

The social determinants of oral health: new approaches to conceptualizing and researching complex causal networks

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Abstract - Oral epidemiological research into the social determinants of oral health has been limited by the absence of a theoretical framework which reflects the complexity of real life social processes and the network of causal pathways between social structure and oral health and disease. In the absence of such a framework, social determinants are treated as isolated risk factors, attributable to the individual, having a direct impact on oral health. There is little sense of how such factors interrelate over time and place and the pathways between the factors and oral health. Features of social life which impact on individuals' oral health but are not reducible to the individual remain under-researched. A conceptual framework informing mainstream epidemiological research into the social determinants of health is applied to oral epidemiology. The framework suggests complex causal pathways between social structure and health via interlinking material, psychosocial and behavioural pathways. Methodological implications for oral epidemiological research informed by the framework, such as the use of multilevel modelling, path analysis and structural equation modelling, combining qualitative and quantitative research methods, and collaborative research, are discussed.

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It has been comprehensively demonstrated that social, economic and environmental factors have a fundamental impact on oral health (1–5). This paper considers how the social determinants of oral health operate, and the consequences of this understanding for the collection, analysis and interpretation of data. It is argued that oral epidemiology is held back by the absence of a theoretical framework of the causal pathways between social structure, social life and oral health and disease. This theoretical void impacts on the ability of oral epidemiology to explain the social causes of oral disease, and understand the biological pathways through which the social is embodied.

Limitations of traditional oral epidemiological approaches

Much of the research into the social determinants of oral health consists of collecting social data about individuals, such as their social class, educational status, income, lifestyle, attitudes to oral health and disease, etc. and relating the variables to oral health status. Using various forms of multiple regression analysis, the relative strength of the association between each variable and oral health is elucidated in order to predict oral disease risk factors and ascertain causal links between the individual risk factors and oral disease (6–8). This is represented diagrammatically in Figure 1.



Fig. 1. A hypothetical model of results derived from a multiple regression analysis. The letters 'a'-'d' represent the degree of relationship between each variable and the oral health outcome after controlling for the effect of the other variables.

There are some problems with this approach. Whilst risk factors are predicted and direct causal pathways are demonstrated, complex causal processes are not explored. Even in 'gold standard' experimental or prospective cohort studies exploring causal processes, if the pathways *between* the various social factors are not teased out, such factors exist as isolated features in a vague social murk with little sense of how they relate to each other or to oral diseases.

In research which informs public health policy, attempting to distinguish between correlational and causal associations is pivotal as non-causal associations will not form the basis for effective interventions to improve population health and reduce oral health inequalities (9). Yet targeting a known causal factor for an oral disease without taking into account the social pathways which relate to that factor may prove largely ineffective. This is demonstrated in the failure of oral health education programmes to impact on oral health behaviours of some social groups, increasing oral health inequalities (10, 11). It is surely in the exploration of complex causal pathways, rather than direct causal associations, that effective and efficient prevention policy is made.

Secondly, the quest to discover the biological processes involved in the connection between social structure and oral health, though important, has lead to a focus on individuals rather than the society they live in (12). Shim argues that in epidemiological studies, social factors become transmuted methodologically into attributes of individuals, and lose their contextual qualities (13). For instance, a measure of an individual's social class is included almost universally in oral epidemiological data, and is regarded as an attribute of that individual. However, the term 'social class' at any given point is a partial indicator of a whole sequence of events which need to be seen in combination, and their cumulative effects observed over time if the effects of social environment on health are to be understood (14). Social class is a multifaceted and historical phenomenon, a process as well as a social position (15). Unless this is acknowledged, the power relations structuring material conditions and life chances that contribute to inequalities in oral health and illness are made invisible.

This also implies a need to examine features of social life which, though impacting on individuals' oral health, are not reducible to the individual. This applies both to the type of data collected in epidemiological studies, and the development of health policy to reduce oral health inequalities. It is necessary to situate oral health and disease within the framework of larger political, economic and cultural forces (16, 17). These forces are more than the sum of individual attitudes and behaviours. Environment and culture impact on health and shape society's response to both disease and health inequalities (18, 19). Socioeconomic and political forces such as globalization, the political economy, corporate structures, the distribution of resources, and the uses of political, economic and social power also have an indirect effect on health (20, 21).

The social processes which contribute to oral disease may vary across groups and societies. Macintyre argues that there is no a priori reason to suppose that the processes generating inequalities are the same at the top as at the bottom of the social scale, among men as compared with women, or in one geographical area compared to another (22).

Thirdly, the traditional oral epidemiological approach described above fails to explain individual and group behaviour in the context of wider social structures. The term 'collective lifestyles' epitomizes how individual practices are shaped by local cultures and shared contexts, at the same time as those cultures and contexts are recreated by individuals (18, 23). In oral epidemiology, understanding the causal association between lifestyle practices such as oral hygiene, smoking or diet, and caries, erosion and periodontal disease, does not explain why individuals and communities choose to engage in such practices and the historical dimension to such behaviour and its change over time (24).

Fourthly, whilst a life-course perspective has been adopted in some oral epidemiology studies (25, 26), the focus is often restricted to the progression of oral health and disease in relation to early childhood socio-economic conditions. The additional study of the varied and complex generational, social class and gender pathways though which oral health impacts are felt over subsequent years is neglected (27). An understanding of how and why social structures and societies change is integral to a life-course perspective but collaboration with social scientists in such studies is rare.

Thus, a theoretical approach that informs future epidemiological research into the social determinants of oral health should acknowledge the presence of complex interlinking causal pathways which vary across time and place, rather than direct causal pathways which fail to recognise how social phenomena are related. The initial need is for more theoretical sophistication, rather than methodological and statistical sophistication (13), although the latter must follow if such complex phenomena are to be adequately investigated.

Modelling the social determinants of health

Ironically, models theorizing the complex pathways between social features and health have existed for some time (e.g. 12, 28, 29). The model described by Brunner & Marmot (12), shown in Figure 2, is useful because of the way biological pathways are shown to exist in a social context. Social structures are linked to individual health via three interlinking material, psychosocial and behavioural pathways. Health behaviours are seen in the cultural and spatial context of the social groups individuals live in, and in terms of the economic imperatives that place them in specific working conditions and expose them to risk.

Newer concepts used to explain health inequalities such as psychosocial stress and social capital fit into the 'psychological' and 'social environment' sections of the model, respectively. Social capital refers to 'the level of social trust that operates within a community, how much help people give each other for their own and collective benefit and the degree of involvement in social and community issues' (30). The model helpfully demonstrates that psychosocial stress and social capital reflect economic power and structures (represented by 'social structure' in the model) rather than existing separately from them. Strong communities with resilient sets of social relationships may produce a healthier population, but will not form in the context of economic inequality (16).

There are some problems with the model. The lack of inclusion of health services and health policy could be criticised. Recent research has shown that the use of health services can impact positively on oral health (31). Moreover, although 'early life' is included, indicating the need for a life course approach, the rest of the model appears to exist in one time frame. The impact of social trust,



Fig. 2. A model of the social determinants of health showing biological pathways in a social context (12) (reprinted with permission from Oxford University Press).

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income inequalities or local material deprivation on health is likely to become apparent over many years (19, 32).

The model is also a gross oversimplification of highly complex processes and current research in mainstream epidemiology and the social sciences is attempting to unpack some of the key determinants. Research into 'social environment', for example, is attempting to look at features such as social cohesion, social capital, service provision, the reputation of an area, social and economic inequalities, and physical, legal and economic resources in neighbourhoods, in relation to health and health inequalities (e.g. 18, 19, 23, 33–36).

Applying the model to oral epidemiology

Oral epidemiological research based on this theoretical foundation is compelled to examine complex interlinking causal pathways which may vary across time, population and place, rather than look for direct causal pathways. The model locates risk factors for oral diseases in society as well as in the individual, forcing an examination of social processes which cannot be reduced to the sum of individual behaviours. It also allows the exploration of how individual oral health practices are shaped by local cultures and shared contexts.

The model is also useful in oral epidemiology because it encourages research into pathways between social structure, social environment and oral health which are not mediated through lifestyle practices, such as neuroendocrine pathways and immune responses. Oral disease processes are largely understood to be mediated through lifestyle practices such as alcohol consumption, smoking, diet etc. and there has been less research looking at other pathways. However, research examining the pathways between psychosocial stress and periodontal disease (37, 38), sense of coherence and oral health-related behaviours (39, 40), and work stress, marital quality and oral health status (41) are examples of the growing interest in the role of psychosocial factors in oral health and disease.

The model has been slightly modified and applied to ecological caries research (42, 43). Ecological studies are useful in that they tend to encourage a focus on socio-economic structures and environmental features rather than individual attributes. There is a growing interest in both mainstream and oral epidemiology into the role of contextual or 'place' factors in explaining health inequalities (5, 23, 34, 44). Research findings are somewhat contradictory, but the current consensus is that neighbourhood quality has a significant impact on health outcomes over and above individual or family level characteristics, although the effect may be less important than individual and family level characteristics (45).

It can be difficult to prove a causal relationship between neighbourhood contexts and health outcomes (46), and disentangle individual and area effects in statistical models (47). People move around, environments change, the health consequences of contextual effects may occur many years after they were experienced, and environments may have different effects on people of different ages and for different types of disease (32, 48, 49). Moreover, environments cannot be isolated from their wider economic and political setting. Notwithstanding, further research into neighbourhood effects on oral health may be a fruitful line of enquiry (4).

Methodological implications

Causal models of complex phenomena are difficult to study empirically (43). There is a danger that what is studied is limited by the research methods and analytic tools available, and that the tradition of quantitative research methods and multivariate statistical analysis in oral epidemiology dictates that these methods are used whether they are appropriate or not (50). Integrating the theoretical model outlined above into research methods, analytic approaches and statistical models, in ways that understand and reflect the underlying complexity of the social and biological processes being investigated, requires the development of new research methods and analytic tools. Several of the methods and tools used in mainstream epidemiology are now discussed.

Statistical modelling

In most oral epidemiological research, data analysis involves some form of regression analysis whereby the relative strength of the association between each variable and oral health is revealed. There are some problems with this approach, particularly in the context of the theoretical model outlined above. First, data collected in oral health research is often clustered or hierarchical, e.g. children live in families, families are based in communities, communities are located in a geographical region, etc. Observations within a group are often more similar than would be predicted on a pooled-data basis, hence the assumption of independent observations necessary for multiple regression analysis is compromised (51). Secondly, it has been shown that multiple regression analysis can give misleading results when analysing sequentially caused relationships (52). It cannot estimate the factors in the sequence of their operational order and assumes that all aetiological factors have direct effects on the outcome in question. Distal and proximal causal factors are treated as being equally distant to the outcome in question, and the effect of a distal causal factor thus tends to be underestimated or dismissed (53, 54). Figure 1 illustrates this problem. Social class is erroneously shown as having a direct effect on oral health, and is treated as being equally distant to the oral health outcome as oral health behaviours, which are more proximal to the outcome. Thirdly, controlling confounding variables in order to pre-

controlling confounding variables in order to predict statistical effects of single factors precludes the study of the complex forces actually involved in the preservation or breakdown of health. Other statistical analytical techniques, e.g. multi-

level modelling (MM), path analysis and structural equation modelling (SEM), are able to overcome some of these problems and have been used recently in mainstream epidemiology to elaborate complex causal pathways (52, 55–60).

MM (51), also known as hierarchical linear modelling (61), provides a framework within which to analyse data which are hierarchical or clustered. The interactions between variables within a level and between levels can be modelled, avoiding the need to aggregate data to a higher level (resulting in loss of statistical power, and a risk of the ecological fallacy), or disaggregate data to the base level (leading to over-optimistic estimates of significance as observations are not independent). MM is increasingly used in dental research because of the inherently clustered nature of most dental data, but has rarely been applied to research on the social determinants of oral health. Examples of MM in mainstream epidemiology include a study of neighbourhood effects on an individual's smoking status (59), and a comparison of family and neighbourhood risk factors for accidents to preschool children (60). An example of MM software is MLwiN (62).

One of the main advantages of MM over traditional regression analyses is its ability to demonstrate where and how effects at different levels are occurring (63). It is also useful when data are sparse, e.g. in research on minority groups which comprise a small percentage of the population (64). However, MM is limited by difficulties in modelling complex causal processes including mediating pathways, problems in modelling indicators for latent variables, and difficulties in assessing the overall fit of the model (65). A latent variable is one that may not be observed directly and for which measurements can only be inferred from values of observed indicators. A good example is the latent variable psychosocial health which is measured via indicators such as hostility and hopelessness (52).

Some of the limitations of MM are the strengths of SEM. SEM and the related technique of path analysis are used to test the plausibility of a previously specified model using sample data. The temporal ordering between various antecedent variables and an outcome are modelled, and the relative size of each of the pathways between the various antecedent variables and the outcome are assessed. A final revised model is created on the basis of the analysis (66). The essential difference between path analysis and SEM is that the former only explores relationships among manifest or observed variables, whereas SEM, in combining path analysis and confirmatory factor analysis, explores relationships among latent variables (67). SEM has the advantage of being able to model measurement error of the predictor variables, and the overall fit of a model can be tested (64, 67). A hypothetical SEM developed from research by Chandola *et al.* (68) is shown in Figure 3.

When compared to multiple regression techniques, path analysis and SEM have some advantages for analysing complex causal patterns in oral epidemiology. Variables are analysed simultaneously in the sequence of their operating order, allowing the factors to have both direct and indirect influences on the outcome. Theoretically important variables are retained, rather than being left out of the analysis or made less interpretable as principal component scores (69). Another advantage is that the model can be developed further to include more factors if the analysis suggests clues for further research (42). SEM has the advantage of allowing latent variables to be modelled, which reduces the likelihood of regression dilution (52, 69).

SEM and path analysis are particularly suitable for a life course approach because of the temporal ordering of the predictor variables (69). However, the few examples of the use of SEM in oral



Fig. 3. A hypothetical structural equation model of the pathways between education and oral health developed from research by Chandola *et al.* (68). The measurement variables for the latent variable 'psychosocial stress' are shown in the rectangular boxes. Measurement variables for the other latent variables have not been included. Each arrow represents a direct effect for which a path coefficient is calculated. The potential errors associated with endogenous variables in the model have not been included.

epidemiology are analyses of cross-sectional surveys (37, 42). The use of SEM or path analysis does not displace the need for well-designed longitudinal cohort studies when attempting to demonstrate causal pathways.

Furthermore, SEM and path analysis are only as good as the hypothesized model, which will always be more simplistic than real life processes, and may reflect contemporary understandings and concepts of disease causation (50). The validity of the findings is also dependent on the content and construct validity of the measures of the various component factors. Commonly used measures of deprivation, for example fail to reflect social as well as material deprivation (4). Other problems relate to identifying confounding variables in observational data. SEM and path analysis are probably not any better than standard multiple regression techniques in this respect (70). Furthermore, unlike MM, SEM and path analysis still involve reducing complex social phenomena such as social capital to individual attributes in the analysis process.

There are also problems at the technical level with path analysis and SEM. Ideally, all the variables employed, and particularly the outcome measures should be continuous and normally distributed. In practice, dichotomous variables are allowed if they are exogenous (a variable is exogenous if its causes have not been measured or tested i.e. no paths going to it), and different SEMs have been created for males and females to overcome the problem of the dichotomous variable of sex. SEM is a developing area, and new programs such as MPLUS (71) are more flexible than older SEM software, both in the range of data types that can be accommodated and the models that can be fitted (69). Recent developments in software have also combined the benefits of MM and SEM in 'multilevel SEM' (65) although this has yet to be applied in epidemiological research.

The current debate or 'epidemiological soup' (72) concerning the possibility of a causal link between periodontitis and coronary heart disease is an area where SEM might be useful. The debate demonstrates the limitations of traditional oral epidemiological methods in which regression models are adjusted for conventional risk factors such as age, sex, smoking, education, physical activity, ethnic group, diabetes, etc. in establishing whether such a link exists (73, 74). There is a distinct lack of focus on the causal pathways between the various risk factors for both diseases in relation to disease outcomes, research which may suggest new explanations for the association between the two conditions. SEM would allow these pathways to be elaborated. Furthermore, if it is eventually

demonstrated that the two diseases are not causally related, but are the product of common causal pathways between particular social factors, the findings would still be instructive for public health policy.

Qualitative research methods

Whilst sophisticated statistical analysis software used with carefully designed case-control and prospective cohort studies may allow complex causal pathways between social factors and oral health to be elaborated, it is questionable whether such studies would actually answer fundamental epidemiological questions suggested by the theoretical model outlined above. Why do individuals in the sample population adopt various lifestyle practices? What features of the flow of their lives link to oral health? Where did those features come from? How are they changing and adapting? How are macro-economic and political forces impacting on the population in question, over what time scale, and how do the impacts vary according to gender, social class, or across generations, and do these changes have any bearing on oral health outcomes anyway?

These questions suggest the need for qualitative as well as quantitative research methods in oral epidemiology. The growing interest in the value of qualitative research methods in mainstream epidemiology (75–77) has yet to be reflected in oral epidemiology, although there are a couple of examples of the use of qualitative techniques in studies of the social determinants of caries (44, 78).

Qualitative methods utilize a holistic approach which preserves the complexity of human behaviour and allows for a detailed exploration of causal pathways (79). The stories people tell about their illnesses and health, their lives and personal troubles, their perceptions of inequality, their opinions on public issues, in relation to multiple facets of identity and social position, are invaluable. They may reveal information such as why individuals and communities engage in particular oral health behaviours, allow exploration of concepts of self-efficacy, and suggest the underlying structures and relationships and processes that determine oral disease and oral health (14). The role of complex social phenomena such as shared histories and ethnic identity in the production of oral health and disease are particularly difficult to study quantitatively. It is challenging to create valid measurement instruments of such multifaceted phenomena. Even if a research instrument was

validated and used in a quantitative study to demonstrate a relationship between, e.g. ethnic identity and oral health, ethnic identity would still need to be situated in its social, economic, historical and geographical context in its relation to oral health. The stratification of ethnic identity by gender, age, region and social class, and the consequent impacts on oral health would also have to be explored. This implies the need for both qualitative and quantitative research methods (16).

The fascination with prediction of risk is little substitute for elucidating what is actually occurring in a situation and working to change it. It is likely that qualitative research in oral epidemiology would be most useful in providing a theoretical base for quantitative research, including the development of valid measures, and in exploring and explaining causal relationships which have been suggested by quantitative analysis (66).

A recent study by Frohlich *et al.* (23) demonstrates how a fusion of qualitative and quantitative research might work in oral epidemiology. The study quantitatively examined how social structure and a variety of neighbourhood characteristics, including smoking-discouraging resources, impacted on pre-adolescent smoking in various communities across Quebec, Canada. The study also used focus groups to explore meanings ascribed to smoking, patterns of smoking initiation, and the way group behaviour and collective lifestyles shaped individual choices regarding smoking, within the context of particular neighbourhoods. This format could be applied to the exploration of other oral health behaviours.

The benefits of collaboration

The difficulties and challenges of undertaking research based on the theoretical framework outlined above are only too apparent. It is unlikely that oral epidemiologists would be able to undertake the complex longitudinal studies required to explore all the pathways in the model alone. However, closer collaboration with researchers in other large-scale projects may be fruitful (80). For example, an ongoing research project funded by the Medical Research Council (UK) is attempting to measure contextual features, such as material infrastructural inputs from public and private services, and features of collective social functioning, such as social capital and social cohesion in a large number of neighbourhoods in England and Scotland. The associations between these findings and health and health-related behaviour of the residents in the same areas will then be analysed (19). If measures of oral health and oral health-related behaviour were included, such a project could illuminate some of the pathways between social structure and oral health.

If traditional variables such as culture, social class, ethnic group or deprivation are to be broken down into their component features and processes, new measures and indices will be required for oral epidemiological research at a population level. Many such measures have already been developed. For instance, social capital is measured in numerous ways, e.g. in behaviours deemed to be prosocial such as voter turnout, confidence in public bodies, social mistrust, attitudes to issues such as helpfulness and fairness, membership of voluntary organisations, and the frequency and adequacy of interactions with voluntary organisations (36, 81-83). Whether such measures adequately differentiate between the sources and consequences of social capital, as well as encompass the relational, material and political aspects of social capital on both a micro- (intra-and inter-community) and macrolevel (state-society and institutional) is very doubtful (36, 84). However, new and more valid research measures are slowly being developed, and such research is a resource for oral epidemiologists to exploit.

Furthermore, it is unlikely that oral epidemiologists would research the detail of 'social structure', such as the generative mechanisms involved in the creation of social inequalities, or the effects of globilization on national economic and political policy. Nonetheless, closer collaboration with social scientists could allow their insights to inform oral health research and ultimately oral health policy. The growing body of evidence of the role of psychosocial factors in oral health suggests that closer collaboration with psychologists would also be beneficial to oral epidemiology.

Conclusion

Explaining the mechanisms which link features of social life to oral health requires theoretical sophistication. A conceptual framework used in mainstream epidemiology which suggests complex causal pathways between social structure and health via interlinking material, psychosocial and behavioural pathways can be applied to oral epidemiological research. Whilst it is not possible to give detailed consideration to every component in the framework in each piece of research, a research approach which aims to study complex causal processes, rather than direct causal pathways will surely yield findings which are more useful for understanding and explaining the mechanisms by which aspects of people's lives, their environment, and wider economic and political forces promote or damage oral health.

The methodological implications of this approach are challenging. The explanatory power of prospective longitudinal and life-course studies, which make use of sophisticated statistical modelling techniques to elaborate complex causal pathways, can surely be augmented by well-designed, rigorous qualitative research. It has been suggested that the final test of new methodologies is if they lead to advances in understanding the determinants of disease among individuals and populations and contribute to their alleviation (50). It is clear that there is much that is not understood about the way the social determinants of health actually operate to produce different oral health outcomes. Taking the next step involves appreciating the complexity that characterizes socio-biological pathways, and boldly choosing research methods which have the power to explore and reflect complex causal processes.

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