

Whilst the Concentration Index (CI) itself lacks a straightforward interpretation, the multiplication of the absolute value CI by x 75 provides an estimation of the percentage of redistribution of health, from the relatively advantaged groups to the relatively disadvantaged groups, which is required to eliminate the inequality by this measure i.e. to produce a value of CI=0. Respective values for this transformation are shown in Table 7-4. While the percentage of health requiring redistribution to create SES equity of $d_3$mft has decreased, overall, since the introduction of ecological interventions across Glasgow (from 1999/00), the same cannot be said for the rest of Scotland, Not-Glasgow, if the same year is used as the reference date, as there was fluctuation and the overall proportion of redistribution required increased by 36% over the same interval. When the data from the geographic subgroups making up Scotland was combined, the results of Meta-analysis of trends in transformed CI from 1993/94-2007/08 indicated that there had been a significant increase in the value of the transformed CI in Scotland ($p<0.05$).

Nevertheless, while in 1993/94 Glasgow required the smallest redistribution to produce equity, inequality gauged by this metric increased markedly (160%) through the 1990s and the greatest percentage redistribution required, overall, to negate systematic SES inequality in $d_3$mft>0 distribution associated with DepCat occurred in Glasgow 2005/06.

Table 7-4: Values for Koolman & Doorslaer's x 75 transformation of CI for DepCat 2001 and $d_3$mft score for each of the geographic areas at successive five-year-old surveys over the period 1993/94 to 2007/08

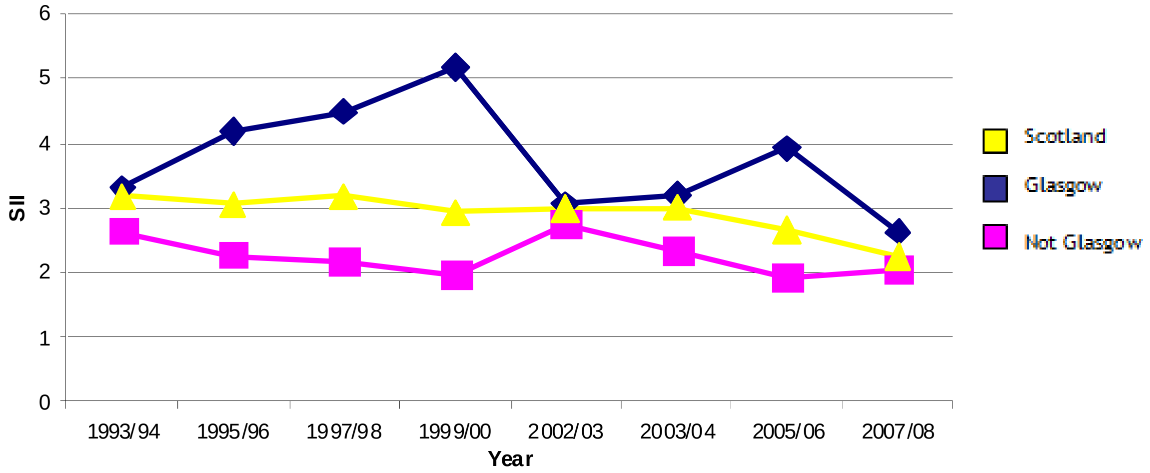
Percentage redistribution of health among five-year-old children required from relatively affluent to relatively disadvantaged groups to negate inequality in distribution of $d_3$mft>0 in the geographic areas over the period T^1 to T^8								
	1993/94	1995/96	1997/98	1999/00	2002/03	2003/04	2005/06	2007/08
Scotland	8.4	7.7	8.3	8.9	8.0	9.1	10.0	9.8
Glasgow	5.2	7.9	9.3	10.7	7.2	7.6	13.5	10.0
Not-Glasgow	7.6	6.1	6.5	6.9	7.2	8.2	7.3	9.4

However, transformed CI decreased substantially by 2007/08, at which time it was not very dissimilar to that in the remainder of Scotland. These trends are evident from examination of the Concentration Curves (Figures 7-10, 7-11 and 7-12). A Meta-analysis using a GLM procedure comparing the trend in transformed values for CI in Glasgow to the trend in the Not-Glasgow area demonstrated no statistically significant difference between the areas at the $p<0.05$ threshold, but did show that there was a significant year effect ($p<0.05$).

7.3.5 Slope Index of Inequality (SII)

The linear regression coefficient that demonstrates the relationship between $d_3$mft scores and DepCat of subjects when ordered in a hierarchy, with weighting for the population proportion in each DepCat category, is defined as the Slope Index of Inequality (SII). This is a measure of absolute inequality. Respective values for the SII in each survey year in the respective geographic areas Glasgow, Not-Glasgow and Scotland, can be seen in Figure 7-13. The direction of change over each interval in Glasgow and in the rest of Scotland are consistently dissimilar over the period. Nevertheless, in spite of the extent of their fluctuations, the SII values for $d_3$mft scores of subjects have become similar in Glasgow and Not-Glasgow, by 2007/08, when each reached its lowest value. Throughout the period of study the SII of Scotland as a whole has remained intermediate. Although Meta-analysis indicated that there was no statistically significant trend in SII in the two geographic subgroups, in Scotland as a whole the reduction in the SII was significant ($p<0.02$). A Meta-analysis of trend comparing Glasgow to the rest of Scotland using a GLM procedure indicated that the difference in trends in SII values was statistically significant ($p<0.001$).

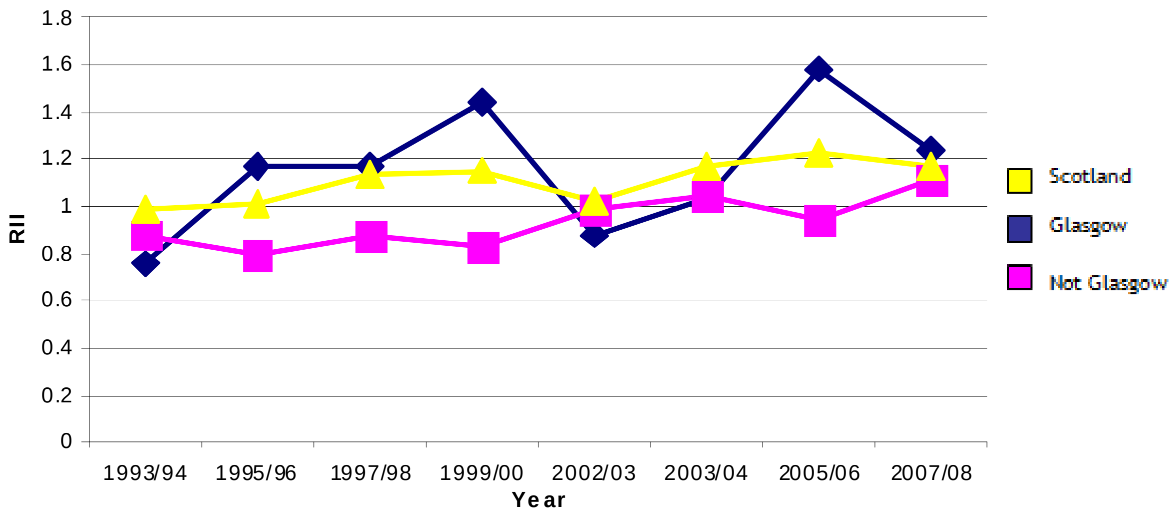
Figure 7-13: The SII for $d_3$mft of five-year-old children in Scotland, Glasgow and Not-Glasgow over the interval 1993/94-2007/08



7.3.6 Relative Index of Inequality (RII)

The RII values for the $d_3$mft scores of subjects at each of the geographic levels over the period 1993/94-2007/08 are illustrated in Figure 7-14. The RII is a relative version of the SII. In Scotland, the overall trend has been a statistically significant increase ($p<0.05$) in RII over the period. This largely reflects the temporal trend in the area outside Glasgow where a similar deterioration occurred ($p<0.02$). The fluctuations in RII coincide with those of the SII. Much of the variation in RII values between geographic areas observed over the interval had diminished and by 2007/08 very similar RIIs were observed in Glasgow and the remainder of Scotland (Meta-analysis using the GLM procedure indicated a statistically significant $p<0.05$ difference in trend when comparing the two geographic subgroups).

Figure 7-14: The RII for $d_3$mft of five-year-old children in Scotland, Glasgow and Not-Glasgow over the interval 1993/94-2007/08

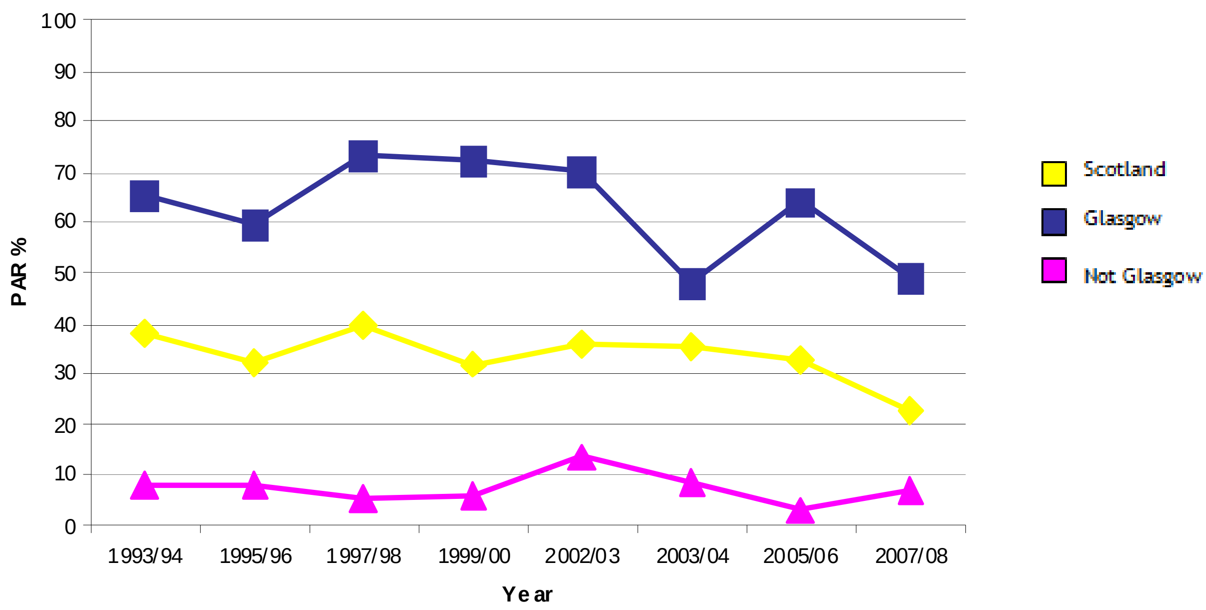


7.3.7 Population Attributable Risk (PAR)

The %PAR percentages denote the % improvement that would occur in dental health over the whole five-year-old population at each geographic level if all five-year-old children in the population were unexposed to deprivation measured by DepCat and consequently enjoyed the dental health prevalence for $d_3$mft>0 equivalent to that of the most affluent DepCat 1 communities, within each geographic area. The respective values for %PAR in each area are illustrated in Figure 7-15. From peak potential gains, in excess of 70% improvements in dental health status in the late 1990s, the %PAR value in Glasgow has fallen by around 24 percentage points from its previous magnitude by 2007/08. Whilst more modest than the previous potential, it remains substantially greater than the %PAR in the remainder of Scotland or Scotland as a whole over the study period. The %PAR values are suggestive of very marked geographic inequality between Glasgow and the rest of Scotland, irrespective of year (GLM procedure, $p<0.0001$). The %PAR for the remainder of Scotland in 2007/08 was unaltered from baseline (1993/94). This is not the case in Glasgow where in spite of considerable fluctuation, following deterioration in the late 1990s, there is latterly an overall reduction in %PAR. Meta-analysis of trends in %PAR over the period 1993/94-2007/08 in the individual geographic areas indicated that the overall trends in the individual areas were not statistically significant.

However, it appears that the Glasgow figures exert a greater effect on the %PAR for Scotland than those from the larger population in the Not-Glasgow area.

Figure 7-15: The %PAR for $d_3$mft>0 among five-year-old children at the levels: Scotland, Glasgow and Not-Glasgow over the interval, 1993/94 to 2007/08

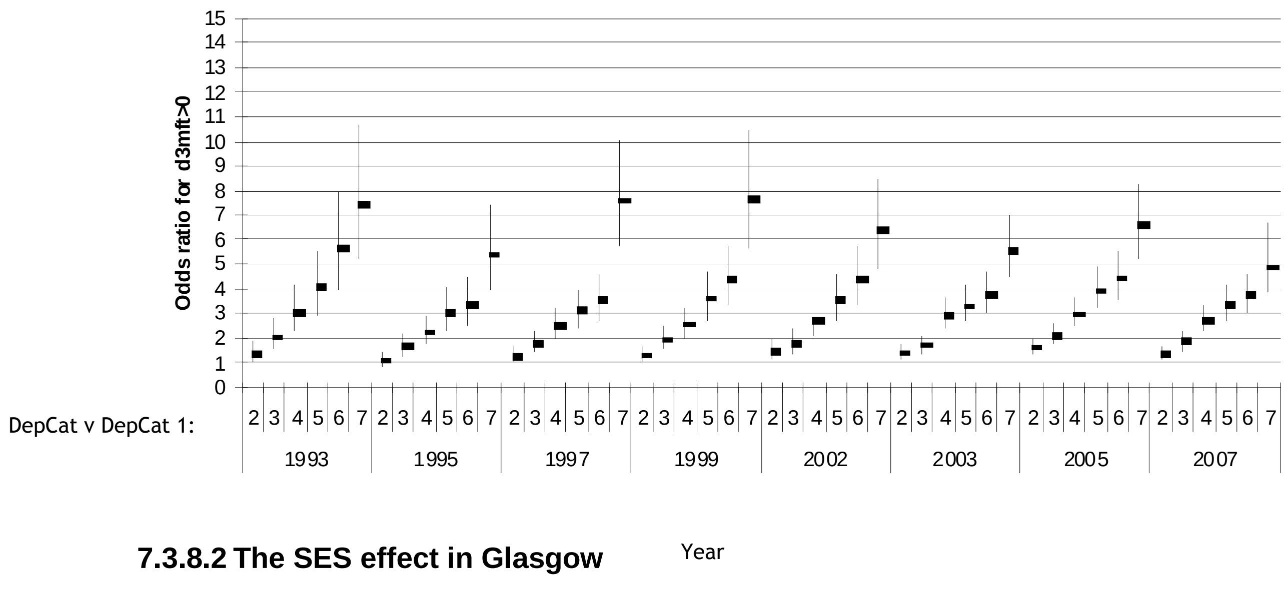


7.3.8 Odds Ratios for $d_3mft>0$ (adjusted for age and sex) for each DepCat group when compared to DepCat 1 in the survey years

7.3.8.1 The SES effect in Scotland

The overall Odds Ratios (95%CI) for $d_3mft>0$ compared to 1993/94, as the reference year, were previously shown for Scotland (Chapter 6, Results 1). In this alternative analysis, DepCat 1 was the reference group throughout the logistic regression comparing prevalence of $d_3mft>0$ in the different SES communities for each year separately in Scotland, after adjusting for age and sex (Figure 7-16). In spite of large confidence intervals, clear trends in the ORs for $d_3mft>0$ by SES are evident within year. At all points, ORs for $d_3mft>0$ were directly associated with deprivation ($p<0.0001$, if DepCat score>DepCat 2). Nevertheless, over the whole study interval, the ORs tended to decrease across the SES spectrum in comparison to DepCat 1 each survey year. In the relatively most deprived DepCat 6 & 7 communities respective decreases were from OR 7.5 (95%CI 5.25-10.70) to OR 4.89 (95%CI 3.9-6.73) and from OR 5.63 (95%CI 4.02-7.88) to OR 3.78 (95%CI 3.06-4.66). Changes across the SES spectrum may be examined in Figure 7-16.

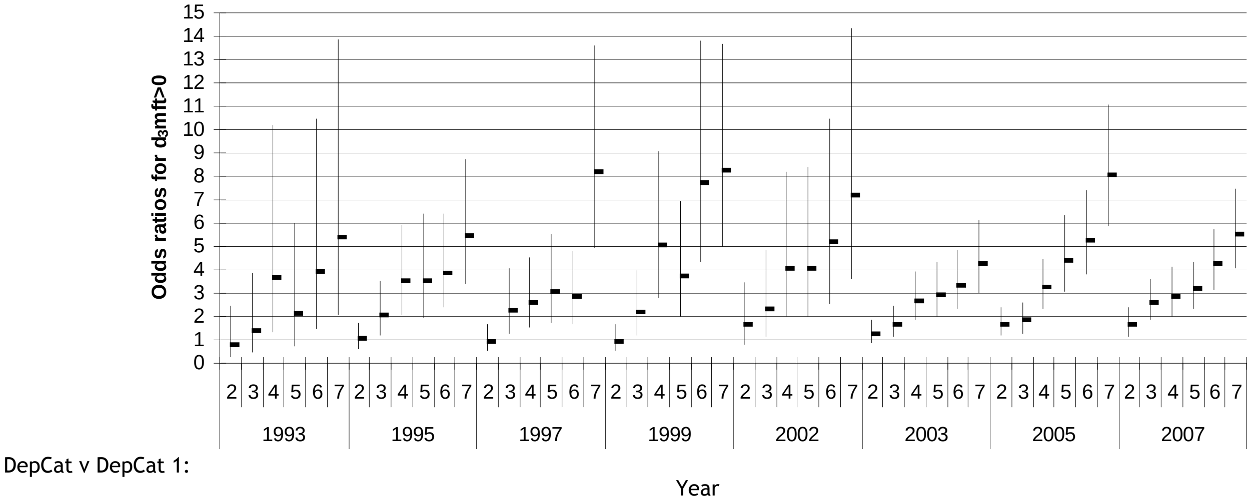
Figure 7-16: In Scotland as a whole, the Odds Ratios (95%CI) for five-year-old children's $d_3mft>0$ by year and DepCat (compared to DepCat 1) from 1993/94 to 2007/08



7.3.8.2 The SES effect in Glasgow

The Odds Ratios (95%CI), adjusted by age and sex, for five-year-old children's $d_3mft>0$ by year and DepCat, compared to DepCat 1, as the reference value, in Glasgow over the interval 1993/94 to 2007/08 are illustrated in Figure 7-17. The 95%CIs are comparatively wide and the SES gradients are less consistent than for Scotland as a whole. There are wide fluctuations in the ORs, marked overlap of confidence intervals and no convincing evidence of meaningful reductions in inequalities by this OR measure.

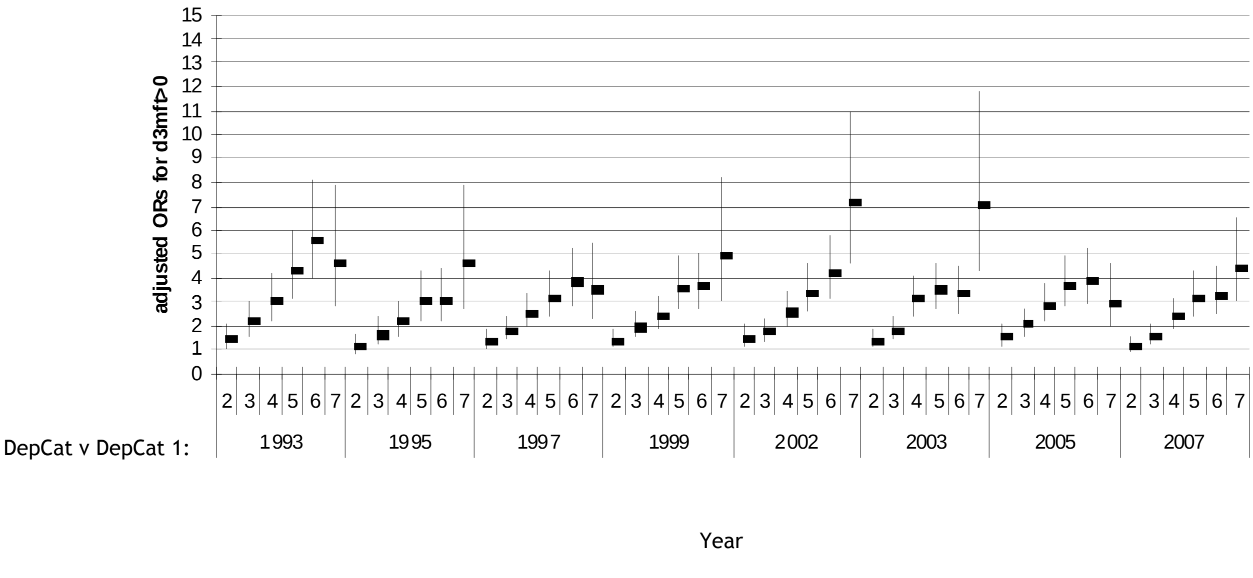
Figure 7-17: The Odds Ratios (95%CI) (adjusted by age and sex) for Glasgow five-year-old children's $d_3$mft>0 by year and DepCat (compared to DepCat 1) from 1993/94 to 2007/08



7.3.8.3 The SES effect in Not-Glasgow

Figure 7-18 illustrates the ORs (95%CI) for $d_3$mft>0 (adjusted by age and sex), by year and DepCat, compared to DepCat 1, as the reference value, in the remainder of Scotland over the interval 1993/94 to 2007/08. The 95%CIs are wide and the SES gradients are not entirely consistent. Moreover, there are wide fluctuations in ORs and although there is an impression of possible improvement in ORs in 2005 and 2007 compared to the 1993 baseline, there is no separation of the confidence intervals and thus, no convincing evidence of meaningful reductions in inequalities by this ORs metric.

Figure 7-18: The Odds Ratios (95%CI) (adjusted by age and sex) for Not-Glasgow five-year-old children's $d_3$mft>0 by year and DepCat (compared to DepCat 1) from 1993/94 to 2007/08



7.4 The 'scale of the problem'

In considering the scale of the inequalities problem as advocated (Harper *et al.*, 2010; Marmot *et al.*, 2010) with respect to $d_3$mft>0, readers should be mindful of the demographic data presented earlier in Table 6-1. Of the n=4331 five-year-olds resident in DepCat 7 postcode sectors in Scotland, as a whole, at the 2001 census, a disproportionate 73% were resident in the NHS Greater Glasgow Board area, just one of 15 Scottish Health Boards at that time. The corollary being that only 27% of Scotland's five-year-old DepCat 7 children were dispersed among the remaining 14 NHS Board areas. This most disadvantaged SES group meanwhile constituted 32% of the Glasgow five-year-old population. Conversely, of the n=3957 children in Scotland, at the same time resident in the most affluent DepCat 1 districts, only 14% were resident in NHSGG and comprised just 6% of the Glasgow five-year-old year-group.

7.5 Summaries of trends in dental health and dental health inequalities of five-year-old children up to 2007/08

Data in Tables 7-5 & 7-6 and 7-7 & 7-8 provide summary overviews of the various trends up to 2007/08 from the respective alternate reference years 1993/94 and 1999/00. Directions of trends in mean $d_3$mft and % $d_3$mft>0 are shown alongside corresponding trends in simple absolute and relative inequality. Whilst this may be useful in some respects, readers are cautioned that they must refer to the preceding detailed epidemiological results, inequalities results and the Meta-analyses to gain a fuller understanding of variations in trend across the eight cross-sectional surveys. In general, the trends reported are highly sensitive to reference year, end-point and may be of trivial magnitude. Only values in cells shaded yellow achieved statistical significance ($P<0.05$).

statistically significant, p<0.05

Table 7-5: Summary of directions of trends in dental health and trends in simple dental health inequalities at the three geographic levels,1993/94 *vs.* 2007/08

Index or test	Population epidemiology		Simple tests of SES inequality [raw data DepCat 7*vs.*1]				Simple tests of Geographic inequality [Glasgow (GGHB) *vs.* Not Glasgow)]						Odds Ratios		
	Overall		Absolute difference		Relative difference		Absolute difference			Relative difference					
Geographic area	Mean $d_3$mft	% $d_3$mft =0	% $d_3$mft =0	Mean $d_3$mft	% $d_3$mft >0	Mean $d_3$mft	% $d_3$mft >0	Mean $d_3$mft	SIC & SIC[10]	% $d_3$mft >0	Mean $d_3$mft	SIC & SIC[10]	SES effect $d_3$mft >0 DepCat 7 *vs.* DepCat 1	Area effect, $d_3$mft >0 Gla. *vs.* Not-Gla.	Year effect 2007 *vs.*1993
Scotland	↓	↑	↓	↓	↑	↑	N/A	N/A	N/A	N/A	N/A	N/A	↓	N/A	↓
Glasgow	↓	↑	↑	↓	↑	↑	↓	↓	↓	↓	↓	↓	No change	↓	↓
Not Glasgow	↓	↑	↓	↓	↑	↓	N/A	N/A	N/A	N/A	N/A	N/A	No change	N/A	↓

Table 7-6: Summary of directions of trends in dental health and the trends in simple dental health inequalities at the three geographic levels since the introduction of ecological interventions in Scotland and Glasgow, 1999/00 *vs.* 2007/08

Index or test	Population epidemiology		Simple tests of SES inequality [raw data DepCat 7 *vs.*1]				Simple tests of Geographic inequality [Glasgow (GGHB) *vs.* Not Glasgow)]						Odds Ratios		
	Overall		Absolute difference		Relative difference		Absolute difference			Relative difference					
Geographic area	Mean $d_3$mft	% $d_3$mft =0	% $d_3$mft =0	Mean $d_3$mft	% $d_3$mft >0	Mean $d_3$mft	% $d_3$mft >0	Mean $d_3$mft	SIC & SIC[10]	% $d_3$mft >0	Mean $d_3$mft	SIC & SIC[10]	SES effect $d_3$mft >0 DepCat 7 vs. DepCat 1	Area effect, $d_3$mft >0 Gla. *vs.* Not-Gla.	Year effect 2007 *vs.*1999
Scotland	↓	↑	↓	↓	↑	↑	N/A	N/A	N/A	N/A	N/A	N/A	↓	N/A	↓
Glasgow	↓	↑	↓	↓	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓
Not Glasgow	↓	↑	↓	↓	↑	↑	N/A	N/A	N/A	N/A	N/A	N/A	↓	N/A	↓

statistically significant, $p<0.05$

Table 7-7: Summary of directions of trends from the complex measurements of dental health inequalities at the three geographic levels, 1993/94 *vs.* 2007/08

Geographic area	From cumulative ranked distributions			Lorenz curve	From the regression equation		From the association of $d_3mft>0$ with exposure to deprivation	
	Whole population			SES-based	SES-based		SES based	
Complex test of inequality	Gini coefficient (ranked d_3mft scores)	SIC	SIC[10]	Concentration Index for d_3mft scores (Koolman & Doorslaer's transformation)	SII (for mean d_3mft of ranked & weighted SES groups)	RII (for mean d_3mft of ranked & weighted SES groups)	ROC (value of C for DepCat & $d_3mft>0$)	PAR% (for $d_3mft>0$ & DepCat)
Scotland	**↑**	**↓**	**↓**	**↑**	**↓**	**↑**	**↓**	↓
Glasgow	**↑**	**↓**	**↓**	↑	↓	↑	**↓**	↓
Not Glasgow	**↑**	**↓**	**↓**	↑	↓	**↑**	↓	↓

Table 7-8: Summary of directions of trends from complex measurements of dental health inequalities at the three geographic levels since the introduction of ecological interventions in Scotland and Glasgow, 1999/00 *vs.* 2007/08

Geographic area	From cumulative ranked distributions			Lorenz curve	From the regression equation		From the association of $d_3mft>0$ with exposure to deprivation	
	Whole population			SES-based	SES-based		SES-based	
Complex test of inequality	Gini coefficient (ranked d_3mft scores)	SIC	SIC[10]	Concentration Index for d_3mft scores (Koolman & Doorslaer's transformation)	SII (for mean d_3mft of ranked & weighted SES groups)	RII (for mean d_3mft of ranked & weighted SES groups)	ROC (value of c for DepCat & $d_3mft>0$)	PAR% (for $d_3mft>0$ & DepCat)
Scotland	↑	↓	**↓**	↑	↓	↑	↑	↓
Glasgow	↑	↓	**↓**	↓	↓	↓	↓	↓
Not Glasgow	↑	↓	**↓**	↑	↑	↑	↑	↑

Chapter 8

8 Discussion

8.1 A contemporary gap in the Scottish literature

As outlined earlier, at the outset of this work no comprehensive analysis of long running geographic and SES-related inequalities trends in Scotland's children's $d_3$mft had been conducted. This appears to be a common international deficit in the health inequalities literature (Petti, 2010). Moreover, many authors and commentators have quite casually used the term 'inequalities' in relation to health and dental health without any definition as to what was actually being described or discussed. Thus, it seemed timely to investigate the potential of selected methodologies for future dental health inequalities assessment and to define exactly what it is that is being referred to when dental health inequalities are discussed.

8.2 The research questions

In summary, the research questions for this thesis were related to: 1) the caries epidemiological trends in Scotland's different geographic areas by SES group and 2) the tests of simple and complex inequality. It is necessary to have a thorough understanding of the epidemiological prevalences and trends before attempting to understand simple and complex inequalities. These topics will be explored more fully from sections 8.3 and 8.5, respectively.

8.2.1 Epidemiological Trends

The research questions first sought to describe the longitudinal epidemiological trends in dental health experience over the interval 1993/94-2007/08. Furthermore, there was a desire to dissect the Scottish five-year-olds' caries datasets to explore whether the same, or different trends were operating in the Glasgow (GGHB) geographic area as were occurring in the remainder of Scotland. The population of the GGHB area comprises around 20% of Scotland's total population. In this geographic area there is a high concentration of SES deprived residents living within the urban core of a large metropolitan area. This contrasts with the remainder of Scotland, which is comprised of a much greater geographic land-mass characterised by smaller cities, towns, villages, rural and semi-rural areas. In the light of the population density and the much greater intensity of SES deprived groups within Glasgow, it seemed logical to consider it separately from the remainder. The topical nature of this subgroup investigation is now apparent, as another research grouping have recently reported on urban-rural differences in P1s dental health (Levin *et al.*, 2010). Moreover, there is a growing body of literature on the '*Glasgow Effect*' on health. It is therefore of interest to be able to study this phenomenon in relation to child dental health.

8.2.2 The complex tests of inequality

This study is the first comprehensive investigation of the applicability and performance with Scotland's caries datasets of a large selection of complex tests of health inequality derived from the generic public health and economics literatures. These formal tests of complex inequality are not yet routinely included in papers published in the dental literature which go on to comment on dental health inequality. Although a number of the tests included in this thesis have been applied singly or in small groups by other authors, a consensus is yet to be established as to which tests of complex inequalities are the most appropriate for use with caries data sets. The dimensions of complex dental health inequality investigated in this study may be expressed in absolute or relative terms. The tests describe population dispersion of $d_3$mft affected and non-affected individuals across whole populations, dispersion in geographic areas and dispersion in SES groups. In other populations it may be more appropriate to study different domains of inequality defined by e.g. gender, ethnicity or years spent in education. This study aims to inform the debate with respect to complex dental health inequalities measurement in Scotland, where geographic and SES associations with dental health have tended to predominate.

8.3 Caries Epidemiology

8.3.1 Some methodological issues

The national SHBDEP and NDIP reports routinely include a figure for the overall adjusted mean $d_3$mft for each NHS Board area, separately, and for Scotland as a whole. It is therefore important that this research has undertaken a fresh SES group-based analysis at the different geographic levels. Otherwise, important indicators of improvement across the whole SES spectrum, even in the most SES deprived NHS Board area (Glasgow) could be overlooked. At baseline, mean $d_3$mft was generally poorer across the SES spectrum in Glasgow, even within the relatively most affluent DepCat 1 subgroup, than would be expected, compared to the values for equivalent groups across the whole of Scotland. However, this could be due to the relatively small sample size and sampling fraction from the Glasgow DepCat 1 community in 1993/94. The sample may have been too small to be truly representative of Glasgow DepCat 1 five-year-old children's dental health experience that year.

The DepCat scale does not categorise SES disadvantage beyond the score DepCat 7. Concealed within this most deprived DepCat 7 septile for Scotland, particularly in Glasgow, there are further (gradients of) deprivations (Hanlon *et al.,* 2005; Whynes, 2008; Gray & Leyland, 2009). It is not possible to discriminate these by use of this index and it is likely that many of the most deprived communities in Scotland, as a whole, are to be found within the DepCat 7 residents of Glasgow, within still further gradients of SES challenge. This shortcoming must be borne in mind when interpreting analyses using the DepCat scale. Use of ranked Carstairs scores or smaller subgroupings e.g. vigintiles could permit identification of groups affected by the most severe deprivation. *Tackling Health Inequalities: 2007 Status Report on the Programmes for Action* (Department of Health, 2007) has emphasised the need for both a SES and an area-based focus in inequalities research.

8.3.2 Justification for use of DepCat (2001) as the SES index in caries epidemiology

The choice of the socio-economic indicator is important in inequalities measurement (Manor *et al.,* 1997; Harper & Lynch, 2005). Tickle *et al.* (2000) reported that of all the census variables investigated and modelled in linear regression studies, the proportion of households with no car, which is considered as a proxy for income, was best able to explain the variability of dmft at English electoral ward level. This census variable is one of the four that contribute to the calculation of Carstairs score and subsequent determination of the DepCat category, at small-area level. The same set of census variables contributes to the DepCat score within and outwith Glasgow.

McLoone (2004) considered that there were differences in some Scottish districts' levels of deprivation over the period between the 1991 and 2001 Censuses. Similar changes have been reported much more recently connected to the successive SIMD 2004, 2006 and 2009 profiles, over relatively shorter periods (Scottish Government, 2009). Thus, researchers are cautioned to use the SIMD SES indices only as relative indicators of deprivation within year. Similar limitations apply to the use of DepCat. As the 2001 Census occurred in the middle of the period under study, DepCat (2001) was used throughout, to attribute SES to the home postcode sector of individual subjects. This accords with the contemporary advice for studies incorporating retrospective datasets (Measuring Deprivation Subgroup, 2004). Furthermore, local studies by this author's research group have compared the abilities of SIMD 2006 and DepCat (2001) to elicit SES gradients in $d_3$mft prevalence among 3-year-old Glasgow children and have reported very high correlations (McMahon *et al.*, 2010). It is nevertheless beyond the scope of this project to assess differences in inequality results in the geographic areas by use of alternative SES indices e.g. SIMD quintiles 2004/2006/2009. Moreover, the Scottish

Executive (2004) consider that retrospective comparisons back to 1993/94 by use of SIMD indices are unjustifiable.

8.3.3 Publication of The Oral Health Strategy for Scotland -trends in P1s' $d_3$mft from 1995/96 to 1999/00

At national level, the significant trend which was observed of oral health improvements (OHI), from 1997/98, is temporally related to efforts to improve children's dental health in all NHS Board areas (as well as in GGHB and Tayside) following the publication and the funding support for '*Scotland's Health A Challenge to Us All, The Oral Health Strategy*' (The Scottish Office, 1995). It may well be that DHE-based approaches were sufficient to bring about DHI in the 14 NHS Board areas outside Glasgow which were not affected by SES deprivation to the same extent as NHS Greater Glasgow Health Board area.

While statistically significant OHIs were evident from this point onward in the area outwith GGHB and in the Scotland-wide data analysis, there was no evidence of DHI in GGHB as early as 1997/98. This could perhaps be due to the temporally related 'dose' of OHP interventions up to that point being inadequate to address the degree of caries morbidity and prevalence in this area, against the background deprivation (at this time OHP was confined to Possilpark pilot area). However, this finding could also be due in part to the relatively smaller sample sizes and resulting datasets from Glasgow, in comparison to the number of subjects in the other two much larger datasets.

Given the differentially greater prevalence of deprivation in Glasgow, its relative concentration and the background of poorer general and dental health experience compared to the rest of Scotland, it is perhaps not surprising that the general DHE-model, alone (up to 1999/00 in most of Glasgow), was insufficient to bring about observable dental health improvements. Nonetheless, the effect of DHE should not be overlooked entirely, as it may have been instrumental in maintaining the fairly static level of dental health observed. Alone, however, DHE appears to have fallen short of being able to bring about significant improvement in Glasgow (GGHB).

8.3.4 The odds of P1 children having experience of obvious dental caries in different geographic areas of Scotland

By 2007/08, relative to 1993/94, as the reference year, the respective Odds Ratios for $d_3$mft>0 in Glasgow and the remainder of Scotland were respectively 0.31 (95%CI, 0.26-0.37) and 0.46 (0.43-0.50). This finding indicates that compared to baseline, the likelihood in 2007/08 of a P1 child developing $d_3$mft in Glasgow has decreased by around two thirds, whilst in the rest of Scotland the likelihood has halved over the interval. This difference is not entirely surprising given the greater historical morbidity to be prevented in Glasgow. Nonetheless, the size of the observed improvements in outcomes are considerable. Ioannidis and co-workers considered large observational effect-sizes i.e. '*risk ratios less than 0.40*' could be sufficient obviate the need for subsequent RCTs to test associated interventions (Ioannidis *et al.,* 2000).

8.3.4.1 The significance of the changes in geographic Odds Ratios for $d_3$mft>0 when compared to 1993/94 and some possible explanations

Over the interval, relative to the 1993/94 baseline values, the Odds Ratios for $d_3$mft>0 decreased at all three geographic levels, achieving statistical significance as early as 1995/96 at the geographic levels Scotland ($p=0.03$) and the Not-Glasgow area ($p=0.039$) after fully adjusting for age, sex and DepCat in a logistic procedure. Levin *et al.* (2009) have already reported similar findings at the whole of Scotland level in their analysis of data from 1993 to 2003. Nonetheless, this has not been reported for the cross-sectional surveys in the geographic subgroups and inspection of only the whole of Scotland trend conceals the geographic differences. A marked statistically significant and substantial downward continuous trend in OR value became evident in Glasgow from 2002/03 ($p<0.0001$), relative to 1993/94.

It is reported to be easier to detect changes in caries morbidity in study populations with high caries increments/prevalences, than in populations with lower prevalences (Whelton, 2004; Marinho, 2008).

Prior to 2002/03, different trends were observed in Glasgow, compared to the rest of Scotland, where the small year-on-year improvements did achieve overall statistical significance. As mentioned earlier, this could have been due to the relatively smaller datasets for Glasgow, preceding 2002/03, in comparison to the size of those for the rest of Scotland. Additionally, given the high prevalence of severe SES deprivation and large population size in Glasgow, the original pilot OHP interventions in Glasgow (described within the ecological context) confined to just two pilot small areas at that time, would not in themselves have sufficient population coverage or momentum to impact on the whole of Glasgow's P1 dental health statistics.

8.3.5 A detrimental "Glasgow (dental health) Effect" was observed in five-year-olds

The adjusted Odds Ratios (ORs) for $d_3$mft>0 were calculated to alternatively compare trends in Glasgow with the rest of Scotland commencing from baseline (1993/94).

During the respective surveys up to and including 1999/00, the OR data are convincing support for the existence of a further detrimental geographic '*Glasgow Effect*' on P1's dental health, over and above that of deprivation measured by DepCat. From baseline to 1999/00, for a Glasgow P1 child, this amounted to a statistically significant excess odds of having $d_3$mft>0, amounting to around one third, compared to the odds of a similar child from the rest of Scotland (p>0.001). This suggests that there was an adverse impact on P1 children's dental health (after adjusting for age, sex and DepCat) associated with their *de facto* residence in the Glasgow area.

These excess odds of having $d_3$mft>0 remained statistically significant over the interval 1993/94 to 1999/00 and are generally in keeping with other reports of excess morbidities and mortality in this geographic area, after adjusting for known confounding factors (Gray, 2007). Furthermore, it is reported that differences between health behaviours and heath outcomes among adults actually resident in the most deprived districts of Glasgow, and the rest of Glasgow, are in reality in excess of the differences between residents of Glasgow compared to those from the rest of Scotland (Gray, 2007). Thus, it is recommended that concerted actions spanning a range of issues would be required in Glasgow, in order to make beneficial inroads. This type of '*broad-brush*' approach generally accords with the 2010 views of Marmot *et al.*, with respect to their recommendations for reducing SES-related health inequalities in England.

8.3.5.1 Previous descriptions in the literature of a *'Glasgow Effect'* on health

As described in the literature review, there is evidence of a detrimental '*Glasgow Effect*' on health. Walsh *et al.* (2010a) suggested that this had not previously been observed in the very young. Thus, this caries study may provide evidence of this generally detrimental geographic effect at an earlier age than observed previously. Furthermore, the Glasgow City Council area (the urban core of the NHS GGHB area) had the highest level of health inequalities within Scotland (Leyland, 2004). The poor general health in Glasgow is said to be even poorer than the level of SES deprivation would warrant and the under-expression of health is said to rise with deprivation (Whynes, 2008). However, an alternative hypothesis is that the four determinants of the Carstairs score do not pick-up additional deprivation (Hanlon *et al.*, 2005). In some respects the findings from the five-year-olds' dental caries epidemiology component of the original 1995/96 'Oral Health Needs Assessment' which preceded the strategic development OHP programme (Greater Glasgow Health Board, 1999) would lead one to a similar conclusion. The previously reported caries prevalences and morbidities were clearly not homogeneous across GGHB DepCat 7 communities e.g. in Possilpark in 1995/96 the mean $d_3$mft was 42% greater than the average for GGHB DepCat 7 communities, overall i.e. mean $d_3$mft=7 (in Possilpark) *vs.* mean $d_3$mft=4.9 (in GGHB DepCat 7). Nevertheless, the respective prevalences of $d_3mft>0$ were similar i.e. 88% and 89%, respectively (Greater Glasgow Health Board, 1999; NHS Greater Glasgow, 2005). The cross-sectional caries gradients for SES morbidity and prevalence presented in the results chapter of this thesis appear to be so sensitive to variations in SES deprivation, that such local excesses are very plausibly related to similar additional deprivations to those postulated by the above authors. Moreover, children's 'early years' are clearly important for later health. Macintyre (2008) suggests that very early effects of parental SES, at, or before birth, in the West of Scotland predicate health risks to a much greater extent than individuals' own eventual SES position.

8.3.5.2 Evidence of a later attenuation of the "Glasgow (dental health) Effect"

The statistically significant so-called '*Glasgow (dental health) Effect'* (independent of DepCat) persisted until 1999/00. However, after this date from 2002/03, there are suggestions that the ORs (adjusted for age, sex and DepCat) tended to decrease. By 2002/03, and thereafter, the 95%CI tended to cross 1, suggesting that there was no longer convincing evidence of any greater Odds of $d_3mft>0$ among P1 children in Glasgow *versus* those in the rest of Scotland, after full adjustment for the known confounders. By 2007/08, the OR value (0.94) lay below 1 ($p<0.0001$, compared to Glasgow's baseline value), although the 95%CI continued to span the value 1 (suggestive that there was no longer any difference in ORs remaining, when compared to the rest of Scotland (i.e. $p=0.2116$). This implies that the earlier apparent detrimental '*Glasgow Effect'* on the P1s dental health was mitigated and had disappeared over the period temporally associated with the OHATs, the SE's *Childsmile* Core pilot interventions and other contemporary child health and welfare interventions e.g. '*Starting Well'* (Killoran Ross *et al.,* 2005; Shute & Judge, 2005; The Scottish Government, 2006). This raft of policies would be in keeping with what Sanders *et al.* (2006) suggest is required to overcome the SES gradient in oral health i.e. the right balance between targeting individuals and targeting the social environment where health behaviours develop and are maintained. Only time will tell if the trends towards consistent improvements over recent times in GGHB's five-year-olds' d_3mft outcomes should give rise to any optimism that the precursors to other morbidities related to the 'common risk factors' may improve similarly.

Furthermore, if Levin *et al.* (2010) and this thesis are both correct, the combined findings suggest that by 2007/08, the greatest magnitude of contribution towards a detrimental Scottish urban-effect (four cities) may not substantially arise from a contributory '*Glasgow Effect*'. Notwithstanding the above, it is important that this does not distract the reader from the substantial concurrent reductions also occurring in the ORs for $d_3mft>0$ in the rest of Scotland. Interestingly, the ORs for $d_3mft>0$ in 2007/08, compared to 1993/94, in Scotland decreased from 1.0 to 0.46 ($p<0.0001$), over the interval. Thus, the totality of Scotland's and Glasgow's approaches towards child health and welfare implemented in advance of the above observations (some of which are described earlier) were temporally related to these geographic improvements.

If the hybrid models of 'directed population' OHP interventions which were adopted are partly responsible for the eradication of the earlier evidenced '*Glasgow (dental health) Effect'*, these types of interventions may possibly also be effective on the intra-Glasgow (dental) health inequalities.

Furthermore, there may be transferable lessons and experience which could potentially be applied in other high-density deprived urban geographic areas for which a successful strategy has yet to be identified e.g. potentially some English 'Spearhead areas' (Audit Commission, 2010) and the other three main Scottish cities which were included alongside Glasgow in the above mentioned urban-rural analysis of the 2007/08 caries dataset (Levin *et al.*, 2010). An excess caries morbidity in the aggregated four cities data was found as late as 2007/08. Thus, this continued to be observed in that study beyond the time point at which the historic similar excess was no longer detectable in the Glasgow geographic area alone, within the research findings of this thesis.

8.3.6 Changes in $d_3$mft in Scotland do not appear to be part of a secular trend

The above improvements are in stark contrast to the deteriorations reported further South in the UK in: '*Giving Children a Healthy Start. A review of health improvements in children from birth to five years*' (Audit Commission, 2010) in geographic and poor SES areas not subject to Scotland's OHP programmes. During the period when improvements occurred at an accelerated rate in Scotland, England's P1 children suffered setbacks in their mean $d_3$mft score. Although the deterioration was relatively marginal for the P1 population as a whole, this nevertheless amounted to +0.29 $d_3$mft (+19.9%) for those residing in 'Spearhead areas' (Audit Commission, 2010). The 'Spearhead Areas' are the 70 Local Authorities in England with the worst health and deprivation indicators. However, it is not reported whether these mean $d_3$mft values are weighted for SES. Likewise, similar improvement has not been reported in Wales (Harker & Chestnutt, 2005; GIG Cymru NHS Wales, undated). Although the dental health of five-year-olds in Northern Ireland improved throughout the 1980s, it reached a plateau in the mid-1990s (Department of Health, Social Services and Public Safety, 2007). Compared to previously, Nunn (2006) described five-year-olds' dental caries experience in Ireland as worsening by 2001. Policy makers there consider that their children continue to have among the highest levels of caries in Europe (Department of Health, Social Services and Public Safety, 2007). In 2002, in the Irish Republic, 55% of five-year-olds in non-fluoridated areas were reported to have $d_3mft>0$ with a mean d_3mft of 2.2 (Irish Oral Health Services, 2009). Further afield, in the USA, dental caries has increased in pre-school children in the past decade (Tinanoff & Reisine, 2009). Moreover, it has even been suggested that in many countries there is a wider pending public health crisis, due to increases in dental caries prevalence (Bagramian *et al.*, 2009) and little sign that inequalities in oral health are narrowing (Sheiham *et al.*, 2011).

The relative magnitude of dental health improvement in Scotland might seem surprising, given its historic reputation for poor dental health and deprivation. However, the greater prevalence of caries at the outset provided more potential lesions to be prevented by intervention. Nevertheless, a similar excess prevalence of d_3mft in English 'Spearhead areas' does not appear to have led to a greater differential rate of improvement in these areas, in fact, quite the contrary (Audit Commission, 2010). A parliamentary 'Select Committee' concluded that 'Spearhead Area' status on its own appeared to have done little to galvanise areas to tackle health inequalities (Health Committee, 2009).

8.3.7 The difference in dental health outcomes in the geographic subgroups

The epidemiological data shows that geographic simple absolute difference and simple relative difference between the weighted mean d_3mft and weighted % $d_3mft>0$ of Glasgow P1 children and those resident in the remainder of Scotland decreased respectively from baseline. For example, between 1993/94 and 2007/08, the respective changes in the absolute and the relative differences in weighted mean d_3mft between Glasgow *versus* the rest of Scotland were -0.5 (-55.5%) *vs*. –0.11 (-8.4%).

Taken in the wider context of Walsh's (2010) suggestions that general health outcomes in Glasgow have worsened compared to other geographic areas in recent decades, this is perhaps somewhat surprising. Furthermore, the relative magnitude of improvement in these caries indices indicates that in spite of the poorer general outcomes for adult groups (due to the effects of their cumulative lifetime exposure to adverse determinants), it is possible to achieve tangible dental health improvements at a developmental stage which underpins the whole of the rest of these cohorts' life-course, even in an area which still appears to have a poor prognosis for health in general.

Nevertheless, the fluctuations in the trend lines for simple absolute and simple relative geographic inequality in mean d_3mft and %$d_3mft=0$ are somewhat disconcerting (especially so in 1999/00, when all reached their maximum values). Nevertheless, this type of pattern, with more extreme fluctuations than are generally observed in chronic diseases' epidemiological trends, does not seem to be at all unusual in depictions of trends of absolute and relative inequality, over time (Harper & Lynch, 2007a). A non-smooth inequalities trend line may be what the Victora *et al.* (2003) diffusion of innovation model should lead one to expect, especially following new or modified interventions. Fortunately, Meta-analysis can help to determine whether the overall change from these oscillating trends is significant, or not.

With respect to changes in simple absolute and relative inequality in the prevalence of $d_3mft>0$ by 2007, the disappearance of the aforementioned '*Glasgow Effect*' partly shows what happened in Glasgow in the preceding period. However, while it is not possible from this study to ascribe the above changes to any particular intervention(s), there was nevertheless a temporal association between the establishment of the OHATs in Glasgow and later observed improvements in the prevalence of $d_3mft=0$ in this area. Notwithstanding this, the Glasgow dental health improvement could potentially be explained by the tendency for reversion to the (Scottish) mean. Albeit, there has been no suggestion of any reversion to the mean in the geographic Spearhead Areas of England during the similar period, 1999/00 to 2005/06 (Audit Commission, 2010).

While the reductions in simple absolute geographic inequality measured in this study were substantial, those for simple relative geographic inequality appear more marginal, although encouragingly both the absolute and relative geographic inequality are nonetheless reducing. The need to always report both absolute and relative inequalities together has been described (Regidor, 2004b; Department of Health, 2006; Starfield, 2007).

Within and between geographic areas, the simple absolute and relative differences do represent different characteristics of the data and both are valid measurements (Shaw *et al.,* 2007). However, arguments for one or another may be motivated by the results produced and the particular message that the researcher wishes to communicate. Because the guidelines on inequalities measurement (Keppel *et al.,* 2005) recommend that: 1) morbidity rather than health is counted and 2) the area with the lowest morbidity is used as the denominator population, it will always be more difficult to achieve improvements in simple relative inequality as prevalence falls (potentially towards zero) in the geographic area or SES group comprising the reference group. Even in the face of substantial improvements in absolute inequality, there is the a theoretical possibility that relative inequality could increase exponentially towards infinity. McLaren *et al.* (2010) have already indicated that they consider that it would not be unexpected for absolute health inequality between groups to decrease, at the same time as relative inequality increases. These authors hold that if a health issue has decreased in prevalence across the whole distribution of a health variable, the residual differences can look large on a relative scale, even in the face of dramatic improvements in excess prevalence. Thus, reliance on relative inequality, alone, as one's measure of inequality would be misleading.

Notwithstanding these caveats, in general, the Relative Risk or difference is considered a better index of aetiological effects, whilst the absolute difference is considered a better indicator of public health importance and since both aetiology and public health are important, both should be reported (Shaw *et al.*, 2007).

Moreover, depending on one's objectives, while we have noted that it is possible to measure whether the gap between the poorest and most affluent areas is altering, it is nevertheless important to assess whether the social gradient is being levelled down across its entirety (Marmot *et al.*, 2010). The next section will discuss the simple distributional impacts, over time, across the SES range. The complex inequality trends from the caries modelling studies which use all of the SES groups' data will be discussed later in this chapter.

8.3.8 Additional epidemiological insights obtained from SES subgroup analysis

The *Marmot Review* (Marmot *et al.*, 2010) cautions readers to be aware that any interventions aiming to improve overall health outcomes may inadvertently result in widening health inequalities. Therefore, attention must always be given to the distribution of health improvements across the whole SES spectrum. Earlier, Fejerskov (1995) actually said as much in relation to efforts to decrease caries prevalence and this was echoed in Petti's (2010) review.

8.3.8.1 Differences in prevalence of $d_3$mft=0 in SES groups

It is encouraging that the unweighted percentages with $d_3$mft=0 in each SES group, over the interval, indicate that there were SES-ranked improvements in Glasgow and the rest of Scotland compared to baseline (1993/94). From the regression studies, using 1999/00 as the reference year, there are indications of statistically significant improvements in the % with $d_3$mft=0 in some SES groups in the rest of Scotland prior to this.

Despite greater detriment to (dental) health in poorer SES groups (Mechanic, 2002), inspection of the values for unadjusted $d_3$mft=0, by DepCat (and their analysis by logistic procedures) show that by 2007/08 *vs*. 1999/00, P1s resident in the most SES challenged DepCat 7 communities in Scotland as a whole ($p<0.001$) and in Glasgow ($p<0.001$) and Not-Glasgow (N/S) were experiencing substantial improvements in their prevalence of '*no obvious caries experience*'.

Prevalence gains of this sort are likely more difficult to achieve than reductions in distribution of $d_3mft>0$ scores which contribute otherwise to the mean. In Glasgow there is no convincing evidence of statistically significant improvements in the prevalence of $d_3mft=0$ in SES challenged groups prior to the establishment of the OHAT programme and *Childsmile* pilot work (both of which were predicated to some extent by the *Possilpark* project). It appears that these complex interventions were temporally associated with the triggering of the trends towards widespread SES improvements in Glasgow. However, readers must bear in mind the earlier cautionary notes.

8.3.8.2 Differences in mean $d_3$mft in SES groups

By 2007/08, the respective mean $d_3$mft values among Glasgow DepCat 1 and DepCat 7 P1 children were 0.6 and 3.1 while concurrent values of 0.9 and 3.3 were recorded for similar SES children in the rest of Scotland. Reductions in mean $d_3$mft values from baseline in Glasgow in DepCat 1 & 7 communities achieved values of -1.4 and -2.1 $d_3$mft, respectively, whilst in the remainder of Scotland, the decreases were much more modest at -0.3 and -1.2 $d_3$mft, respectively.

8.4 A summary of some possible explanations for the geographic dental health improvement

Some possible explanations for the improvement in P1 dental health indices observed latterly in Glasgow and Scotland are as follows:

1) The high prevalence and mean $d_3$mft burdens at the outset and thus the availability of many potential lesions to prevent. The potential to prevent $d_3$mft will diminish as prevalence decreases, until the theoretical point that there are no more potential lesions to prevent (Sheiham & Sabbah, 2010). Furthermore, Batchelor & Sheiham(2004) describe a differential caries susceptibility by tooth-type and tooth-site, which suggests the presence of an intra-individual hierarchy of sites at caries-risk. They suggest that larger sized susceptible groupings of teeth are present in populations with high caries levels. These authors comment that preventive factors which increased resistance to the caries challenge at one site, also affect most sites in a particular tooth-grouping (but not necessarily sites in other groupings).

2) The aforementioned potential tendency for reversion to the (Scottish) mean. Reversion to the mean is a statistical phenomenon (http://mathworld.wolfram.com/ReversiontotheMean.html, undated).

3) A secular trend towards dental health improvement could be occurring in conjunction with the general improvements in nutrition and living conditions i.e. as in *"McKeown Theory"* (1976). These factors are said to have brought about improvements in population general health in the 20th century and could potentially be part of the explanation for improvements in dental health along with e.g. greater female participation in the work-force and longer involvement in secondary education (Sheiham, 1997). Broad social factors were found to explain 53%, 62% and 57% of the variation and changes in dental caries status in BASCD surveys of five-year-olds in England and Wales in 1985, 1987 and 1989, respectively (Nadanovsky & Sheiham, 1994).

4) Significant improvements in dental health outcomes were observed in Scotland as a whole as early as 1997. However, in Glasgow temporal associations were observed between the establishment of convincing epidemiological trends towards DHI and the establishment of OHATs, Scotland's *Childsmile* programmes and GGHB's *Starting Well* Programme. These complex interventions have previously been described in this thesis and earlier in peer reviewed publications (Blair *et al.*, 2004; Killoran Ross *et al.*, 2005; Blair *et al.*, 2006; Shaw *et al.*, 2009; Macpherson *et al.*, 2010; Turner *et al.*, 2010) and all of this activity may have been necessary to kick-start improvements.

If Fejerskov (2004) and Marmot *et al.* (2010) are correct about the cumulative effectiveness of over-layered activities and McLaren *et al.* (2010) are also right about the relative importance of structural strategy compared to agency, this preceding complex action since 1999/00 may be temporally related to the absolute geographic epidemiological differences in percentages of P1 children with $d_3$mft=0 (weighted for DepCat), likewise the weighted mean $d_3$mft scores and the decreasing absolute magnitudes of SES-related differences between DepCat 1 and DepCat 7 five-year-olds.

Furthermore, the temporally associated reduction in adjusted Odds Ratio for $d_3$mft>0 between the geographic areas, over time, is indicative of a reduction in the relative difference in dental health which was evident between the areas at earlier cross-sectional surveys.

It must always be borne in mind that the epidemiology of the P1s reflects *all* cumulative events and experience in their (dental) ‘life-course’ up to their age and stage of development (McLean, 2010) and continuation of monitoring will be important.

8.5 Measurement of P1s' caries inequalities

8.5.1 Introduction

The literature review on health inequalities suggests strongly that it is important to have considered the temporally associated Oral and General Health Promotion, the epidemiology of Oral Health Improvements, and to then proceed to consider the simple and complex inequalities outcomes together in one text. The *Marmot Review* (2010) drew readers' attention to the particular need to focus on the reduction of differences in health across the whole SES spectrum. However, it may also be appropriate to consider the whole distribution of dental health outcomes by different domains than SES e.g. by gender or ethnicity etc. To effectively assess complex inequalities within the caries datasets requires the application of an array of tests of complex inequality. At present, there is no consensus how best to measure health inequalities within the generic literature and therefore there is certainly no agreement within the dental health literature.

The forthcoming section will move beyond the routine analysis of simple absolute and relative epidemiological inequalities outcomes, to specifically consider the complex absolute and complex relative inequalities in dental health outcomes of Scotland's five-year-old children across i) the whole spectrum of individuals within populations, ii) between those resident in different geographic areas and iii) across the full range of the SES spectrum.

8.5.2 Justification for this selection of tests of inequality

It is believed that the selection of inequalities measures is important, as the literature review suggests that the methods by which inequalities are actually measured will affect the results and the conclusions one will reach (Wagstaff *et al.*, 1991; World Health Organization, 2000; Wagstaff & van Doorslaer, 2002 & 2004; Regidor, 2004b; Kepple *et al.*, 2005; Harper & Lynch, 2007a; Shaw *et al.*, 2007; Khang *et al.*, 2008; Harper *et al.*, 2010).

Thus, as a starting point, this study has used all of the generic tests of simple and complex inequality recommended since the commencement of this research by the Scottish Public Health Observatory, *ScotPHo,* for use in Scotland (Munoz-Arroyo & Sutton, 2007) and later endorsed by '*Equally Well, Report of the Ministerial Task Force on Health Inequalities, Volume 2*' (The Scottish Government, 2008). These selected tests have been used to explore trends in dental health inequality from 1993/94-2007/08 and from an alternative reference date, 1999/00, onwards, as this is the point from which the ecological OHP and child health and welfare policies were widely implemented. The complex inequalities tests which Munoz-Arroyo & Sutton (2007) considered appropriate for use in Scotland were namely: the Population Attributable Risk (PAR), the Concentration Curve and associated Concentration Index (CI, and Koolman & Doorslaer's transformed CI), the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII).

In addition to the above recommended tests, the Gini Coefficient, Significant Caries Index (SIC), the SIC^{10} and the Receiver Operator Curve (ROC) plot (none of which were included in the aforementioned recommendations) have been explored for their potential usefulness with caries data. It should be pointed out at this stage that while it is helpful for readers to consider inequalities test results defined under the four headings: 'simple absolute', 'simple relative', 'complex absolute' and 'complex relative' inequalities, some of the tests which follow may be applied and interpreted in more than one way of these ways e.g. the Concentration Index may be calculated to express complex relative or absolute inequality. Throughout this research the CI and CC refer to complex relative SES-related inequality. Thus, while complex inequalities assessment is indeed complicated due to the large assortment of potential tests, clarity about what is being measured will aid understanding of which of the dimensions of inequality actually is being described by the results. The researcher must always be very clear about the ways in which the results of tests may be interpreted and be explicit about this in discussion of his/her reporting.

8.5.3 Measurement of P1 population and geographic inequality by the Significant Caries Index

8.5.3.1 Use of the conventional Significant Caries Index (SIC)

The measurement of simple absolute dental health inequality using the Significant Caries Index (SIC) methodology developed by Bratthall (2000) has since been advocated by many authors e.g. Armfield & Spencer (2008) and the World Health Organization (2009). The SIC value quantifies the mean $d_3$mft of the worst third of the age specific population ranked by $d_3$mft score, from the best to the poorest. In this study, the SIC has demonstrated a large reduction in simple absolute geographic inequality, compared to the 1993/94 baseline. The SIC value has decreased markedly within Glasgow over the study interval, where it has fallen from a value of 9.4 $d_3$mft in 1993/94 to 5.9 $d_3$mft (-37%) by 2007/08. This is a greater reduction than observed in the rest of Scotland over the period, where the respective decrease has been from 7.6 to 5.4 $d_3$mft (-29%). This will likely be due in part to the reasons discussed earlier. However, by 2007/08, although the Glasgow SIC remained marginally higher than in the remainder of Scotland, the amplitude of the 'gap' had reduced markedly from baseline. Therefore, it is reasonable to conclude that, by the SIC measure, the simple absolute dental health inequality reduced between the two geographic areas i.e. Glasgow and the rest of Scotland. It is reassuring that in addition to dental health improvements among those with propensity for marginal $d_3$mft involvement, the dental health improvements were observed in the third of the population with the predisposition to be most severely affected. This part of the population distribution of $d_3$mft is where one would expect to find at least some of the sub-group denoted *'hard to reach'* (irrespective of their SES).

The simple absolute inequality in SIC values between the geographic areas was 1.8 in 1993/94 decreasing to 0.5 by 2007/08, whilst the simple relative inequality in SIC decreased from 1.24 to 1.09 $d_3$mft, over the interval. Thus, when measured by both absolute and relative change in SIC values from 1993/94-2007/08, it is justifiable to claim that geographic inequality between Glasgow and the rest of Scotland has decreased over the interval. Moreover, there were statistically significant reductions in the SIC index in all three geographic areas studied ($p<0.005$) over the period since 1993/94. This is of some reassurance now, coming after a suggestion that up to 2002/03 there had not been any improvement in the dental health of Scotland's five-year-old groups with a potential for high $d_3$mft (Levin *et al.*, 2009). Child Health, OHP and welfare programmes effective in bringing about OHI, but which were nevertheless unable to produce any impacts on those with high potential for $d_3$mft, would be of doubtful value to the inequalities agenda.

8.5.3.2 Use of a modified Significant Caries Index (SIC^{10})

The use of different cut-points in calculating the SIC was described by Morgan *et al.* (2005). The SIC^{10} measures the mean $d_3$mft of the most severely affected decile of the population of interest. As the subject of this thesis is the study of inequality in distribution of $d_3$mft, the author believes that there is added relevant information to be gained from an examination of the whole distribution of $d_3$mft, over all the deciles of the population ranked by $d_3$mft score, rather than simply from the SIC^{10} score of the poorest decile. By thus taking account of the whole distribution of $d_3$mft, it is possible to use the SIC^{10} to measure complex absolute inequality across the whole population of five-year-olds in this study. The mean $d_3$mft of the worst affected $d_3$mft-decile has nevertheless decreased over the interval of study, at each of the geographic levels and this has been most apparent in Glasgow where it decreased from 13.0 $d_3$mft to 9.8 $d_3$mft (-25%). Meantime, in the rest of Scotland, SIC^{10} has decreased from 11.6 to 9.0 (-22%) over the interval. Over the whole period, in Glasgow and in the rest of Scotland, the differences in mean $d_3$mft scores of the poorest decile (SIC^{10}) decreased by 3.2 and 2.6 $d_3$mft, respectively, within these geographic areas. The redistribution of the underlying d_3mft data indicated that there were statistically significant changes from 1993/04 to 2007/08 in each of the geographic areas ($p<0.001$, respectively). These results demonstrate that over and above the discriminatory potential exhibited by the SIC^{10} in identifying those with the greatest propensity for d_3mft, further stratification is possible across the d_3mft affected portion of each area's P1 population. This method exposes the extent of improvement in the high-disease tail-end of the caries distribution and somewhat reassuringly, inspection of the temporal trend would lead one to similar conclusions as the SIC. However, use of the whole SIC^{10} distribution permits the researcher to focus on both prevalence aspects and the relative impact of d_3mft burden affecting the minority with the poorest dental health experience and the greatest future propensity for d_3mft. This could be useful for fine tuning future strategy, as burdens of d_3mft across population SIC^{10} deciles become less common. The minorities who left to themselves have little potential for low d_3mft could be thus identified for future targeting of intensive salutogenic interventions such as those described by e.g. Scottish Intercollegiate Guidelines Network, 2005 & Hallas *et al.*, 2010.

In keeping with the Caldicott principles, the dataset used for this research has been stripped of the data-fields with the potential to identify individuals. However, forename, surname, date of birth, full postcode and school identification code are mandatory fields at NDIP data collections. As a starting point, it would be worthwhile to investigate one year-specific full dataset from Glasgow, as these fields are potentially available to this author. It would be of interest to see whether there is any area-based or school-based clustering of the individuals appearing in the P1 population SIC^{10} decile with the poorest d_3mft scores. In future, as the Scottish Government's ambitions for improved data linkage and full integration of child health surveillance systems are realised, it would be possible for individuals identified within the high-d_3mft-end of the SIC^{10} distribution to be followed-up.

Measurement of differences in dental health inequality between the geographic areas Glasgow and the remainder of Scotland by the SIC^{10} measure indicates that simple absolute geographic inequality in the SIC^{10} reduced from 1.4 to 0.8 d_3mft and the simple relative inequality decreased from 1.12 to 1.08, over the interval. Readers unfamiliar with inequalities trend analyses could be tempted to dismiss the forgoing as a trivial reduction in relative inequality. However, because of the dependence on ratios in the measurement of relative inequalities, the literature does indicate that it is extremely difficult to hold relative inequalities steady against a background of improving population health, let alone to bring about improvement by relative metrics. Thus, while absolute inequality in SIC^{10} between the two geographic areas definitely did decrease, it is all the more encouraging to be able to report that this change occurred against a background of population health improvement and stable to marginally reducing relative inequality.

8.5.3.3 The utility of SIC and SIC^{10}

It is important to remember that neither the SIC nor SIC^{10} are SES ordered and thus, respectively, they describe the distribution of $d_3$mft across tertiles and deciles of the whole population, irrespective of their SES. In spite of the increased skew in the distribution of $d_3$mft and caries being manifest in increasingly smaller proportions of the P1 population, it is reassuring to note that the amount of $d_3$mft among those with the propensity to be most affected is nevertheless decreasing over time. The SIC^{10} is able to provide powerful visual evidence of this trend. This implies that at least some diminution of the determinants of poor dental health are indeed occurring in those most 'at risk' within the populations of Glasgow and the rest of Scotland. However, within the limitations of this study it is not possible to know whether this is due to extensive reach of some universal OHP, due to some more 'directed population' elements, individual targeting via *Childsmile Practice* or changes in the general psycho-social and welfare environment. The ‘right and down’ shift in the distribution of SIC^{10} indicates that while the dental health experiences of children with marginal propensity to $d_3$mft are indeed improving, at the same time there have been decreases in the burden of morbidity in those affected by greater propensity to $d_3$mft.

This compression of the distribution of five-year-old children affected by $d_3$mft within each geographic level could potentially be viewed as an increase in inequality, or a decrease in inequality, depending upon the reader’s philosophical perspective. The population burden of dental disease increasingly is less dispersed and is being concentrated in smaller proportions of five-year-old children. Proponents of the Lorenz curve-type of inequality measurement, derived from the field of incomes economics would view a decreased dispersion of this type as an increase in inequality. Nevertheless, the decrease in burden of disease occurred within all affected population deciles of $d_3$mft, as population dental health improvement occurred. Thus, it does appear that the Scottish Government's ambitions to improve population dental health of five-year-olds have not been at the expense of increasing inequalities between the geographic areas or within each of the populations' distribution of $d_3$mft scores. Thus, at least on a superficial basis, the SIC^{10} is able to meet the requirements for the ‘test’ laid out in ‘*Equally Well*’ (The Scottish Government, 2008) for Scotland's raft of health and social policy, which asks the following questions “*does it work to improve health? and does it work to reduce health inequalities?*”, whatever '*it*' actually was.

However, the epidemiological results presented earlier have demonstrated the pervasive enduring association between d_3mft and SES status when measured by DepCat and one of the features of the SIC indices which could be considered as shortcomings are the absence of a SES dimension. Notwithstanding this, the whole population approach to measurement of health inequalities, irrespective of SES has been advocated (Silber, 1982; Le Grand, 1987; Machenbach & Kunst, 1997; Murray *et al.*, 1999; Gakidou & King, 2001). Nevertheless, this author believes that in the Glasgow and Scottish contexts, there is no moral justification for the dismissal of SES considerations within the health and social policy framework or in the monitoring of dental health outcomes. It must always be borne in mind that the distribution of P1 SIC^{10} deciles of d_3mft and the DepCat- (or in future SIMD-) based distributions are not synonymous or interchangeable.

The full SIC^{10} distribution would nevertheless meet the requirements of the above authors who wish to consider the whole distribution of inequality at individual level without reference to SES.

Nonetheless, this author would caution against use of the SIC and the SIC^{10}, alone, as SES is such a substantial predictive factor for $d_3mft>0$ in Scotland. However, it does provide information in another dimension of inequality than SES. A future modification to the way SIC^{10} has been used in this study could be to produce a SIC^{10} distribution for each SES category, in addition to that of the overall population. Nevertheless, when compared to some of the other potential tests of dental health inequality, the full SIC^{10} distribution provides an easily understandable, comparatively stable distributional measure of inequality, over time, which does not fluctuate rapidly. Thus, for this very reason alone, Marmot *et al*. (2010) would likely consider its use advantageous.

8.6 The simple tests of inequality in the distribution of dental health in the extreme SES groups

8.6.1 Introduction to simple inequality tests

The strength of the association between DepCat and poor dental health indices in Scotland, makes omission of the following SES subgroup analyses unjustifiable.

As suggested earlier, relative inequality is considered to be a better index of aetiological effects, whilst absolute inequality is considered to give a better indication of public health importance. As these aspects of inequality are important, it is good practice to report both (Shaw *et al.*, 2007). Notwithstanding that both absolute and relative SES inequalities outcomes should be reported together, the caries epidemiological trend data should always be required to be reported alongside, so that readers may adequately interpret what is happening in the population, as a whole and in the SES subgroups.

8.6.2 Simple absolute and simple relative SES inequality

8.6.2.1 Trends in P1s' simple absolute and simple relative SES inequality in % $d_3$mft>0

It may seem counterintuitive to some readers that while the trends in simple absolute SES inequality in % $d_3$mft>0 (1993/94-2007/08) tended to indicate that overall, simple absolute SES inequality in caries prevalence at d_3 decreased (N/S) in Scotland as a whole, and in the area outwith Glasgow, over the study interval, the respective values for simple relative SES inequality in prevalence of $d_3$mft>0 increased in both geographic areas (in Scotland, $p<0.05$). However, these findings do not negate each other and indeed contradictions of this sort are just what the literature would lead one to expect during periods of changing prevalences of morbidity across populations.

Understanding the often opposing absolute and relative SES inequalities trends associated with epidemiological evidence of health improvements is problematic (Asada, 2005). Hence, the cautionary notes from the methodological reviews (e.g. Wagstaff *et al.*, 1991; Harper & Lynch, 2007a) on the need for multiple testing and to have the full epidemiological trend data readily available for examination, in addition to the inequalities trend data (Harper *et al.*, 2010). Oliver *et al.* (2002) have condemned the selective reporting of relative inequality data alone, without showing absolute differences, as a “*lobbyist attitude*” towards health inequalities, believing that relative inequalities data alone risks misleading future policy. This can be amply illustrated in a hypothetical situation drawing on inequalities analysis results from this thesis e.g. in a competitive bidding process for resource allocation, selective use of relative tests would permit the unscrupulous to selectively show that over the period studied i.e. from 1993-2007 (simple) relative SES inequality in %$d_3$mft>0 was increasing in Scotland from 2.28 to 2.54 ($p<0.05$) while omitting to point out that simple absolute SES inequality in %$d_3$mft>0 was decreasing substantially in Scotland (from 44.6% to 35.3%) i.e. overall background population dental health was improving. The above trend indicates the tendency towards poorer relative equity while population dental health improves and is due to the effects of calculating ratio-differences.

The international literature shows that this finding is not unexpected in inequality analyses of caries datasets. Antunes *et al.* (2004) and Armfield *et al.* (2009) concluded that similar apparent increases in relative caries inequality in their respective studies were a consequence of the improvements in population-wide dental health. It appears that this is also the case in Scotland. Thus, however unwanted, these relative inequalities results are potentially an effect of universal programmes and overall improvements in population (dental) health.

8.6.2.2 Trends in P1s' simple absolute and simple relative SES inequality in mean $d_3$mft

The importance of including both simple absolute and simple relative inequalities analyses is further illustrated by the observations of inequalities in the mean $d_3$mft values e.g. in each of the geographic areas, respectively, SES simple absolute inequalities in mean $d_3$mft decreased (in Scotland as a whole, $p<0.02$). Although failing to reach significance at the $p<0.05$ level, the Meta-analysis results nevertheless give fairly convincing indications of trends towards increases in respective simple relative SES inequality in Scotland ($p<0.055$, $R^2=0.48$) and in Glasgow ($p<0.062$, $R^2=0.46$). This too could seem contradictory and is another direct example from this study of the inherent complexities described by the previous researchers.

8.6.3 P1s' oral health outcomes, corresponding inequality outcomes and implications

From the examples outlined previously, readers can begin to gain an impression of what will happen to values for simple relative SES inequality, as prevalence or mean $d_3$mft falls towards zero across the population. The effect of changes in dental epidemiology on the values for simple relative inequality will be all the more if the tendency towards zero happens earliest, and to a proportionally greater extent, in the denominator group i.e. in this case the SES advantaged group. The SES most advantaged group will usually form the reference population (and the literature suggests that this group would tend to improve first). Clearly, any denominator tending towards zero will tend to have the effect of inflating the ratio outcome, unless the proportional decrease in the morbidity or prevalence denoted for the numerator population reduces by an equal or greater amount.

An illustrative example would be the hypothetical situation, in which at baseline, %$d_3$mft=0 in DepCat 1 & 7 communities is 90% and 60%, respectively. The guidelines on inequalities measurement require that it is disease, not health, which is measured. Thus, at the outset the corollaries are 10% and 40% with $d_3$mft>0, respectively, giving a simple absolute inequality in $d_3$mft>0 of 40-10 i.e. 30% and a simple relative inequality of 40/10 i.e.4.0. If, over time, the prevalence of dental health improves by 5% points in each community to give 95% and 65% with $d_3$mft=0, respectively, the resulting simple absolute value would remain unaltered i.e. 30%, while the simple relative inequality value would rise to 7.0. In this example, to keep the simple relative inequality in %$d_3$mft=0 steady against the 5% points gain in the DepCat 1 community, would require that the magnitude of improvement in the DepCat 7 group was 15% points. This amply illustrates the difficulty in keeping simple relative inequality steady, never mind bringing about reductions, against a background of overall DHI.

However, given that eradication of caries to the greatest extent possible is the goal, and providing that health gains for the SES advantaged are not at the expense of the SES disadvantaged, we must not allow ourselves to become too distracted by increases in simple relative inequality which may become apparent, as overall population dental health indices improve. Nevertheless, it will be a requirement that caries inequalities researchers ensure that policy makers receive all of the information that they require in order to reach rational evidence-based conclusions/decisions about trends in dental health inequality. This will require the provision of full unbiased explanations of the simple relative inequalities results in the light of the epidemiological findings (and likewise for the results of the other inequalities tests).

In a further example over the whole period 1993/94 to 2007/08, simple absolute inequality in caries prevalence increased in Glasgow (although this was not the case in just the later interval from 1999/00 to 2007/08). However, the increase in simple absolute inequality amounted to only 2.5 percentage points against a background of very large significant reductions in the proportions of P1s with $d_3$mft>0 by 2007/08, i.e. in DepCat 1 & 7 communities, respectively, from 47.4% to 20.8% and from 81.9% to 57.8% ($p<0.05$ & $p<0.0001$, respectively). Value judgements will potentially have to be applied with respect to the relative priority given to creating aggregate (dental) health gains, compared to decreasing SES inequality (Macintyre, 2007; Macintyre, 2008; Harper *et al.*, 2010) and this theme will be considered in more detail later in this chapter. It has even been suggested that targeting the advantaged could produce even greater aggregate health gain at comparatively lower cost than targeting the most disadvantaged, which potentially could produce less health gain at much greater financial cost (Macintyre, 2007; Macintyre, 2008).

8.7 The complex tests of Scotland's P1s' dental health inequality, 1993 to 2007

8.7.1 The Gini-Coefficient, a complex test of inequality between individual P1 children

It is important to proceed now to consider the complex summary tests of inequality which take account of the whole population's dental health. As the Scottish P1 population dental health improved, with ever increasing $d_3$mft=0 percentages over successive NDIP epidemiological surveys, the Gini-coefficient tended to indicate ever more increasing inequality. As already explained, similar findings have been reported in other countries by research groupings (Antunes *et al.,* 2005; Armfield *et al.,* 2009). The Gini-co-efficient places more importance on describing the decreasing dispersion of $d_3$mft than on quantifying the increase in dental health ($d_3$mft=0) across the whole population. Originally Gini-coefficient was devised to measure inequality in income or wealth. Decreasing dispersion of income/wealth are considered to have negative connotations for society. Nevertheless, this is a counter-intuitive, potentially misleading and politically dangerous test of inequality when applied with an index which counts caries morbidity. For these reasons, one must be sure to take into consideration the overall dental health of the whole population and be cautious in wishing for decreased inequality in dental health by this measure, as this could represent either the very best, or the poorest, possible dental health outcome for the population. Neither the ScotPHo, the U.S. Department of Health, *Equally Well* nor the *Marmot Review* recommend use of this test (Lynch & Harper, 2005; Munoz-Arroyo & Sutton, 2007; The Scottish Government, 2008; Marmot *et al.,* 2010) and a review by Braveman (2006) could not commend it. Nevertheless, the inverse Gini (i.e. the Robin Hood Index described by Shaw *et al*., 2007) could possibly have merits with caries data. However, it does not yet appear to have been applied in this way in any publication known to this author.

As already suggested, the founding premise in interpreting the Gini coefficient is that the dispersed variable e.g. income , is a 'good' asset. In applying this test to dental health inequalities, it must be remembered that the variable of interest i.e. $d_3$mft is a detriment. Armfield *et al*. (2009) examined Australian trends in dental inequality by secondary data analysis using the SIC and Gini-coefficient, likely due to lack of data to permit the complex SES-related tests. That research group comment that all persons having the maximum amount of disease and alternatively all having no disease is taken to indicate perfect equality. Furthermore, if 99.9% have no disease and 0.1% have a dmft score of 1, the Gini-coefficient will indicate almost perfect inequality, while on the other hand if 99.9% have a $d_3$mft of 1 and 0.1% have $d_3$mft=0 the Gini will indicate almost perfect equality). Almost any improvement in population dental health outcomes will be designated as increasing inequality by this metric.

8.7.2 Complex tests of inequality by SES group

8.7.2.1 Performance of the ROC plots and (c-values) from P1's % $d_3$mft>0 *vs*. $d_3$mft=0 and DepCat

None of the contemporary recommendations of appropriate arrays of health inequalities tests recommends use of Receiver Operator Curves (ROC). Nevertheless, examination of the ROC plots for $d_3$mft>0, by DepCat, in Scotland, show a similar pattern of departure from the diagonal to those seen in the depictions of the Concentration Curve, which will be the next test to be considered in this discussion. At all times up to 2007/08, the area between the diagonal of equity and the ROC curve has been greater in Glasgow than in the rest of Scotland or Scotland as a whole. The ROC curve is not a conventional measure of SES inequality. Rather, it may be considered to be a combined measurement that is able to depict the predictive potential of DepCat for the dichotomous outcome $d_3$mft>0/$d_3$mft=0.

Inspection of the ROC curves for DepCat and $d_3$mft>0 presented in this study do indicate that it has good discriminatory potential. This author believes that the ROC plots provide an intuitive picture of the relationship between deprivation and $d_3$mft>0 and permit ready comparison between the geographic areas and of the trends in ROC plots, over time. The ROC plots indicate that DepCat had the highest predictive potential for $d_3$mft>0 in both 1999/00 and 2005/06 in the Glasgow area, corresponding with the times when the CC, SII and RII values were least favourable with respect to complex relative SES inequality. Thus, information from the ROC plots indicates that the relationship/predictive potential between deprivation and high caries prevalence among P1 children was at its peak at these times. The reduction in the area under the ROC plot, towards the diagonal by 2007/08, indicates that the relationship between deprivation and poor dental health in Glasgow was mitigated by the later time, compared to the association between these factors at the majority of the earlier cross-sectional data points.

Because of the degree of fluctuation, the Meta-analysis is important for understanding of the overall trend. While the SES inequalities trends are important, as already explained, this does not detract from the importance of the overall improvement in the five-year-olds P1 population's dental health, not least in the poorer SES groups over the whole period. This must be borne in mind, equally.

The ROC plots and the corresponding values of c, over the interval, in the rest of Scotland and in Scotland as a whole remained relatively constant over the period, consistently with a value of around 0.6. Meanwhile, the values of c in Glasgow rose steadily from baseline to 1999/00 when c reached its maximum, c=0.71, before decreasing substantially thereafter, eventually towards a similar value to that of the rest of Scotland.

There was a spike in the value of c in Glasgow which reached c=0.68 in 2005/06, hence the cautionary notes with respect to interpretation. It is worth reiterating that the epidemiological trend shows clearly that this spike is not due to worsening dental health indices, overall, or in the relatively SES deprived groups. It has instead occurred due to the aforementioned ability of the comparatively affluent groups to outstrip the magnitude of health gains occurring in the SES deprived groups (Victora *et al.,* 2000; Victora *et al.,* 2003).

Furthermore, the ROC plot and c value are a summary measure of the sensitivity and specificity of exposure to deprivation in the whole P1 population, at each geographic level for the outcome $d_3$mft>0. The enduring relationship between deprivation measured by DepCat and caries prevalence and burden of morbidity has been amply demonstrated in this research and in other studies (Sweeney *et al.,* 1997; Sweeney *et al.,* 1998; Sweeney *et al.,* 1999). Thus, because of its ability to test both sensitivity and specificity of DepCat as a predictor of $d_3$mft>0, the author of this thesis would likely commend the ROC plot and c value for the following reasons. The ROC plot has all of the illustrative advantages of the Concentration Curve and over and above this, the c value is an expression of predictive potential, which has an intuitive meaning which can be conveyed, even to lay audiences. Moreover, being able to demonstrate a falling value of c towards 0.5 and the mitigation of the direct association between deprivation and the $d_3$mft>0 outcome has great appeal at an emotive level. Surely, being able to demonstrate a future decreased potential for $d_3$mft>0 in association with future SES deprivation, so visually, makes this an ideal tool to assist in communicating (dental) health inequality-impacts, over time. Nonetheless, the ROC has not been advocated as a measure of health or dental health inequality in any of the recent inequalities methodology guidelines/reviews. Nevertheless, a consensus has developed since Wagstaff *et al.* (1991) cautioned that conclusions about inequalities trends may depend on the type of measure used. Multiple inequalities testing is widely advocated and there need be no scientific hesitation about conducting as many tests of inequality as one feels are merited by the questions in hand. Multiple testing is not considered to be ‘data dredging’ in the case of inequalities measurement.

The value of c for Scotland as a whole was consistently more similar to that of the rest of Scotland than to Glasgow. This again illustrates the added value of subgroup analysis in understanding the relationship between deprivation, prevalence of $d_3$mft>0 and place. There is a strong argument for including this type of analysis routinely in future caries inequalities assessments.

There is an additional difficulty achieving the $d_3$mft=0 outcome (which is necessary to impact on ROC plots and c-values) in the short-term *vs*. improvements in mean $d_3$mft scores of five-year-old groups with propensity to high mean burdens of carious teeth.

8.7.2.2 Concentration Curves and Koolman and Doorslaer's transformed CI from P1s' $d_3$mft scores and DepCat

Since the Concentration Curve plots cumulative individual $d_3$mft scores of subjects, ranked by SES affluence (and the sample share of each SES group), examination of the successive years' Concentration Curves for each of the geographic areas shows that the departure from the diagonal of equity was maximal in Glasgow in 1999/00 and 2005/06. Inspection of the caries prevalence trend data suggests that this 'worse' complex relative SES inequality is associated with the relative size of the differences between prevalence of $d_3$mft=0 and the mean $d_3$mft in the DepCat 7 group and the relatively advantaged DepCat 1 & 2 groups in 1999/00 and the DepCat 1, 2 & 3 groups in 2005/06. Nevertheless, the Concentration Curve provides a useful graphical summary of the magnitude of relative inequality which could be readily understood by policy makers and the public alike. It therefore has potential for use in explaining changes in the extent of SES inequality.

As the transformed values of the CI indicate, and may also be appreciated by careful examination of the CCs and the summary epidemiological data, the above periods in Glasgow were those at which the greatest percentages of redistribution of health from the comparatively affluent to the relatively deprived SES groups would have been required to achieve equity, by this measure. Since the transformed CI also is an inequality index which takes into account the whole distribution of SES and the consequent distribution of the variable of interest ($d_3$mft score) within SES groups, it too can provide summary information on inequalities with intuitive appeal which could assist in communicating the extent of inequalities. Between 1993/94 & 2007/08 an increase in transformed CI has been most notable in Glasgow, where inequality was apparently lower at the outset than in the rest of Scotland. This was due to the much poorer dental health experience in general, over all SES groups, even the comparatively affluent SES groups i.e. the SES distribution of $d_3$mft was historically much more equal. By 2007/08 there were only marginal differences in the values of transformed CI between the three geographic areas.

In common with the other inequality tests, Meta-analysis is required to determine significance of trends. Nonetheless, to fully understand change in inequality, over time, examination of the whole inequality trend line is required alongside the epidemiological trends. This must be considered as a further complexity to the measurement and interpretation of inequalities.

The CI has certain characteristics which should be taken into account: a) it may only be used with data with a strict hierarchal ranking, b) it is insensitive to changes in SES deprivation which do not affect SES ranking e.g. the DepCat index value 7 and SIMD quintile 1 do not permit scale extension beyond these points, c) the CI uses average population health as the reference point which can be important, d) it is sensitive to changes in the distribution of SES in the sample data (Wagstaff *et al.*, 1991; Regidor, 2004b). Nevertheless, the CI may produce trends showing declines in inequality due to worsening health among the groups with previously better health at the outset (Harper & Lynch, 2007b). Hence, there is a need to have the epidemiological data at hand prior to performing any interpretation. The Concentration Index nevertheless permits analysis of the extent to which poor health is concentrated among those in the more disadvantaged groups (The Scottish Government, 2008; Marmot *et al.,* 2010). The CI is mathematically related to the RII, nevertheless, the results of each may not always lead to the same conclusion about inequalities (Wagstaff *et al.*, 1991).

8.7.2.3 The Slope Index of Inequality for Scotland's P1s' $d_3$mft scores and DepCat

Over the interval between 1993/94 and 2007/08, the Slope Index of Inequality (SII) for P1s' dental health in Scotland, as a whole, decreased most notably after 2002/03. The SII in the rest of Scotland, Not-Glasgow, also improved over the period from 1993/94 until 1999/00 before deteriorating in 2002/03. After this time the downward trend in SII re-established, indicating that complex absolute SES-related inequality was decreasing. Over the study interval, the SII in Glasgow was far more erratic (similar to trends in the c-value metric) than in the rest of Scotland and remained higher at all times. However, in 2007/08 the SII values in each of the geographic areas were at their lowest overall and not dissimilar, compared to other years.

Unlike the alternative tests of SES inequality considered previously, the SII weights for the '*true*' population proportion in each deprivation category (Keppel *et al.,* 2005). Thus, it takes account of more than just the magnitude of difference in average morbidity across the SES spectrum. The SII is indicative of the total experience of the individuals within the whole population and is sensitive to alterations in the mean (Harper & Lynch, 2005) $d_3$mft within the respective DepCat groups and to the population mean. Furthermore, it is responsive to changes in group size. This analysis assumes stable population demographic distribution, as recorded at the 2001 Census.

The SII can be interpreted as the absolute effect on (dental) health of moving from the lowest SES group though to the highest (Munoz-Arroyo & Sutton, 2007; Marmot *et al.,* 2010). The SII, as used in this study could be described as capturing the absolute difference in $d_3$mft morbidity across the spectrum of categories from DepCat 1 to DepCat 7 e.g. a SII value of 3 would indicate that the mean $d_3$mft score increases by around three teeth over the population of interest ranked from the lowest DepCat to the highest.

The earlier erratic behaviour of the SII in Glasgow was somewhat disconcerting. Nevertheless, by 2007/08 it has achieved its smallest values in Scotland, Glasgow and the Not-Glasgow areas. This signifies that by the end-point, absolute improvements in the overall dental health of the populations has not been at the expense of increasing SES inequalities in either of the geographic subgroups. Nonetheless, the Meta-analyses of the SII outcomes, over time, using a logistic regression procedure is able to give an indication of the significance of overall trend in each of the geographic areas. The results of Meta-analysis showed that there had been a significant reduction in complex absolute SES inequality in Scotland's five-year-olds' dental health from the 1993/94 baseline by this measure ($p<0.02$). Furthermore, the SII is considered to be a consistent measure of health inequalities across local populations which avoids the defects of the simple absolute inequality metric (Wagstaff *et al.,* 1991; Low & Low, 2004 & 2005) and is advocated by the Equally Well task force (The Scottish Government, 2008) and the Marmot Report (Marmot *et al.,* 2010).

8.7.2.4 Some explanation and reassurance about the spiking values of SII in Glasgow in 1999/00 and 2005/06

The differential absolute magnitudes of improvement in the different halves of the SES spectrum which explain the behaviour of c, also explain the behaviour of SII. There were clearly poorer inequalities outcomes in Glasgow in 1999/00 & 2005/06. These worse SII scores are likely the result of a combination of factors. Firstly, the ‘gap’ in raw mean $d_3$mft scores between the relatively affluent SES groups and the relatively deprived groups was maximal. Secondly, the relative weights applied in the calculation of SII with respect to differences in the overall population proportions of resident P1s from comparatively deprived SES backgrounds, compared to proportionately fewer from relatively affluent SES home postcodes will be reflected in the overall calculation of SII for Glasgow.

For the reader accustomed to viewing trend lines from data for prevalence of chronic diseases, the extent of fluctuations in absolute (and relative inequalities trends) for the corresponding data is initially somewhat disconcerting. In comparison, the former tend to change relatively slowly. Reference to a review of *Selected comparisons of Measures of Health Disparities, NCI Cancer surveillance Monograph Series, Number 7,* (Harper & Lynch, 2007a) will provide reassurance that the undulating trends observed here are far from unusual. Although that report utilises a different selection of inequalities tests than those applied to the caries data in this thesis, that USA report provides a selection of illustrations of health trends with some corresponding inequalities (absolute and relative) trends by e.g. SES, race, gender and educational status for chronic conditions such as lung cancer, prostate cancer, smoking etc. Comparison of epidemiological trends with inequalities trends using the same source data show comparatively smooth epidemiological trends alongside 'jagged' trajectories for inequalities. It seems that a prominent common feature of the inequalities trend lines is their marked fluctuations over relatively short periods of time compared to prevalence trends. However, in the analyses for this thesis, some of the difficulty in interpreting inequalities trends has been addressed by the Meta-analyses using logistic and GLM procedures.

8.7.2.5 The main conclusion about use of the SII

Because of its ability to reflect the true background population proportions in the respective SES groups, this author believes that the SII is therefore an appropriate test for comparison of absolute complex SES inequalities in dental health over time, within and between geographic areas.

8.7.2.6 The Relative Index of Inequality measured from P1s' $d_3$mft scores and DepCat

The Relative Index of Inequality (RII) may be considered as the relative version of the SII (Regidor, 2004b). It measures complex relative SES-related inequality from the proportion of the health variable of interest with respect to the average population level, rather than only the difference between the extreme SES groups, as in the estimations of simple relative inequality (Harper & Lynch, 2005). Furthermore, it may be considered to represent the relative gradient relative to the mean ($d_3$mft score) of the whole population (Marmot *et al.*, 2010). Readers are reminded that the RII is not a measure of association, frequency ratio or Odds Ratio and it must never be interpreted as such (Keppel *et al.*, 2005). Over the period of study, the RII increased in each of the geographic areas, most notably in Glasgow. However, by 2007/08 the RII was of similar value in all three areas.

The Glasgow RII trend has a similar pattern to that of the SII, which is not surprising, as RII is derived from SII. Whilst absolute inequality decreased at all three geographic levels, the RII indicates that the improvements in the more deprived groups have not been proportionally as great as those measured in the relatively more affluent groups. The increases in RII in Scotland as a whole and the in area outwith Glasgow were significant. Wagstaff *et al*. (1991) predicted such a scenario i.e. the SII and RII moving in opposite directions and this tendency is said to be driven by change across the SES range *vis a vis* the intra group mean (e.g. the beta-coefficient decreasing against a decreasing overall mean).

8.7.2.7 Differences in Population Attributable Risk of $d_3$mft>0 from exposure to deprivation and some implications

Whilst the Population Attributable Risk (%PAR) may be used to quantify the effect of exposure *versus* non-exposure to a particular variable on a health event, with respect to SES inequalities, the %PAR measures the proportional (relative) improvement in the occurrence of a health event that would arise if the prevalence in the most advantaged group could be generalised to the whole population (Gefeller, 1990 & 1992; Benichou, 2001; Regidor, 2004b; Harper & Lynch, 2005).

Computation of the %PAR compares the prevalence of $d_3$mft>0 in each SES group to that of the reference group, DepCat 1, which is considered not to have had exposure to deprivation. By comparing all the other SES groups to the group with the 'best health', the %PAR thus differs from the CI, the SII and the RII which compare health in SES groups to average health. Examination of the %PAR for $d_3$mft>0 shows a startling difference between the gains which could be anticipated in Glasgow, compared to the rest of Scotland, if the hypothetical premise for the %PAR could be brought about. Theoretical gains for the combined populations making-up Scotland as a whole are intermediate. Recent reviews echoed earlier descriptions of the %PAR as a measure of preventable disease, useful in quantifying the potential impact of ‘control measures’ in a population and relevant to public health decision making (Coggon *et al.,* 1993; Benichou, 2001). Nevertheless, the magnitude of difference in %PAR between the geographic populations will have been affected by differences in the reference group in each of the three populations with respect to both group-size and the frequency of the health event of interest (i.e. $d_3$mft>0) in the more SES disadvantaged groups. The greater the association between the SES variable and the health problem and/or the larger the variation in the distribution of the SES variable, the larger the %PAR findings (Regidor, 2004b). The calculation of the %PAR weights for the respective SES population group sizes (Mackenbach & Kunst, 1997).

A measure of complex relative SES-related inequality, the %PAR in the rest of Scotland has more or less remained around 10% (range, 3.3%-13.7%) of the P1 population's $d_3$mft>0, whilst in Glasgow the %PAR value (*theoretically preventable disease*) ranged from 48.2%-72.5%. Most recently, 49.1% of $d_3$mft>0 can be considered to be preventable in 2007/08. In Scotland as a whole, the %PAR ranged from 22.8%-39.7%. Thus, use of the %PAR alone to demonstrate the potential to decrease P1s dental health inequality and the epidemiological data together could be used to argue for differentially greater 'directed population' interventions and resource allocation into the Glasgow area. It is accepted that this phraseology could be too difficult for some politicians to swallow. Nevertheless, the argument for differentially targeting the most at-risk groups at the whole of Scotland level could be more palatable and would likely bring about beneficial readjustment of resource allocation, if applied over and above core universal programmes. Furthermore, use of the %PAR in inequalities measurement is already advocated by both the *Marmot Review* (Marmot *et al.,* 2010) and *Equally Well* (The Scottish Government, 2008).

The magnitude of Scotland's most SES deprived DepCat 7 group in Glasgow (i.e. 73% of the national share) is proportionally far greater than that residing in the remainder of Scotland and this is part of the explanation for the large %PAR differences between the areas. Because of the stability of the reference group in each geographic area over time, the differences in the %PAR findings within each area, should be kept under observation. The %PAR is likely of most use for comparisons within each separate geographic area.

8.7.2.8 The P1s' adjusted Odds Ratios (ORs) for $d_3$mft>0 in different SES groups

While technically a statistical measure of ratios of probability, rather than a recognised test of inequality, the Odds Ratios (adjusted for age and sex) for $d_3$mft>0 in the poorer DepCat groups versus that of the most affluent DepCat 1 group (the reference value) is helpful when considering Scotland's dental health inequalities. It is comparatively straightforward to obtain adjusted ORs and associated estimates of the 95%CI, which are necessary to meet the American CDC guidelines for inequalities estimation (Keppel *et al.,* 2005). Furthermore, the 95%CIs may be used to form an impression of the likely significance of differences in inequalities, over time and between SES groups. However, Khang *et al.* (2008) caution that use of ORs can both over- or under-estimate relative inequalities when the outcome prevalence is high (e.g. >10%), especially when prevalence varies significantly over time.

At most times, at each of the geographic levels, there were highly statistically significant associations between relative deprivation and $d_3$mft>0 in all SES groups with a DepCat score of DepCat 3, or greater. The exception was Glasgow in 1993, when no such consistent association of OR value to SES was observed that year. As afore mentioned, this was due to the relative SES prevalence of $d_3$mft=0 not conforming to the usual SES gradient. Nevertheless, over the study interval, the ORs for $d_3$mft>0 in Glasgow P1 children from DepCat 6 and 7 communities, compared to those in DepCat 1, remained of the greatest relative magnitude, within remarkably clear and consistent direct SES gradients.

In Scotland as a whole, it was in the DepCat 6 and 7 communities, which consistently had the greatest association between deprivation and $d_3$mft>0 scores, that showed the greatest magnitude of reduction in ORs from 1993/94 to 2007/08. The ORs for $d_3$mft>0 reduced in DepCat 7 and 6 communities, between baseline and 2007/08, respectively, from OR =7.5 (95%CI, 5.20-10.70) to 4.98 (95%CI, 3.90-6.73) and 5.63 (95%CI, 4.00-7.88) to 3.78 (3.06-4.66). Whilst there is no separation of the confidence intervals in the DepCat 6 or the DepCat 7 groups, over time, these represent substantial reductions in ORs, when compared to the modest improvements in relatively more affluent DepCat groups over the same interval.

8.7.2.9 Some conclusions from intervening papers

Due to the time-frame associated with this part-time research and in advance of the conclusion of this thesis, an inequalities analysis of the Scottish P1 data from 1993-2003 was published (Levin *et al.,* 2009). While the resulting paper does describe inequalities trend by some statistical measures, namely Odds Ratios (OR) and Relative Risks (RR), it did not conduct similar geographic sub-group analyses, or the modelling of inequalities using recognised contemporary complex methods for measuring health inequalities (Flowers & Pencheon, 2004; Harper & Lynch 2005; Munoz-Arroyo & Sutton, 2007). Levin *et al.* (2009) instead compared the ORs and RRs of dental caries in SES groups, to those in DepCat 1, as the reference group for each survey year. By carrying out their secondary analyses of the SHBDEP and NDIP datasets both Levin *et al.* and this research team do seem to have addressed some past criticisms of inequalities research e.g. the non-use of existing government funded datasets. Commenting on CDC research, Billheimer & Klein (2010) suggest that larger population sample sizes are required to permit exploration of inequalities pertinent to major population sub-groups. Clearly, a foresight originating back in the 1980s has resulted in no such lack of data for Scotland's P1 group over the intervening decades.

Moreover, both this and the foregoing Scottish research group have attempted to answer questions i.e. ‘how much good’ for ‘which population subgroups’, over time.

8.7.3 Further discussion of Scotland's caries inequalities outcomes

8.7.3.1 Potential explanations for the changes in the SES-related dental health inequalities and implications for the future

This research has shown a differential excess SES burden of prevalence and of mean $d_3$mft in five-year-olds in SES disadvantaged families. It likely takes far more intervention (Macintyre, 2007; Macintyre, 2008) with commencement far earlier in a child's life-course to maintain a SES deprived child with $d_3$mft=0, than it does for a comparatively affluent child with a more marginal propensity for caries (Watt, 2001). As suggested earlier, it may be that more minor interventions, commencing later, can be sufficient (over and above other better life-course prognosticators of dental health) to maintain the dental health of a child who would otherwise have relatively marginal experience of $d_3$mft. Furthermore, a child who would as a matter of course develop with $d_3$mft=0, may not achieve enhanced dental health outcomes beyond this, from similar interventions, when caries is measured at d_3. However, this would not necessarily be the case if caries experience was measured by a more sensitive indicator e.g. the International Caries Assessment and Detection System (ICDAS II), which provides a range of caries severity scores for application at lesion stages earlier than d_3 (ICDAS Foundation, 2010). ICDAS II evolved from earlier published methods for assessment of activity in carious lesions (Ekstrand *et al.*, 1997; Nyvad *et al.*, 1999). Notwithstanding this, to date, the NDIP programme continues to rely on the BASCD criteria for caries diagnosis in Scotland's caries epidemiology surveys. However, as Scotland's prevalence of $d_3$mft decreases, potentially due to decreases in the rate of penetration of enamel of the sort reported by other authors (Sheiham & Sabbah, 2010), it may become appropriate to introduce ICDAS II into the NDIP programme. The use of an alternative threshold for caries diagnosis may well result in different conclusions about inequalities outcomes.

Nevertheless, the day-to-day amendments required to a SES deprived child's life-course to completely overcome their propensity to high numbers of $d_3$mft, by contributing OHP programme-derived salutogenic factors, may be very considerable indeed. This will be all the more so to render their score $d_3$mft=0. This, along with greater motivation, better education, high self-belief, internal locus of control and more economic ability to exert parental choice etc. in affluent groups explains, in part, the greater difficulties encountered in past attempts to improve dental health in SES deprived communities and reduce inequalities (The Scottish Government, 2008). It is reportedly very difficult to obtain at least equal (dental) health outcomes from equal (dental) health interventions and financial investment (Macintyre, 2008) and decisions about future resource deployment in this regard are a further manifestation of the inequalities 'value judgement' discussed earlier. Nevertheless, universal interventions do continue to have a core place in future programmes to avoid the negative effect of stigmatisation, which can cause alienation to Scottish OHP programmes (Holme *et al.,* 2009) and to bring about overall population improvements in line with government targets.

However, if the SES inequalities are nevertheless to be overcome, there will remain a need for additional enhanced differentially directed population dental health interventions in SES deprived communities (Watt, 2005; Batchelor & Sheiham, 2006; Sagheri *et al.,* 2008). The recently published '*Strategic Review of Health Inequalities in England post-2010*' would seem to argue likewise (Marmot *et al.,* 2010).

Based on this study's epidemiological observations, there was marked improvement in dental health indices of the DepCat 6 & 7 P1 children in Glasgow from 2002/03 and increasing improvements in these groups' dental health indices have continued to be observed since. When they reached five years of age, the 2005/06 P1 cohort were the first across Glasgow to benefit from a temporal relationship with the two ecological OHP programmes outlined earlier (with lead time) during their pre-school nursery years. Nevertheless, it was not a '*from-birth*' association for the children who were born earlier than the OHP programmes' commencement i.e. born in the year 1997-1998 and they could only have had a temporal association with interventions at the life-course stage when they commenced in nursery (which for the majority would not be before age three years). However, in SES deprived populations in Glasgow in the mid 1990s there was historical evidence of manifest caries morbidity by the age of 36-47 months with the mean $d_3$mft=3.9 (95%CI 2.8-5.1) with a prevalence of $d_3$mft>0 of 62% (Blair *et al.*, 2004). More recently, although improvements were observed in the 3-year-olds in the mid 2000s, caries morbidity remains prevalent in the age group e.g. mean $d_3$mft=1.5 with 33% $d_3$mft>0 in this geographic population and age group (McMahon *et al.*, 2010).

Clearly, a population affected to the former extent, at such a young age, must have been exposed to a substantial cariogenic onslaught. Thus, in the early years within this study, the OHP programmes likely began too late in the life-course of relatively disadvantaged children and had too little population coverage to confer protection from their already manifest experience of $d_3$mft>0 (McMahon *et al.,* 2010). Although the interventions may have been potentially too late for some of those who had already accumulated more negative life-course exposures over time, it seems that the later introduction (than '*from birth*') of altered determinants of dental health (however these originated) could possibly have given protection from $d_3$mft>0 to a proportion of the children who would otherwise have been likely to experience caries at the d_3 level.

There is evidence of statistically significant improvement right across the whole SES spectrum at the Scotland level and this is more or less the case in the two geographic subgroups.

Unfortunately, as yet, there is no scientific evidence of causality for the observed dental health outcomes in Scotland. However, if the Victora *et al.* (2003) theory is correct, and from an observational perspective, only, these timings of epidemiological trends might lead one to tentatively suggest that there could be a temporal association with some intervention(s). By 2007/08 there is clearly evidence of altered determinants of five-year-olds' dental health right across the SES spectrum. From 2006 onward, the *Childsmile* programme components consolidated the earlier targeted OHP and ensured that the of the principles of 'anticipatory care' as laid out in the *Kerr Report* (Scottish Executive, 2005) were applied to OHP across Scotland.

Some clues as to what could possibly be contributory to the observations herein, may lie in the recognised evidence-base which supports the regular use of 1000ppm F^- dentifrice for caries prevention in young children. A Cochrane review and Meta-analysis concluded that there was a significant anti-caries effect from toothpastes containing F^- at 1000ppm, or above (Walsh *et al.*, 2010). Thus, some efficacy from the sustained widespread population distribution of toothpastes containing F^- at 1000ppm is not at all implausible at population level.

Furthermore, the foregoing results suggest that there is a probability that both total duration of exposure (to whatever the altered determinant(s) of dental health) and the point in the life-course from which young children received the exposure are both important, as the OR values tend to decrease over time in successive P1 cohorts in Scotland and Glasgow, after 2002/03.

8.7.3.2 Some contemporary opinions on different (dental) health outcomes and the inequalities implications arising

Within the current state of knowledge, it is not possible to predict with certainty what the short and long-term inequalities outcomes will be against an overall background of population health improvement interventions. The Scottish Government has persistently made it clear that improvements on both fronts are called for.

Contemporary expert consensus suggests that it will be necessary to provide, proportionally, the extra support that poor population groups need to compensate for their generalised shortfall in overall salutogenic factors. Their needs will likely be comparatively greater at each stage further down the SES spectrum. The Marmot *et al.*

(2010) description of what is required does provide further clarity. In the past, whilst universal interventions clearly meant '*for all*', targeting too tended to be a '*one-size fits all*'. If we are in future to follow the Marmot review's recommendations, their line of reasoning calls for a much more sophisticated methodology for differentially applying interventions along the whole SES gradient (Marmot *et al.,* 2010), against a more general background of improvements in participation and in social welfare policies (Wilkinson, 2005; Macintyre, 2007). Thus, in future, it may be necessary to increase differentially the directed interventions relative to the universal interventions and this does seem to be what Marmot *et al.* (2010) are suggesting by use of the term '*proportional universalism*'.

8.7.3.3 An estimation of the 'scale' of the problem of poor dental health and inequality outcomes at five years of age

The *Marmot Review* (Marmot *et al.,* 2010) considered that there are three fundamental considerations when measuring/monitoring inequality. The three factors are 1) the absolute range of inequality which measures 'How big is the gap?', 2) the RII which measures 'How steep is the gradient across the deprivation scale?' relative to the mean health of the whole population and 3) the scale i.e. 'How big is the problem? At the 2001 census, 73% of the national-share of Scotland's five-year olds resident in DepCat 7 home circumstances actually lived within the NHS Greater Glasgow Health Board (GGHB) area, where they accounted for 32% of the P1 population. Moreover, due to the relative size of the resident DepCat 6 & 7 groups in GGHB (forming 48% of the area's P1 population) the influence of the relatively poor SES groups' poor dental health has had the predominant effect on the Glasgow area's dental health statistics. Large population proportions of the most SES deprived children were also resident in the contiguous areas of NHS Lanarkshire, NHS Argyll & Clyde and NHS Ayrshire & Arran. The SHBDEP & NDIP reports since 1987 have consistently demonstrated the enduring problem of poorer dental health statistics for West-Central Scotland (WCS) NHS Boards' P1 children. Thus, in spite of the improvements observed since the late 1990s, due to population size and the relative density of SES deprivation in WCS, there continues to be a large problem to address there.

Furthermore, for Scotland as a whole, the problem of dental health inequalities, by age five years, is large because of the size of the population share residing in the GGHB area. The population of the current administrative entity, namely, NHS Greater Glasgow & Clyde (NHSGGC), expanded from that of Glasgow (NHS GGHB) in 2005, and now alone amounts to over a quarter of Scotland's total population and it has the highest prevalence of the most severe multiple deprivations when measured by SIMD 2009 (Scottish Government, 2009). However, the dental health problem is perhaps not as big as it was formerly, due to the substantial inroads reported here, with respect to dental health and dental inequalities improvements.

Thus, improving the dental health of people in the NHSGGC Board's area should improve the overall health of the Scottish population and has the potential to reduce overall national inequalities in (dental) health (The Scottish Government, 2008). This study provides some evidence for this i.e. the %PAR trends hint that the GGHB area has a larger effect on the overall %PAR value for Scotland than the area making up the remainder of Scotland.

8.7.3.4 Examples of some 'value judgements' related to dental health inequalities

The topic of 'value judgements' has arisen earlier in relation to health inequalities (Harper & Lynch, 2005; Harper *et al.*, 2010). The associated issues are generally related to i) what is measured, ii) in whom iii) how it is measured and iv) the relative importance given to different findings. Choice of one measure to the exclusion of others may impose normative judgements e.g. whether individuals or groups count more, which should be prioritised and by how much etc. (Harper *et al.*, 2010).

This author could argue that based on the foregoing evidence of the direct SES-related distribution of $d_3$mft>0 and the dispersion of Scotland's most SES challenged five-year-olds, that there could be a case for differentially greater allocation of resources to the WCS region. However, on the other hand, caries remains prevalent in the whole of Scotland's P1 population and one could also argue that the lower densities and numbers involved does not mean that the dental health needs of the individuals, groups and geographic areas affected are of any less importance. Clearly, complex 'value judgements' have to be made with respect to resource allocation.

Another illustration of a 'value judgement' which has to be made relates to the relative weights given to the result of one inequalities test compared to another in reaching, framing and reporting ones conclusions about inequality. In the opinion (value judgement) of this author, the magnitude of ‘prevented morbidity’ in this Scottish study is well worth the comparatively small inequality trade-off in e.g. in simple relative inequality and in RII outcomes observed in this instance. This is especially so if these are 'traded' against the substantial simple absolute and complex absolute SES-related inequality gains reported herein e.g. in Scotland's SII. While reducing inequalities remains an important goal, it has nevertheless been suggested that it would be undesirable for society if the health inequality agenda took primacy over all other concerns, and if health inequalities were addressed at all costs (Oliver *et al.*, 2002).

It is nonetheless encouraging that over the period in this study, trends towards improvements in caries epidemiological outcomes were associated with the decreasing geographic and SES inequality, which was measurable by several of the inequality indices tested in this research project. This consistency certainly does help to give researchers more confidence when making the value judgements which are inescapable in inequalities research. The shortcomings/difficulties with the tests which do not show improvements in this study have already been rehearsed e.g. the Gini co-efficient, the simple relative inequalities differences and the CI. Previous authors on generic inequalities topics have already reported the often apparent dissonance between the results of one inequalities test and another. Hence, there will always be a requirement for the multiple testing and whenever possible, results from the broadest range of measures should be considered (Harper *et al.*, 2010).

Furthermore, if everything that the literature review has suggested about general and social and welfare policies is correct, the recent announcements from the Westminster Government which aim to rebalance the economy can reasonably be envisaged to exert future effects on the (dental) health inequalities of young children. This clearly reflects a contemporary 'value judgement' within the political context. However, eventually, society informed by health inequalities researchers will be the arbiter.

8.7.4 Summary of evidence that Scotland's absolute SES-related dental health inequality has decreased and some implications

There are consistent indications that both simple and complex absolute SES-related dental health inequalities have improved in Scotland, since 1993. Reductions in the simple absolute SES inequalities in the mean $d_3$mft ($p<0.02$) and percentages of five-year-olds with $d_3$mft>0 have been achieved. Furthermore, the SII test results indicate that statistically significant improvements in complex absolute SES-related inequality occurred in Scotland ($p<0.02$) over the interval from 1993/94. This latter finding is a demonstration that change beneficial to society has occurred beyond the DepCat 7 group alone, extending throughout P1s in all of the relatively SES deprived DepCat communities of Scotland. Indications from the ROC results for Scotland over the period from 1993, with respect to reliably predicting young children's dental morbidity (and the corollary), show that the determinants of P1s' dental health associated with deprivation have been mitigated to a statistically significant extent ($p<0.005$), over the interval. Simultaneously, the %PAR findings for DepCat and $d_3$mft>0 indicate that over time, from 1993, the proportions of P1s in both Glasgow and the whole of Scotland with experience of obvious dental caries, which would be overcome if the effects of deprivation on dental health could be negated, have decreased.

The %PAR results highlight the striking SES-related inequality in the magnitude of the preventable fraction of five-year-olds with $d_3mft>0$ experience in Glasgow (latterly, PAR=49%), compared to elsewhere in Scotland (latterly, PAR= 7.0%, overall geographic difference in trend 1993-2007, $p<0.0001$). However, these dramatic findings are due in part to the way that %PAR is calculated and the very different distribution of SES-related deprivation (measured by DepCat, 2001 for Scotland) among Glasgow P1 residents, compared to those from the rest of Scotland.

8.7.4.1 *Childsmile* programme design – possible consequences for dental health and inequality

Universal interventions will be necessary to accord with national policy objectives to continue to improve the dental health of the whole population of P1s. As the respective universal and 'directed population' *Childsmile Practice* and *Childsmile Nursery* interventions i.e. regular F^- varnish programmes (Health Scotland, 2009) became established following roll-out from their pilot sites, additional universal and 'directed population' effects may well be observed. Moreover, at present *Childsmile* is 'targeting' differentially intense individual interventions via *Childsmile Practice* (Health Scotland, 2009).

The new target for OHP set by the Scottish Government requires that by March 2014, at least 60% of children in each SIMD quintile (at NHS Board level) are to have received at least two topical F^- varnish applications in their fourth and in their fifth year of life (The Scottish Government, 2010). It is anticipated that this Fluoride Varnishing Programme (FVP) will predominantly be delivered by *Childsmile Practice* to the relatively affluent SES groups who tend to have regular dental visiting behaviour and via *Childsmile-nursery* in the case of the less advantaged SES groups. Furthermore, any children receiving the FVP intervention in nursery may also receive additional intervention from their *Childsmile Practice*.

Commencing in *Childsmile Nursery* and through *Childsmile School*, the Scottish Government will ensure that the above SIMD 1 group of nursery children receive sustained FVP interventions, both before, and as they enter primary school. In their P1 & P2 school year the target groups of children currently continue to receive additional support to take-up the FVP intervention(s) and this will be extended to include their P3 and P4 school years, by 2012, to meet a further government target [some parts of Scotland already exceed this by offering FVP throughout primary school i.e. to years P1 to P7]. *Childsmile Nursery* and *Childsmile School* are providing FVPs in 'priority' nurseries and schools i.e. the 20% of nurseries and primary schools, throughout Scotland, with the highest proportion of children living in the most deprived local quintile of postcode areas, identified by SIMD (2009) determined at local NHS Board level. To avoid stigma, this intervention is 'setting-specific' i.e. all children in each 'priority' setting receive the same offer of FVP interventions, irrespective of individual SES.

Thus, there are likely to be both 'cross-population' and 'directed population' beneficial effects. When assessing effectiveness, it will be of importance to measure the dental health and inequality impacts at the whole of Scotland and geographic sub-group levels and to take account of respective population and SES-group sizes.

As explained earlier, SES deprivation in Scotland is not distributed evenly across the NHS Board areas and is differentially concentrated in the NHS Board areas in WCS. Thus, the geographic subgroup analysis undertaken in this study hints that targeting that is appropriate by SIMD score derived within each NHS Board may not necessarily be the most appropriate method by which to identify those who are the 20% most SES challenged at the level of Scotland as a whole.

8.8 The complexity of dental health and inequality outcomes

There appear to be temporal associations between the onset of ecological OHP interventions, the improved health and welfare provision for young children and the subsequent observations of population level dental health improvements in five-year-olds' dental health indices. Nevertheless, a major pattern in the dental health and inequality outcomes has been that of complexity. This author feels a moral obligation to encourage continuation of this research in order that future inequalities outcomes are kept under continual review, as new cross-sectional datasets become available. Much of the preliminary work to enable this has already been undertaken by the programming undertaken in SAS and the validations of the dental health inequalities tests carried out in the course of this work. It is appropriate at this stage to consider how the various findings elicited here may inform future dental health inequalities testing.

8.8.1 Different selections of dental health inequality tests are required depending on what one's questions are about inequality and the target audience

8.8.1.1 Introduction

There has been much mention in the course of this work about Kunst & Mackenbach's (1997) view that choice and merit of one inequality test over another depends partly on ones perspective about inequality in health and the message to be conveyed. As explained earlier, selection decisions need to be taken following close inspection of the underlying sub-group specific dental health outcomes data. The nature of the research question(s) which arise then have to be considered. If one is only interested in comparing two groups, reporting of the simple absolute and relative inequality may be sufficient. The relative measure will provide information on the position/progress of one group versus the other, regardless of their levels of dental health. However, the simple absolute inequality values will provide the context and the public health perspective from which to view the relative inequalities observed. In the case of caries epidemiological data, because of the population proportions which continue to be affected, it appears that absolute inequality is the most important. [However, this would not necessarily be the case for a condition with comparatively low prevalence with a catastrophic outcome e.g. the relative inequality metric would likely be of more importance when considering the SES-related inequalities in incidence and mortality from oral cancer reported by ISD (2010) between the SIMD most advantaged and challenged groups in Scotland.] The Odds Ratios (ORs) from regression analysis may be considered to provide a more sophisticated measure of simple relative inequality due to their ability to generate confidence intervals and p values and should be used whenever possible to make statistical inference.

8.8.1.2 Summary indicators of inequality for ordered social group

Successive ORs may be used to make comparisons with a reference time-point or a reference group across a range of e.g. SES groups or cross-sectional data and are further recommended whenever possible for reports and presentations incorporating ranges of SES groups and times. However, for social groups with a natural order, the Slope Index of Inequality (SII) will provide summary information on complex absolute SES-related inequality in dental health while the Relative Index of Inequality (RII) and the Concentration Curve (CC) and transformed Concentration Index (CI) measure complex relative SES-related inequality. These tests take account of differences in the size of the SES groups within the underlying data and are sensitive to the direction of the SES gradient in dental health (the latter factor is what primarily distinguishes these metrics from the Gini-coefficient). The SII is sensitive to the population mean $d_3$mft and to the frequency of the morbidity in question and if the mean increases by the same proportion in all the SES groups, the SII will increase, while the relative differences remain constant. Furthermore, as already suggested, the SII and RII have a mathematical relationship with each other and both may be weighted by the distribution of SES in the background demographic population, as has been the case in this study. Nevertheless, an advantage of the CC over the SII and RII is the ability to graph the associated data to aid communication of information on inequalities trends to health policy makers. Nevertheless, a drawback is that the CC/CI may not register inequality when SES group(s) the middle of the SES distribution are disproportionally affected. Notwithstanding this, the CC and the RII are said to be better metrics for comparing SES inequality between different areas than either the %PAR or the SII.

Notwithstanding the above, and although not generally used in the literature for this purpose, because of the very strong direct relationship between SES disadvantage and poor dental health outcomes in Scotland, the Receiver Operator Curve (ROC) plot or the Population Attributable Risk (PAR) may be used in place of the CC especially to show changes over time in the direct systematic association between SES deprivation and $d_3$mft>0. These metrics may be simpler for lay audiences to understand than the CC (generally considered difficult to interpret). Interpretation of the c-values associated with the ROC plots gives a clear indication over and above the linear relationship which may be seen in the grouped epidemiological data, that without intervention the SES-related determinants of poor dental health outcomes at five-years-of age are systematically bound into the life-course of developing children to a directly variable extent across the SES gradient.

In terms of communication, the ROC has the visual advantage of a graph, whilst the interpretation of the %PAR gives an actual quantification in percentage terms to the prevalence of preventable morbidity across the whole population, if exposure to SES deprivation-related determinants could be eliminated. Both of these tests are useful to demonstrate the systematic relationship between SES deprivation and the potentially preventable/prevented morbidity from intervention(s) which act to mitigate the effects of SES-related deprivation.

Nonetheless, the concept associated with the interpretation of the transformed CI i.e. of 'health transfers' from the SES-advantaged to the SES-deprived, to produce equity, could also have powerful emotional resonance which could influence lay, policy and political audiences alike. This could be especially so for those who place a high value on their own health and that of their own or their constituents' children.

8.8.1.3 Tests for non-ordered social group data

The aforementioned Odds Ratios may be used as described above. They do not rely on SES group order and may be used between one group and any others as long as the reference group has been clearly indentified from the outset e.g. for migrants or ethnic minority groups in comparison to the indigenous populations. For use with data from more than two groups, the OR would test each other group against the selected reference group and would produce a succession of ORs i.e. repeated, directly comparable simple tests of relative inequality. With respect to complex tests of inequality for non-ordered groups, this study considered the Significant Caries Index (SIC), the SIC^{10} and the Gini-coefficient. The Gini cannot be recommended for use with caries data for reasons outlined earlier i.e. the ability of Gini to take account of only dispersion, not gradients and to place an equal equity value on $d_3$mft=0 as on $d_3$mft=20, providing either one of these entities was universally dispersed (Armfield *et al.*, 2009).

Nevertheless, the SIC and the SIC^{10} performed well with caries data and will prove useful with non-ordered data. Whilst the SIC and the SIC^{10} scores provide useful insights into the extent of morbidity (and any changes) in the high-disease end of the skewed caries distribution, it is inspection of the whole distribution of the SIC^{10} which gives 'at a glance' summary information about morbidity and prevalence across the whole population. This research strongly suggests that the whole SIC^{10} distribution should form part of the routine suite of tests presenting the findings from inequalities analysis of caries data.

8.8.1.4 Suites of caries epidemiology and caries inequality tests for different audiences

This thesis has sought out a relationship between the five-year-olds' population dental health improvement and dental health inequality. While it would have been satisfying to identify just one or two tests of inequality which would meet the requirements of Dental Public Health researchers, it has become clear that there are not just one or two inequalities relationships to describe. Although successive reviews on generic health inequalities have made this explicit, perhaps one has to actually carry out the multiple tests with various baseline and endpoints to fully realise the difficulties in interpretation and the previously described potential for manipulation or misuse which can arise from the selective presentation of inequalities results (Oliver *et al.,* 2002).

Recommendations on the foundation information which requires to be provided to all dental health inequalities audiences will be described next. Some suggestions on the additional information which specific audiences may require will follow.

8.8.1.5 The foundation information required by all audiences considering dental health inequalities

The following recommendations assume the availability of SES ordered data. All reports or presentations for caries inequality audiences should commence with Figures showing overall weighted %$d_3$mft=0 and mean $d_3$mft for the population in question. Additionally, data for the unweighted %$d_3$mft=0 and mean $d_3$mft, by SES group, should be provided to demonstrate SES gradients. Furthermore, it is useful to show the ORs (95% CI & p values) for %$d_3$mft>0 in comparisons of SES groups with the reference group (SES most affluent).

In addition to showing the number of subjects studied in each SES group examined, it is also necessary to describe the distribution of SES and actual numbers of persons within the age group within the background demographic population(s). Unweighted or weighted simple absolute and simple complex SES (or geographic) inequalities for %$d_3$mft=0 and mean $d_3$mft should be reported, as appropriate. Weighted values are appropriate for comparing whole populations' $d_3$mft indices to demonstrate geographic dental health inequalities and unweighted values should be used to show simple SES inequalities within populations.

If results from more than one cross-sectional dataset are being shown, time-series OR data will be useful. Furthermore, it will aid understanding of the distributional impacts of $d_3$mft across the whole population if the SIC[10] distribution is also reported.

8.8.1.6 Further information suitable for lay audience

For lay audiences the addition of a graphical depiction of the ROC plot and the inclusion of the appropriate information on the c-value and its interpretation may be helpful. The %PAR could also be presented to give dimension to the extent of the theoretically preventable caries experience.

8.8.1.7 Additional information suitable for professional audiences with an interest in inequalities

For professional audiences, Information as above (from 7.8.1.5), with the addition of the CC, the transformed CI, the SII and the RII should be considered to show the extent of similarities and differences between the different inequality test outcomes from the complex tests of SES-related inequality. If time-series data is being presented, the results of Meta-analysis for all simple and complex inequalities tests should be shown.

8.8.1.8 The information that policy makers require

Rational policy making to overcome SES inequalities requires the fullest information possible on which to base decisions. On this basis, one could be criticised for withholding any of the above perspectives, which inform on dimensions of inequality. However, the aim and objective should be taken into account, when deciding on which results to place emphasis. It is important to take the whole population health improvement over time into account and thus the foundation information above would be important. In the first instance, the same information as recommended for lay audiences should be provided. With successive cross-sectional datasets it will be important to produce the results for the SII and the RII to give quantification about the stability or change in complex absolute and relative SES inequality in dental health in the totality of the true background demographic population.

If resource allocation arguments were being pursued, the %PAR findings and the ROC plot information would be to the fore. However, if one wished to provide reassurance on the distribution of absolute improvements in beneficial outcomes across the whole population, or across SES groups then one would emphasise the SIC[10] distribution changes and the significance of the SII results, respectively.

Policy makers need information on what is happening with respect to relative inequalities and either the CC or the RII could be selected to provide this. The CC would give a visual impression of what was happening, over time, within the subjects examined across the SES groups and between populations in different areas, whilst the RII would give comparable values for complex relative SES-related inequality weighted according to the true background distribution of SES in each of the populations being compared.

8.9 A socio-political dimension to children's dental health inequalities

This dental health inequalities analysis shows that it has been possible for Scotland to impact beneficially on simple and complex ($p<0.02$) absolute SES-related dental health inequalities of five-year-olds (from 1993/94) and on their simple absolute geographic dental health inequalities (with no associated increase in simple geographic inequality) over a relatively short time frame to 2007/08. For the time being, the improvements in unadjusted mean d_3mft scores, the increases in % with $d_3mft=0$ in Scotland across the SES spectrum and the overall improvement in complex absolute SES-related dental health inequality should provide some reassurance to policy makers that even in the face of extreme SES deprivation in some DepCat 7 communities, the combined effects of Scotland’s social, welfare and OHP provision have been able to make inroads towards overall population dental health improvement and simultaneous inequalities reductions for five-year-olds. This should be particularly encouraging to Scotland's policy makers, as the observed improvement in Scotland occurred during a period in which large investment in England's deprived ‘Spearhead areas’ has not as yet produced similar evidence (Health Committee, 2009; Audit Commission, 2010).

However, there are no grounds for complacency. Without root-cause social and welfare interventions, (dental) health inequalities are likely to persist between groups, if the fundamental causes of (dental) inequality are not addressed further (Fejerskov, 2004; Macintyre, 2008; Gruer, *et al.,* 2009). Even some of the more egalitarian countries have yet to develop the institutional frameworks for health systems that actually promote health (Johansson *et al.*, 2010).

The trends towards decreasing dental health inequalities were not generally smooth and increases in dental health inequalities were observed at various times by different tests explored herein. The timing of some of this apparent worsening of dental health inequality in the mid- to late-1990s resonates with similar reports in the literature about worsening inequalities in general indices of child health, morbidity and mortality (with lag-time) toward the end of the last UK Conservative administration (e.g. Shaw *et al.,* 2001; Fairley & Leyland, 2006). Of the areas studied for this thesis, the similar dental inequality observations were most notable in Glasgow, which has the poorest population profile with respect to density of SES deprivation and the number of families affected.

Nonetheless, there has clearly been a wider effect on child health inequalities than just the deteriorating SES inequalities in five-year-olds' dental health picked-up towards the end of the 1990s by some of the inequalities tests in the research for this thesis. Spencer (2010) holds that child health inequalities are most profoundly affected by changes in living standards emanating from decisions in the socio-political arena. These changes in living standards go on to affect life-course (Braveman & Barclay, 2009). Furthermore, in spite of methodological shortcomings related to observational ecological studies akin to those in the research for this thesis, in New Zealand (NZ), Thomson *et al.* (2002) relate changes in political economic rationalism i.e. simultaneous reductions in welfare benefits, increased rents and labour market reforms, to later deteriorations in child dental health among the most disadvantaged of NZ's five-year-olds. These resulted in reported increases in dental health inequality in indigenous minority group children, compared to their peers.

On the wider horizon within the UK, it seems that the 'comprehensive' Spending Review 2010 (Controller of Her Majesty's Stationery Office, 2010) with its announcements of £7 billion in welfare reductions, alone, notwithstanding associated impacts and social-costs on housing provision, rent increases and public sector job losses to come, may herald a similar deterioration in the ecological environment here, in the future. It already is clear that the nature of the new UK administration will impact upon the social and welfare policy of Scotland, in spite of the health system itself being a devolved matter. Already, *The Institute of Fiscal Studies* considers "*Families with children are the biggest losers*" from the Westminster Government's *Comprehensive Spending Review* (Browne, 2010).

Furthermore, simultaneous public service reductions are predicted to have a further regressive impact on the poorest income decile (O'Dea, 2010). The announced fiscal changes appear to have potential future impacts on many of Dahlgren and Whitehead's (1998) postulated layers of influence on health. It is premature to know whether these fiscal changes will have a differentially detrimental effect in Scotland, or not, compared to the rest of the UK. Nonetheless, it is not irrational to suggest that there will likely be further unwelcome effects, especially on families, their children (Philip, 2010) and, if previous dental authors are correct with respect to their descriptions of the psycho-social/social capital and internal HLOC influences, we may also expect deleterious influences on dental health (e.g. Brunner *et al.*, 1999; Chase *et al.,* 2004; Newton & Bower, 2005; Lencova *et al.,* 2008).

Thus, there will be a role for the Scottish Dental Public Health Community to point-out the historically observed dento-political associations, to act as advocates for the continuation of interventions to mitigate against similar impacts in Scotland and to continue monitoring dental health inequalities trends by the tests described herein.

8.10 Other important considerations

The *Marmot Review* authors believe that the human costs of health inequalities are enormous (Marmot *et al.,* 2010). Globally, caries causes dental pain, problems eating, chewing, communicating and with appearance and self-confidence which all have major impacts on life and well-being, with the disadvantaged carrying the greatest burden (Petersen *et al*. 2005a; Casamassimo *et al.*, 2009). In the USA, children from poor families suffer 12 times more restricted activity days due to dental disease than their relatively affluent peers (US Department of Health, 2000). If Weaver (2001) is correct in estimating the prevalence of child poverty in Great Britain, this is likely to be of relevance here too, as in spite of the welfare state, it is estimated that from *circa* 10% in the 1970s, by 2001, more than four million i.e. 30% of children were living in SES circumstances poor to an extent which made their health and life-course vulnerable. The effects persist into adulthood, and potentially are ‘imprinted’ into future generations (Weaver, 2001). The Audit Commission (2002) considers that it is a major public health concern that at the beginning of the 21st century so many children suffer from such a preventable disease as dental caries. Moreover, Gussy *et al*. (2006) found that children experiencing early caries were more likely to have more dental problems in future. Furthermore, an editorial considered that:

> “Preventing oral disease is important and achievable. Evidence-based, simple and cost-effective approaches exist, but they need to be rigorously promoted and implemented. …………… Politically, commitment is needed to integrate oral disease prevention into programmes to prevent chronic

> diseases and into public-health systems. Good oral health should be everybody's business." (The Lancet, 2009)

The COSLA paper *Smarter Scotland: Reducing Health Inequalities in the Early Years* (COSLA and The Scottish Government, 2008) has proposed that dental decay at age five years (P1) is a relevant '*performance indicator*' (PI) of improvements in general health inequalities. In the past this has been restricted to examination of epidemiological trends, only, without the additional information on the dimensions of inequality which may be gained from the recognised tests of inequality etc. carried out for this thesis. A later paper '*Giving Children a Healthy Start*' (Audit Commission, 2010) also identifies five-year-olds' dmft as one of the headline PIs for child health and well-being in England. Thus, there may be an appetite for a similar *basket full* of caries inequalities tests further afield.

8.10.1 Dental health inequalities metrics for 5-year-olds do hold potential for application as performance indicators of policy

Improvement in P1 five-year-olds' caries epidemiology from the SHBDEP/NDIP surveys explicitly has been the main means of assessing improvement towards the 'milestone' set in the government's '*Scottish Dental Action Plan'* that 60% of P1s should have $d_3$mft=0 by 2010 (Scottish Executive, 2005b). This 2010 target has now been met (Macpherson *et al.*, 2010a). However, clearly, the studies comprising this thesis which model the accepted measures of health inequality in Scotland (Munoz-Arroyo & Sutton, 2007; The Scottish Government, 2008) and England (Marmot *et al.*, 2010) with the caries epidemiology data are a more recent aspiration. Nonetheless, a battery of selected inequalities metrics would appear to have potential for application as a future performance indicator of Scotland's '*early years*' policies aiming to improve child health, welfare and health inequalities.

In future, it may well be appropriate to include measurement of inequalities in the findings published for Scotland and individual NHS Board areas in the biennial Primary 1 NDIP reports. Consideration should also be given towards including future inequalities targets for dental health outcomes in Scotland. It may be that the %PAR and the SII could be further explored to this end.

8.10.2 Evidence of confounding factors

The chapter following the Literature Review within this thesis described the development process connected to novel OHP strategy and the programmes that subsequently operated in Scotland and Glasgow (GGHB). However, this author does very well realise that due to the limitations of this ecological observational study e.g. due to the lack of randomisation, the potential for bias, absence of sustained matched control areas, the influences of a plethora of local and national child health, social and family welfare policies and reforms over the period of interest, there will undoubtedly be very serious confounding effects. It is clearly not possible to use the epidemiological data to draw any inferences about OHP programme effects. It is only possible to point out the temporal relationship between the OHP programmes and the dental health and inequalities trends.

8.10.3 The extent of coherence

The potential biological effectiveness of the interventions described as forming the *Childsmile* programme etc. do accord with contemporary scientific consensus and guidelines (e.g. Scottish Intercollegiate Guidelines Network, 2005; National Institute for Health and Clinical Excellence, 2007a & 2008; Marmot *et al.,* 2010; Walsh *et al.*, 2010). These underpin the translational OHP intervention programmes described therein. Furthermore, the earlier outlined OHAT programme did incorporate many of the so-called behavioural theories, since endorsed by NICE (National Institute for Health and Clinical Excellence, 2007b). Their later inclusion in the NICE Guideline does suggest that their adoption in Glasgow and Scotland was reasonable and may have been contributory. It is therefore plausible that the dental health and inequalities outcomes are associated with the interventions to some extent, against a background of enhanced child health and welfare policy in Scotland. Albeit, the extent can never be known.

In spite of this, both the OHATS and the *Childsmile* programmes which were outlined earlier, did use a 'Theory of Change' approach (Weiss, 1995; Allen, 2010), which is considered to strengthen the scientific case for attributing subsequent changes to programme actions. This is said to be particularly so, providing that the following two *a priori* requirements have been met i) the health outcome target has been stated and ii) the actions and the milestones which should form part of a logical pathway to the outcome have been made clear in advance (Judge & McKenzie, 2002). This is the type of approach to evaluation which has been adopted for the national programme of Health Action Zones in England (Judge & McKenzie, 2002). Notwithstanding the potential for confounding, the more the events predicted to occur actually happen, in association with an (O)HP project's lifetime, the more confident evaluators are permitted to be that their underpinning theory is correct (Judge & McKenzie, 2002). Furthermore, commenting on the Scottish 2007/08 NDIP data, Davies *et al*. (2011) have gone as far as to suggest that "*the reduced caries levels in Scotland may be attributed to the pro-active health improvement measures affecting this cohort*".

8.10.4 Some cautionary notes on the potential for a health improvement-health inequalities trade-off

Contemporary opinion suggests that improving population health, whilst at the same time reducing inequalities is a complex task requiring careful consideration about the ways to bring about maximum health gains for the disadvantaged (Mechanic, 2002; Pickett *et al.,* 2005; Kempf *et al.,* 2006; Macintyre, 2007; Marmot *et al.,* 2010).

One must always bear in mind that interventions which promise the greatest possible health gains for the SES deprived may nevertheless bring about increases in inequality (Victora *et al.,* 2003) and that these are sometimes contrary competing goals (Kempf *et al.,* 2006; Macintyre, 2007). Thus, continuing to monitor for unintended effects on inequality will always be important (Starfield, 2007) in Scotland.

However, reductions in inequality are not an end in themselves and should simultaneously result in gains or benefits to society e.g. the paper by Ljungvall & Gerdtham (2010) entitled “*More equal but heavier*……..” charts decreasing inequality in obesity at the expense of increased prevalence of obesity across all income groups. A recent paper by Harper *et al.* (2010) specifically discusses the inherent value judgements implicit in programmes aiming to decrease health inequalities which were touched on earlier.

8.11 The interventions-outcomes baton passes to *Childsmile*

Over the interval of study, the epidemiological trends presented in this thesis indicate that there has been a period of dramatic dental health improvement in Glasgow and Scotland and beneficial changes have been observed in all SES groups. Furthermore, population, geographic and even some SES inequalities appear generally to have decreased. As already explained, it is not possible with hindsight to know all concurrent details of all health and social interventions across Scotland. In spite of Fejerskov's (2004) assertion that a multitude of interventions are necessary to control caries, some of the criticisms which were made earlier in relation to the pragmatic approach adopted in the ‘*Possilpark*’ programme were related to the multiple interventions strands. This was principally due to an inability to know what/which had been effective.

It now falls to the *Childsmile* programme to begin to disentangle some of the individual intervention’s dental health improvement and dental health inequalities effectiveness. Society, scientists and policy makers all require answers to questions about the ‘added value’ from each intervention strand within programmes (Hausen, 2004) and this research contributes nothing towards answering these questions.

Notwithstanding the above, and in the light of the extensive literature on the upstream influences, which will always predominate, it has nevertheless been optimistically suggested that

> “If successful, *Childsmile* has the potential to deliver children into adulthood with little or no experience of dental disease.” (Glen, 2009)

Only time, community-based participation at all stages to develop and implement a suitably responsive Theoretical Model of interventions, sympathetic policy makers, a positive socio-political climate, family welfare and psychosocial-environment combined with continued surveillance will tell if this potential is indeed fulfilled in Scotland.

Thus, it now falls to the *Childsmile* programme team to more fully address the questions about the relative effectiveness and inequalities impacts of different interventions (Sanson-Fisher *et al.,* 2008) via *Childsmile's* developing ‘*Theory-based’* intervention models and their associated funding for a comprehensive complex monitoring and evaluation strategy (Turner *et al.*, 2010).

8.12 In summary-what this study adds to the literature

Statistically significant improvements in overall P1 population dental health and simultaneous reductions in population, geographic and some SES-related inequalities have been observed. This study demonstrates that it will be necessary to continue to monitor population, geographic and SES dental health inequalities, as the intervention/socio-welfare climate is continually evolving. The battery of tests herein show that there are temporal associations between altered ecological environments and alteration in the determinants of P1’s dental health and SES inequality, over relatively short time-frames.

8.12.1 The suitability of the inequalities tests with caries data

Most of the inequalities tests applied to these caries data are able to detect changes in dental health inequality over fairly short time frames. The SIC^{10}, the SII and the RII showed good stability at the whole of Scotland level, over time. Thus, if one had to choose just a limited number of the above tests to apply to caries epidemiological data, the SIC^{10} distribution would be a good candidate with which to demonstrate the overall dispersion of population $d_3$mft scores and prevalence, along with the SII and RII to provide respective estimates of complex absolute and relative SES-related dental health inequalities, fully taking into account the whole SES distribution of $d_3$mft score, weighted according to the background denominator populations' SES distribution. The foregoing does not diminish the usefulness of the other inequalities tests in particular circumstances. All of the additional inequalities tests, with the exception of the conventionally interpreted Gini-Coefficient, have been found to lend explanatory insights into dental health inequalities trends.

Furthermore, there may not always be concordance between the apparent direction of change in inequality when comparing absolute change and relative change in dental health inequalities, nor the results of one test with another. Absolute SES inequality seems to be of more importance than relative SES inequality with respect to dental health inequalities because of the population proportions affected in Scotland. However, for the reasons outlined in this thesis differences in absolute and relative inequalities outcomes should not overly disconcert the dental health inequalities researcher.

The observations of absolute dental health improvements across the SES spectrum, no less in the most SES deprived group, over time, and the mitigation of a 'Glasgow (dental health) Effect', reported herein, are in sharp contrast to those associated with another high profile geographic community intervention programme in the UK. In their submission to the Ministerial Taskforce on Health Inequalities (The Scottish Government, 2008), the Convention of Scottish Local Authorities (COSLA) comment that the *Sure Start* programme in England has struggled to help the most vulnerable children, as the more motivated and educated parents with higher incomes tended to benefit most. This has clearly not been the case in Scotland with respect to child dental health. It has been suggested that positive consent in dental surveys, e.g. in England, results in a sample in which children with caries are under-represented (Monaghan et al., 2011). Therefore it could be that the English dental survey results reported by the Audit Commission actually under-report the prevalence and morbidity there. Thus, however they have arisen, the general overall consistency of Scotland's beneficial dental health and inequality trends from 1999/00, when measured by a variety of metrics, are all the more remarkable.

Furthermore, no study known to this author has been published which has modelled the SHBDEP/NDIP dataset or other UK caries dataset using a battery of selected inequalities tests from the general health inequalities literature. With respect to the tests of inequality, it has been demonstrated that it is possible to measure dental health inequalities using the same array of metrics as is recommended for general health inequalities measurement in Scotland and England. Nevertheless, additional useful information will be obtained by the incorporation of specific tests of distribution of $d_3$mft (Bratthall, 2000; Morgan *et al.*, 2005), of sensitivity and specificity of exposure to

SES deprivation for $d_3mft>0$ and use of the products of the Meta-analysis, logistic regression and GLM studies.

Chapter 9

9 Conclusions and recommendations

9.1 Caries Epidemiology

- Substantial overall improvements in five-year-olds' dental health indices have occurred in Scotland as a whole and in the two geographic subgroups over the period 1993/94 to 2007/08.

- There is evidence of greater prevalence of $d_3mft=0$ and decreased mean d_3mft scores in Scotland and the area outwith Glasgow as early as 1997/98. However, in Glasgow similar improvements were not observed until 2002. Nevertheless, in each of the geographic areas there was latterly evidence of statistically significant improvements in these dental health indices over more or less the whole SES spectrum.

- Substantial dental health heath gradients in mean d_3mft and the percentages of five-year-olds with $d_3mft>0$ were evident at the outset, in direct association with DepCat ($p<0.0001$). In spite of the overall level of improvement and the improvement within all SES groups these gradients have persisted over the period from 1993/94 to 2007/08.

- The improvements in prevalence of $d_3mft=0$ in Scotland's five-year-olds by the mid-late 1990s do not appear to be part of a wider secular trend across the UK [there was no statistically significant improvement reported between the 1993 and 2003 UK surveys (Pitts & Harker, 2005). Moreover, it was reported that the 2005/06 BASCD study of five-year-old children in Great Britain shows that there has been no overall improvement in the mean d_3mft of those with caries experience in the interval since the previous BASCD survey of the age group (Pitts *et al.*, 2007). With respect to children's dental health in England and Wales, there are no reports of similar recent improvements in five-year-olds' dental health which can be ascribed to HP / OHP programmes (Davies *et al.*, 2011).

- Over and above the aforementioned SES gradients in caries epidemiology at each geographic level in Scotland, there is evidence that there was initially a statistically significant geographic inequality in five-year-olds' dental health between those residing in Glasgow, when compared to those living in the rest of

Scotland. This detrimental ‘Glasgow Effect’ on five-year-olds’ dental health was associated with the fact of their residence in the Glasgow area (independent of DepCat). Nonetheless, there is also evidence that this former geographic detriment had ameliorated by 2005/06 and in 2007/08, by which point no significant difference remained in the ORs for $d_3$mft>0 in Glasgow compared to the rest of Scotland, when adjusted for DepCat.

Consideration of the research questions would lead to the further conclusions with respect to the null hypotheses:

Null hypothesis 1: there is no change in dental caries experience or SES dental caries inequalities in Scotland as a whole during the period.

- The null hypothesis (1) may be rejected with respect to dental caries experience.

Null hypothesis 2: there is no change in dental caries experience nor in dental caries inequalities of five-year-olds at the Scotland minus GGHB level, during this period.

- The null hypothesis (2) may be rejected with respect to dental caries experience.

Null hypothesis 3: There are no differences in dental caries experience or in dental caries inequalities with respect to direction, magnitude and timing comparing Scotland without GGHB to the whole of Scotland.

- The null hypothesis (3) may be rejected with respect to dental caries experience.

Null hypothesis 4: There is no evidence of any changes in dental caries experience among NHS Greater Glasgow five-year-olds across the time period 1993-2007.

- The null hypothesis (4) may be rejected.

Null Hypothesis 5: There is no difference in timing of trends in dental caries experience and dental health inequalities in Scotland without GGHB compared to GGHB alone.

- The null hypothesis (5) may be rejected with respect to dental caries experience.

9.1.1 Recommendation 1

- In Scotland, the NDIP surveillance programme has the potential to monitor age-specific population-wide individual, geographic and SES related dental health and inequalities trends. Data should be used for the forgoing types of analyses periodically, subsequent to future NDIP surveys. Potentially, the IT programming and macros developed for this thesis could be employed for this purpose.

- In caries epidemiological trend and dental health inequalities analyses, the choices of baseline and endpoint may both be determinants of conclusions about overall trend magnitude and direction. Therefore, the start-point and end-point should both be defined and stated *a priori*. Furthermore, Meta-analysis of epidemiological and inequalities cross-sectional data-points should be performed.

- There have been no follow-up cohort studies relating five-year-old P1 cohort outcomes to later P7 outcomes. There is currently potential to proceed to investigate two aggregated cohorts at both P1 (SHBDEP 1999/2000 & NDIP 2002/03, respectively) and the later P7 stage (NDIP 2006/07 & 2008/09, respectively).

- Sustainability of the observed improvements will be dependent on maintenance of the recently altered determinants of P1s' dental health. These should continue to be supported by the wider Public Health and *Childsmile* workforce etc. in Scotland.

9.2 Importance of geographic and SES subgroup analyses in caries epidemiology

- No comparison of caries epidemiological trends between different geographic areas of Scotland broken down into the component areas of Glasgow and the remainder of Scotland have been reported previously.

- Over the interval, from baseline, to the latest cross-sectional survey year, there is evidence that the respective odds of a five-year-old child from Glasgow and from the remainder of Scotland experiencing caries at the d_3 level decreased by two thirds and by a half.

9.2.1 Recommendation 2

- While some of the variation between Glasgow and the rest of Scotland could be related to the difference in population and sample sizes, some of the differences are likely due to the extent of the Glasgow population's deprivation. It would therefore seem reasonable for similar geographic analysis of this and the other component Health Board areas of Scotland in which SES deprivation predominates to be analysed separately from the data for the remainder of Scotland, periodically. It would be interesting to repeat this type of geographic analysis using Scottish regional geographic areas e.g. the combined data from the current entity NHS Greater Glasgow & Clyde, NHS Lanarkshire and NHS Ayrshire & Arran which are co-located in West-central Scotland.

- It would be of interest to examine the P7 caries datasets to assess the extent of any apparent 'Glasgow Effect' on the dental health of P7s.

9.3 Dental Health Inequalities

9.3.1 In general

- Measurement and interpretation of cross-sectional dental health inequalities and inequality trends are much more complex to conduct than carrying out conventional dental epidemiological measurements and interpretations.

- It is necessary to have available simultaneously the fully analysed caries epidemiological dataset for inspection, if one is to properly understand trends in dental health inequality, by whichever test(s) applied.

- Because of the tendency to undulating and spiking trajectories of change in dental health inequalities in the geographic subgroups, Meta-analysis of trends using regression and Generalised Linear Modelling techniques was required to understand whether there were any apparent inequalities trends (at the $p<0.05$ level), or not, in geographic and SES subgroups.

- As described by other authors with respect to general health inequalities, value judgements have to be made as to which factors one considers important in caries inequalities of P1 children e.g. individuals, SES, geographic population group, size of population group etc. in inequality testing. Whilst it has been recommended that absolute and relative inequality should always be reported together, one has to make decisions on the groups to compare e.g. the extremes of the range or those with the poorest health versus the mean/median and whether simple tests, complex tests, or both, should be carried out. There is evidence that the methodological choices will affect the inequalities outcomes from inequalities tests and thus, the conclusions one would reach.

9.3.2 Recommendation 3

- From the tests examined, all future analyses reporting testing of cross-sectional dental inequalities and longer term inequalities outcomes need to adopt carefully selected and tailored tests for the data and for the audience in question.

- In addition to the provision of the results of the selected inequalities tests, full explanation of what has been measured also requires to be provided alongside a full impartial interpretation. All of these factors must be clearly communicated.

- Multiple dental health inequalities testing is always likely to be required and the array of tests applied should be sufficient to fully understand the inequalities aspects of the data.

9.4 Geographic caries inequality across the whole five-year-old population

- After accounting for confounding factors, both simple absolute and simple relative dental health inequalities improved in Glasgow five-year-olds' when compared to their peers from the rest of Scotland, as the reference group.

- Improvements in simple absolute and relative geographic dental health inequalities in SIC at five years of age were observed against a background of overall improvements in dental health indices in the geographic areas.

- The SIC^{10} distribution profiles improved in each of the geographic areas studied over the interval from 1993/94. Moreover, in spite of suggestions in the literature that this would be very difficult to achieve, the SIC^{10} values of the five-year-old population deciles with the greatest propensity to $d_3$mft>0 decreased simultaneously, in Scotland, Glasgow and in the rest of Scotland.

- This author is not aware of any previous report describing that, at the whole of Scotland level, there has been a reduction in simple absolute inequality in the burden of disease among those five-year-old caries deciles who have experience of $d_3$mft>0.

Null hypothesis 6: There is no difference in dental caries experience at Scotland level compared to GGHB. Therefore, there is no geographic inequality.

- The null hypothesis (6) could be rejected at the start of the period (after controlling for confounding factors). However, the null hypothesis may not be rejected by 2007/08.

9.4.1 Recommendation 4

- Appropriate tests of geographic dental health inequality should be carried out routinely, in addition to testing caries datasets for SES inequality.

9.5 Simple SES related inequalities

- The observed pattern of an initial increase in simple absolute inequality, by SES, in DepCat 7 Glasgow children of five years of age compared to their DepCat 1 peers may not be an unusual pattern, when the overall population dental health indices are changing. The explanation potentially lies in the Victora *et al.* (2003) model described in the literature review. It may well be that following each novel intervention strand or environmental/ecological change aimed to improve child health and/or dental health, simple absolute SES inequality will increase prior to a potential later decrease in SES inequality, as the determinants of dental health inequality are not the same as the determinants of dental health.

  During the later period (i.e. from 1999/00 to 2007/08) there is evidence that simple absolute SES inequality in P1 children's $d_3$mft prevalence, when comparing DepCat 7 to DepCat 1 children, decreased within each of the geographic areas. However, this was not the case in the longer overall interval of study (from baseline 1993/94) during which the simple absolute SES inequality in $d_3$mft>0 did not decrease in Glasgow (due to the smaller range between the DepCat 1 and DepCat 7 communities at the 1993/94 baseline).

- In each geographic area, compared to DepCat 1 as the reference group, the simple absolute SES related dental health inequality in the burden of mean $d_3$mft in DepCat 7 children aged five years decreased over the whole interval from 1993/94 to 2007/08, whereas the simple relative SES inequality increased.

- Over the interval 1993/94-2007/08, very substantial absolute dental health gains (e.g. in % $d_3$mft=0) were accrued at each end of the SES spectrum, in each of the areas. These trends towards SES improvements in dental health have not necessarily translated into improvements in simple absolute inequalities e.g. in Glasgow. Moreover, in spite of the foregoing magnitudes of health improvement among the most SES challenged, there is no example of improvement in simple relative SES dental health inequality. Hence, the cautionary notes in the literature about 'value judgements' and 'trade-offs' having to be made with respect to health inequality outcomes *versus* health improvement outcomes. In this study there is evidence that the groups at the extremes of the SES spectrum benefited substantially and neither group suffered detriment to the benefit of the other. Thus, in spite of some apparent deteriorations in inequality, in this type of circumstance this author believes it is morally defensible to continue with the health, welfare and OHP policy framework which may have been contributory.

- If the Keppel *et al.* (2005) recommendations that a) inequality measures always compare morbidity data rather than the corollary and b) that the relatively advantaged SES group forms the denominator were adopted, simple relative dental health inequalities will never improve unless the proportional improvement in the comparatively disadvantaged group exceeds the proportional improvement in the affluent comparator group, even in the event that the absolute value of the improvement in the SES deprived group is greater.

- Measurement of the simple absolute and relative SES inequality compares only two population subgroups, usually the SES extremes, as in this study. This tells nothing of the extent of inequality in intermediate groups and is regardless of population shares.

9.5.1 Recommendation 5

- Both simple absolute and simple relative SES-related inequalities should always be reported together. Each informs on different dimensions of inequality.

- In reports of dental health inequality, presentation of simple absolute and relative SES-related inequality should be augmented with the results of other tests which take into account the extent of inequality in intermediate population groups.

9.6 Complex inequalities

9.6.1 The distribution of dental health in the whole population of five-year-old individuals

- The Gini-coefficient was developed to measure wealth inequality within a population of individuals and this author contends that it is not intrinsically suitable for measuring dental health inequalities, although it does appear widely in the literature for that purpose. With respect to the $d_3$mft index, the Gini-coefficient behaves in a counter-intuitive way, as it was designed for assessing equity in dispersion. In the hypothetical circumstances that mean $d_3$mft increased in Scotland's P1 population and the % affected by $d_3$mft>0 rose, the Gini would show decreasing inequality (as the dispersion of $d_3$mft>0 was becoming more equal). Thus, this test has the potential to greatly mislead and cause enormous confusion to the unwary when applied to dental health data.
- The Significant Caries Index (SIC) and the SIC^{10} distribution provide useful information about the segments of populations with the greatest propensity towards $d_3$mft>0, irrespective of their SES. Furthermore, the SIC^{10} distribution gives an 'at a glance' summary of prevalence and the distribution of $d_3$mft>0 scores.

9.6.2 The SES-related distribution of dental caries

- Although it was beyond the scope of this study, examination of the SIC^{10} distribution in each SES group within the three different geographic areas would likely produce additional useful information, which could be used for inequalities monitoring.
- Both the Concentration Curve (CC) and the transformed Concentration Index (CI) are potentially useful and both are capable of informing on the amount of, and fluctuations in, complex relative SES-related dental health inequalities compared to the population mean, when the whole cumulative distribution of $d_3$mft score is considered ranked by SES group, across the population in question. The ability of the CC to illustrate the extent of cross-sectional inequality is an advantage in communication and the concept of 'health-transfers' from affluent to SES deprived has emotive appeal which could be internalised by lay audiences (especially those who place a high value on their own and their children's dental health). The CC is particularly appropriate for demonstrating differences in complex relative SES-related dental health inequality between different geographic populations.

- The Slope Index of Inequality (SII) is indicative of the total absolute experience of $d_3$mft>0 (i.e. based on each subject's $d_3$mft score within each SES group) and is a sensitive measure responsive to alterations in the population mean, the SES subgroup means and changes in relative size of SES groups, which may alter over time. The SII has decreased to a statistically significantly extent since 1993/94 in Scotland. The greatest rate of improvement in Scotland's SII is evident, post 2003/04. This measure provides a comprehensive summary of complex absolute SES-related inequality (weighted for distribution of SES in the background demographic population).

- The Relative Index of Inequality (RII) is derived from the SII and alternatively provides a tool for measurement of complex relative SES-related inequality in caries experience, as it too takes into account the whole SES spectrum. The RII provides a convenient summary of complex relative SES-related inequality which takes into account the population mean, the means of the SES subgroups and their size (weighted as above).

- It will always be a greater challenge to policy makers and NHS services to bring about improvements in the RII for $d_3$mft in comparison to the SII. Over the interval from 1993/94, there was a statistically significant increase in the RII for Scotland. However, SII & RII trends for health inequalities occurring in opposite directions have been predicted and observed previously (Wagstaff *et al.*, 1991).

- Findings herein demonstrate that it is possible to observe a statistically significant decrease ($p<0.02$) in complex absolute SES-related dental health inequality when measured by SII against a background of rapid improvement in overall population caries indices among five-year-olds. The simultaneous increase in RII is not unexpected.

9.6.3 Recommendations 6

- As the caries dataset analysed in this study gave various SES-related inequality results when the variety of simple and complex SES-related tests of inequality were applied, it would not be unreasonable to apply the same 'raft' of tests to other caries datasets to further assess the performance of the tests.

- Although no examples could be found, The Robin Hood Index (the inverse Gini-coefficient) would appear to be worth exploring with caries datasets, as a further potential future measure of dental health inequalities.

9.7 Other miscellaneous tests useful for measuring SES related caries inequalities

- The Population Attributable Risk (PAR) has not historically been used as a measure of health inequalities. Nevertheless, %PAR has been very enlightening with respect to dental health inequalities, due to its ability to expose the relative extent of 'preventable caries' at each geographic level in the hypothetical circumstance that 'the exposure' (in this case to SES deprivation) could be eliminated. The %PAR values for children with $d_3$mft>0 have improved from baseline to 2007/08 in Glasgow and in Scotland as a whole. Nonetheless, there remains a startling difference in the %PAR in Glasgow compared to the %PAR for the remainder of Scotland.

- The %PAR would be readily understood by lay audiences and policy makers alike. From this analysis, %PAR as a test of SES inequality in caries distribution would alone (along with the epidemiological data) provide a persuasive case for differential resource allocation and for performance targets to be altered to reflect the differential distribution of SES deprivation within individual NHS Boards' areas. Thus, the 'theoretically' preventable poor dental health within the individual Scottish Health Boards could potentially be addressed by a dental health equity-oriented resource allocation to enable proportionally appropriate intervention/support.

- The ROC plot has intuitive visual appeal which could be readily understood by both lay and professional audiences. Even although the ROC was not among the inequalities tests recommended by ScotPho, this author believes that it is potentially more readily understandable than the Concentration Curve for explaining the relationship between deprivation and dental caries in Scotland, and changes over time, due to its ability to depict in a single illustration both the sensitivity and specificity of DepCat for $d_3$mft>0.

- The ROC and value of c trends in Glasgow indicate that the relationship between DepCat and caries at age five years strengthened throughout the 1990s. Nevertheless, the extent of the predictive potential of DepCat for $d_3$mft>0 reported in the earlier survey years has been mitigated by 2007/08. Thus, the ROC may be an indicator of the extent to which the SES-related determinants of $d_3$mft inequalities operate. Results indicate that there is the potential that these determinants may variously be mitigated or exacerbated.

- In coming to decisions on the relative importance of addressing one (dental) health inequality *versus* another, the scale of the problem of excess morbidity must always be taken into account with respect to the sizes of the geographic and/or SES groups affected. Dental health inequalities continue to be of importance to individuals, society, governments and policy makers because of 1) the high prevalence of children who continue to be affected by caries at a young age, and 2) the persistent direct relationship between prevalence of $d_3$mft>0 and caries morbidity with SES status.

These further conclusions thus permit the following statements to be made with respect to the research questions:

Null hypothesis 1: there is no change in dental caries experience or SES dental caries inequalities in Scotland as a whole during the period.

- The null hypothesis (1) may be rejected with respect to dental caries inequalities.

Null hypothesis 2: there is no change in dental caries experience nor in dental caries inequalities of five-year-olds at the Scotland minus GGHB level, during this period.

- The null hypothesis (2) may be rejected with respect to dental caries inequalities.

Null hypothesis 3: There are no differences in dental caries experience or in dental caries inequalities with respect to direction, magnitude and timing comparing Scotland without GGHB to the whole of Scotland.

- The null hypothesis (3) may be rejected with respect to dental caries inequalities.

Null Hypothesis 5: There is no difference in timing of trends in dental caries experience and dental health inequalities in Scotland without GGHB compared to GGHB alone.

- The null hypothesis (5) may be rejected with respect to dental caries inequalities.

9.7.1 Recommendations 7

- The %PAR should be performed routinely with future Scottish caries data sets at the geographic levels used within this study and potentially at each individual Scottish Health Board area.

- In future, policy makers could consider the %PAR for $d_3$mft>0 *vs*. $d_3$mft=0 the SII for $d_3$mft score and Scotland's DepCat or SIMD to determine dental health inequality targets.

- The Receiver Operator Curve (ROC) will provide additional useful information and should be carried out periodically with the Scottish caries datasets. This test may also be of use in the event of changing/reversing health, social or welfare policy for use in future 'health impact' assessments.

- In keeping with contemporary recommendations for health inequalities, the scale of the problem should always be made explicit i.e. the size of the SES or other population subgroup e.g. decile affected. In this way the government, policy makers and citizens may be made aware of the potential for dental health improvement and reduction of inequalities etc.

9.8 Summary conclusions about inequalities testing with Scottish caries datasets.

- The SES inequalities in five-year-olds' dental health have generally been more pronounced in Glasgow than in the remainder of Scotland when measured by e.g. SIC, SIC^{10}, ROC plot and c value, %PAR and OR for $d_3$mft>0 by SES.

- A variety of inequalities tests are required to fully understand the whole five-year-old population's individual dental health inequalities, their geographic inequalities, and their SES-related dental health inequalities.

- Whole population dental health improvement and significant reduction in complex absolute SES-related dental health inequalities can occur simultaneously in Scotland.

Thus, with respect to the final conclusions is possible to say:

Null hypothesis 7: the selected additional tests for health inequality and dental caries inequality add nothing to understanding of dental health inequality.

- The null hypothesis (7) can be rejected.

9.8.1 Recommendations 8

- Further analysis of Scotland's caries dataset 1993/94-2007/08 should be undertaken to examine for changes in a) the intra-oral distribution of $d_3$mft, b) the stage of lesion (whether lesions are arrested, visibly within the dentine, cavitated into dentine or extending into the pulp are all recorded in the dataset for this thesis) and c) the surfaces involved.

- The 2009/10 NDIP dataset should be sought to provide the successive cross-sectional data points to augment the foregoing geographic, population and SES inequalities models, herein described up to 2007/08.

- The selection of inequalities tests is not without value judgements. This author has found that the following array of inequalities tests is appropriate for the investigation of the Scottish five-year-olds' caries data set, namely: the SIC value and the SIC^{10} distribution; the simple absolute inequality; the simple relative inequality; the Concentration Curve and the transformed Concentration Index; the Slope Index of Inequality; the Relative Index of Inequality; the Population Attributable Risk; the Receiver Operator Curve and the corresponding value of c and furthermore, the statistical test the Odds Ratio. All of the foregoing make differing contributions to understanding cross-sectional inequalities and longitudinal trends in five-year-olds' dental health and all should be performed periodically with Scotland's caries datasets, as they all are necessary for the most complete understanding of the different dimensions of inequality.

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Appendix 1

Validation Tests for Programming of Inequalities Tests

Table 1: Source material: the previously published peer reviewed datasets used to validate the tests of complex health inequality modelled in this thesis

Test	**Reference to source materials used to validate IT programming in SAS for the analyses**	**Published outcome replicated (Yes/No)**
Gini Coefficient & Lorenz curves for continuous variable	GINI coefficient - continuous variable - individual level analysis, data copied from an example by Travis Hale (undated), University of Texas Inequality Project (available from jthale@mail.utexas.edu)	Yes
	GINI coefficient - continuous variable - individual level analysis, data copied from paper for Pan American Health Organization technical report (2001).	Yes
Gini Coefficient & Lorenz curves for binary events	Gini Coefficient binary outcomes data copied from Pan American Health Organization, (2001).	Yes
Concentration Curve and Concentration Index	Concentration Curve and Index, data copied from the World Bank technical report, O'Donnell *et al*, (2008).	Yes
	Concentration Curve and Index, data copied to replicate the ScotPHo Report, Munoz-Arroyo & Sutton (2007)	Yes
	Concentration Curve and Index, data copied to replicate Regidor (2004b)	Yes
Significant Caries Index	SIC data copied from weblink published in Nishi et al., 2001	Yes
Slope Index of Inequality (SII)	Slope Index of Inequalities data copied from ScotPHo Report, Munoz-Arroyo & Sutton (2007)	Yes
	Slope Index of Inequalities data copied to replicate Regidor (2004b)	Published SII result not replicated ?mistake? in published paper?
	Slope Index of Inequalities data copied to replicate Schneider. *et al.*, (2005	Yes
Relative Index of Inequality (RII)	Relative Index of Inequalities data copied from ScotPHo Report, Munoz-Arroyo & Sutton (2007)	Yes
	Relative Index of Inequalities data copied to replicate Schneider. *et al.*, (2005).	Yes
	Relative Index of Inequalities data	Yes

	copied to replicate Hayes & Berry (2002)	
Population Attributable Risk (PAR)	Population Attributable Risk data copied from ScotPHo Report, Munoz-Arroyo & Sutton (2007) Population Attributable Risk data copied to replicate Schneider M.C., Castillo-Salgado C., Bacallao J., Loyola E., Mukica O.J. *et al.*, (2005). Methods for Measuring health inequalities (part II). *Epidemiological Bulletin Pan American Health Organization*; **26**: 5-10.	Yes Yes

Appendix 2

Table 1: The raw percentage (95%CI) of P1 children in Scotland, Glasgow and Not-Glasgow with $d_3mft=0$ in each DepCat by year of survey, 1993/94-2007/08

Year	DepCat	Scotland			Glasgow			Not-Glasgow		
		% $d_3mft=0$	95%CI	n=	% $d_3mft=0$	95%CI	n=	% $d_3mft=0$	95%CI	n=
1993/94	1	65	(59-71%)	142	53	(28-77%)	10	66	(60-73%)	132
	2	58	(54-62%)	277	61	(43-78%)	20	58	(53-62%)	257
	3	47	(45-50%)	640	46	(34-58%)	30	47	(45-50%)	610
	4	39	(36-41%)	440	25	(16-33%)	24	40	(37-43%)	416
	5	32	(29-35%)	253	36	(25-47%)	25	31	(28-35%)	228
	6	25	(22-28%)	149	23	(16-29%)	36	26	(22-30%)	113
	7	21	(17-24%)	102	18	(15-22%)	72	30	(21-39%	30
1995/96	1	60	(55-66%	158	59	(49-68%)	53	61	(54-68%)	105
	2	58	(55-62%)	385	59	(53-65%)	133	58	(54-63%)	252
	3	48	(46-50%)	726	43	(35-51%)	59	49	(46-51%)	667
	4	40	(38-43%)	641	30	(24-36%)	59	42	(39-44%)	582
	5	34	(31-37%)	274	30	(22-39%)	32	34	(31-37%)	242
	6	31	(28-35%)	222	28	(23-32%)	86	34	(29-38%)	136
	7	22	(19-25%)	154	22	(19-25%)	127	25	(17-33%)	27
1997/98	1	64	(60-69%)	242	62	(51-72%)	48	65	(60-70%)	194
	2	59	(55-62%)	396	63	(55-71%)	85	58	(54-62%	311
	3	50	(48-52%)	789	41	(33-49%)	53	51	(48-53%)	736
	4	42	(40-45%)	688	39	(32-45%)	67	43	(40-45%)	621
	5	37	(34-40%)	327	35	(27-42%)	45	38	(34-41%)	282
	6	34	(31-38%)	255	36	(30-42%)	88	34	(30-37%)	167
	7	20	(17-23%)	140	17	(14-19%)	95	35	(27-43%)	45
1999/00	1	67	(63-72%)	252	67	(58-76%)	62	68	(62-73%)	190
	2	61	(58-64%)	573	68	(60-75%)	90	60	(56-63%)	483
	3	51	(49-53%)	963	47	(37-57%)	43	51	(49-53%)	920
	4	45	(42-47%)	746	29	(21-36%)	35	46	(43-48%)	711
	5	37	(33-40%)	289	34	(24-44%)	28	37	(33-0%)	261
	6	32	(29-36%)	199	21	(15-27%)	34	36	(32-40%)	165
	7	22	(18-25%)	107	20	(16-23%)	78	30	(21-39%)	29
2002/03	1	67	(62-72%)	192	71	(57-85%)	29	66	(61-72%)	163
	2	57	(54-60%)	559	59	(53-66%)	114	57	(53-60%)	445
	3	53	(51-55%)	1176	50	(44-56%)	113	53	(51-55%)	1063
	4	42	(41-44%)	1122	37	(32-41%)	136	43	(42-45%)	986
	5	37	(35-39%)	543	37	(32-42%)	94	37	(34-39%)	449
	6	32	(29-34%)	358	31	(27-36%)	104	32	(29-35%)	254
	7	24	(22-26%)	241	24	(22-27%)	198	22	(17-27%)	43
2003/04	1	71	(67-75%)	351	65	(58-72%)	95	73	(69-78%)	256
	2	63	(60-65%)	924	59	(56-62%)	370	65	(62-68%)	554
	3	57	(56-59%)	1407	53	(50-57%)	235	58	(56-60%)	1172
	4	45	(43-47%)	1081	41	(38-44%)	239	47	(44-49%)	842
	5	42	(40-44%)	608	39	(36-42%)	170	43	(40-46%)	438
	6	39	(37-41%)	531	36	(33-38%)	284	44	(40-48%)	247
	7	30	(28-32%)	402	31	(29-33%)	374	28	(19-36%)	28
2005/06	1	77	(74-80%)	475	78	(75-81%)	228	76	(71-80%)	247
	2	67	(65-69%)	992	68	(64-71%)	290	67	(64-69%)	702
	3	61	(59-62%)	1527	66	(62-70%)	230	60	(58-62%)	1297
	4	52	(51-54%)	1547	52	(49-55%)	304	53	(51-54%)	1243
	5	46	(43-48%)	598	45	(40-50%)	127	46	(43-49%)	471
	6	43	(40-46%)	464	40	(36-44%)	174	45	(41-48%)	290
	7	34	(31-37%)	338	31	(28-34%)	265	52	(44-60%)	73
2007/08	1	77	(74-80%)	519	79	(76-82%)	263	75	(71-80%)	256
	2	71	(69-73%)	1102	70	(65-76%)	173	71	(69-74%)	929
	3	64	(63-66%)	1642	60	(56-64%)	217	65	(63-67%)	1425
	4	55	(53-57%)	1481	58	(52-63%)	142	55	(53-57%	1339
	5	50	(48-52%)	975	55	(52-58%)	296	48	(46-50%)	679
	6	48	(46-50%)	804	49	(47-51%)	446	47	(44-50%)	358
	7	42	(39-45%)	412	42	(39-45%)	332	41	(34-47%)	80