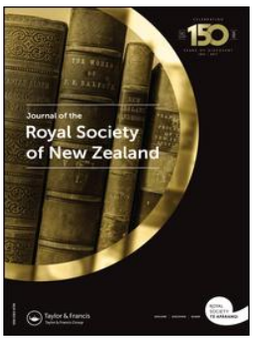

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REVIEW ARTICLE

The Dunedin Multidisciplinary Health and Development Study: oral health findings and their implications

Chuen Lin Hong[a], Jonathan M. Broadbent[a], W. Murray Thomson [a] and Richie Poulton[b]

[a]Department of Oral Sciences, University of Otago, Dunedin, New Zealand; [b]Department of Psychology, University of Otago, Dunedin, New Zealand

ABSTRACT

Longitudinal research is needed to better understand the natural history of oral conditions and long-term health and social outcomes. Oral health data has been collected periodically in the Dunedin Multidisciplinary Health and Development Study for over 40 years. To date, 70+ peer-review articles on the Study's oral health-related findings have been published, providing insight into the natural history of oral conditions, risk factors, impacts on quality of life, and disparities in oral health. Some of these report new findings, while others build upon the existing body of evidence. This paper provides an overview of these findings and reflects on their public health implications and policy utility in New Zealand.

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Cohort; caries; periodontal disease; health services; male; female; dentistry; service utilisation

Introduction

The oral health of New Zealanders improved into the twenty-first century, but these improvements have not been experienced by all New Zealanders (Ministry of Health 2010). Oral health appears to be worsening for some, including Māori and Pacific children (Shackleton et al. 2018) as well as older adults (CBG Health Research 2015). Access to dental care is a challenge for many New Zealanders (Health and Disability System Review 2019). Efforts to improve oral health must be supported by ongoing research into the demographic, biological and socio-behavioural characteristics that affect susceptibility to oral conditions.

Birth cohort studies are scarce, and those that feature oral health data are particularly so. Examples of birth cohorts that have investigated oral health are the four cohorts from the Brazilian city of Pelotas (commenced 1982, 1993, 2004 and 2015), the Longitudinal Study of Australian Children (2003), the Christchurch Health and Development Study (1977), and the Dunedin Multidisciplinary Health and Development Study (1972). The Dunedin Study is a longitudinal study of development and health of a birth cohort born in Dunedin, New Zealand (Poulton et al. 2015). The cohort comprises children born at Queen Mary Maternity Hospital in Dunedin, New Zealand, between 1 April 1972 and 31 March 1973. Perinatal data were collected at the time of birth and the

CONTACT Jonathan M. Broadbent jonathan.broadbent@otago.ac.nz

Table 1. Sample retention in the oral health component.

Year	Age	Number living	Number seen	Percentage seen	Number dentally examined	Percentage dentally examined
1976	5	1037	991	95.6	923	89.0
1980	9	1035	955	92.3	683	67.2
1987–88	15	1029	976	94.8	781	75.9
1990–91	18	1027	993	96.7	867	84.4
1998–99	26	1019	980	96.2	932	91.3
2004–05	32	1015	972	95.8	935	91.6
2010–12	38	1007	961	95.4	928	92.4
2017–19	45	997	938	94.1	896	89.9

cohort for the longitudinal study was defined at age 3. The cohort of 1037 children were assessed within a month of their third birthdays and then again at ages 5, 7, 9, 11, 13, 15, 18, 21, 26, 32, 38, and 45 years. Approximately, 90% of participants self-identify as being of New Zealand European origin.

The Dunedin Study is the only longitudinal study in the world to have clinically investigated dental health in a population-representative cohort from birth to middle age and has maintained a good participation rate over time (Table 1). Many aspects of the Dunedin Study members' oral health have been investigated (Table 2), including dental caries experience and oral self-care. Some aspects of oral health became topics for investigation as the Study members have aged. For example, dry mouth was first assessed at age 32 years, while periodontal health has been assessed from age 26 onwards. While maintaining continuity in key oral health measures, the Study has continued to evolve alongside new advances in dentistry, and, at age 45 years, dental digital scanning technology was used for the first time.

The multidisciplinary scope of the Study means that data have been collected from other areas of health and development, enabling multidisciplinary research on interactions between oral health and cardiovascular health, mental health, and multiple aspects of psychosocial functioning. The Dunedin Study has also enabled investigation of intergenerational aspects of oral health (through collection of data from the Study members' parents

Table 2. Oral health-related data collected in the Dunedin Study.

	Age in years							
	5	9	15	18	26	32	38	45
Dental caries	✓	✓	✓	✓	✓	✓	✓	✓
Periodontal health	–	–	✓[c]	✓[c]	✓[a]	✓	✓	✓
Plaque scores	✓	✓	✓	✓	✓	✓	✓	✓
Enamel defects	✓	✓	✓	–	–	–	–	–
Dental service use	✓[b]	✓	✓	✓	✓	✓	✓	✓
Dental health-related beliefs	–	–	✓	✓	✓	–	✓	–
Malocclusion	–	–	✓	✓	–	–	–	✓[d]
Dental anxiety	–	–	✓	✓	✓	✓	✓	✓
Dental neglect	–	–	–	–	✓	✓	✓	✓
Impact of oral health on quality of life	–	–	–	–	–	✓	✓	✓
Dry mouth	–	–	–	–	–	–	✓	✓
Temporomandibular joint disorder	–	–	–	–	–	–	✓	✓
3D scans	–	–	–	–	–	–	–	✓

[a]Half-mouth data was available at age 26.
[b]As reported by parents.
[c]CPITN.
[d]Derived from 3D scan.

and children). The study is thus well placed to provide answers on how risk factors act at key stages of the life course (and across generations) to affect the experience of oral conditions. Findings from the study have informed (and continue to inform) the development of appropriate oral health policy, resource allocation and oral health promotion efforts.

An overview of past findings

The Study members are now in their fifth decade of life, with the most recent age-45 assessments completed in April 2019. As the Study members enter midlife, it is an appropriate time to reflect upon past findings and their implications for the future of oral health care in New Zealand. Over 70 peer-reviewed articles using Dunedin Study dental data have been published in the international scientific literature. In this paper, we discuss some key findings from the Study about oral health from childhood to adulthood, access to care, and consider their implications for oral health policy and practice.

Child oral health

Early dental research from the Dunedin Study primarily focused upon the prevalence of childhood dental caries and its associated protective and causative factors, including community water fluoridation (which commenced in Dunedin in 1967, well before the Study members were born), self-care, and use of dental services. Over 90% of the Study participants had attended a School Dental Service (SDS) clinic by the age of 5 years, and more than half of those were enrolled with the SDS prior to age 3 years. The most frequent reason for a child having been seen in the SDS was that he/she had been enrolled through Plunket (a provider of support services for the development, health and wellbeing of children under 5 in New Zealand). On the other hand, the most common reason for non-enrolment was the belief by the parents that it was unnecessary to seek dental care until a child started school (Evans et al. 1980). During the mid-1970s dental restoration counts and plaque scores were high despite high SDS enrolment, and it was perceived that this reflected the nature of the SDS at that time as a treatment service rather than a preventive service, and the investigators considered there to be a 'lack of effective prevention' through the SDS (Evans et al. 1982). In terms of public health efforts, it was found that Dunedin Study members who resided in fluoridated areas of Dunedin had lower dental caries experience, a difference that was particularly marked among those of lower socio-economic status (Evans et al. 1984).

Developmental defects of enamel

Dunedin Study investigators were involved with the development of the Developmental Defects of Enamel index (Commission on Oral Health Research and Epidemiology 1982). The three broad categories of developmental defects of enamel were diffuse opacities (qualitative defects of discoloured hypomineralised enamel with no clear border with adjacent normal enamel), demarcated opacities (qualitative defects of discoloured hypomineralised enamel with a well-defined border with adjacent normal enamel), and hypoplasia (quantitative defects of enamel thickness such as pits or grooves). The Dunedin Study was among the first to use the index to describe the prevalence of developmental

defects of enamel (Suckling et al. 1985) and found that 57% of children had at least one tooth with defective enamel, many of which were <2 mm in diameter. Demarcated defects of permanent teeth were associated with a history of trauma (Suckling et al. 1985, 1987), while a history of chicken pox was associated with the occurrence of hypoplasia (Suckling et al. 1987). Furthermore, if deciduous teeth are affected by dental caries or lost due to trauma/extraction, their permanent successors were placed at significantly greater risk of being affected by demarcated defects (Broadbent et al. 2005).

Access to care

The New Zealand dental care system ensures access to State-funded dental care until age 18 years, after which dental care is largely privately funded. This abrupt shift of responsibility of the financial burden of dental care onto young adults who may not have yet entered the workforce adversely affects oral health for many. The proportion of Study members who were routine dental attenders fell from age 15–18 (81.7% and 66.7%, respectively), dropping still further to ages 26 and 32 (31.2% and 27.7%, respectively) (Thomson et al. 2010). Long-term dental attendance from young adulthood and into middle age was associated with better adulthood oral health. Loss of permanent teeth due to dental caries was virtually unknown while Study members had access to universal publicly-funded dental care through to age 18 (Thomson, Poulton, et al. 2000; Broadbent et al. 2013). By age 32, the profound oral health effects of under-utilisation of dental services had become even more apparent. Study members who had not accessed dental services (at ages 15, 18, 26 and 32) had four times more decayed tooth surfaces (DS) than those who were regular attenders at all four ages, and a marked gradient in tooth loss experience was observed (Thomson et al. 2010; Crocombe et al. 2011, 2012).

Trajectories of dental caries and caries-associated tooth loss

Subsequent to age 18, many Study members had DS, and social inequality in tooth loss due to caries became evident (Thomson, Poulton, et al. 2000). Such differences continued to widen into middle age. Firstly, the greatest burden of DS was observed during the mid-twenties, consistent with findings from New Zealand's 2009 oral health survey (Ministry of Health 2010). One in four (24.8%) Study members had any DS at age 18, but this increased to nearly two in three (63.8%) by age 26 (Broadbent et al. 2013). DS subsequently declined, giving an illusion of improving caries experience, but this was due to an increase in tooth loss. Turning to the total count of decayed, missing, and filled tooth surfaces (DMFS), the increasing burden of dental caries among those with the highest rate of caries appeared to have slowed once Study members entered their thirties. This was not due to a change in susceptibility to dental caries but rather due to rising tooth loss and dental restorations leaving fewer sound tooth surfaces available for new carious attack (Broadbent et al. 2008; Broadbent et al. 2013).

Inequalities and intergenerational continuity in oral health

It was early in the history of the Dunedin study that investigators first considered the intergenerational aspects of oral health. At age 5, children of parents who rated their

oral health as 'good' or 'excellent' had lower dental caries experience than those whose parents were edentulous or rated their oral health as below average. Children whose parents assisted them in toothbrushing also had better oral health (Evans et al. 1982). At age 32, the oral health team investigated the association between maternal self-reported oral health at age 5 and the child's cumulative caries experience 27 years later. There was a consistent gradient in caries experience across the categories of maternal self-rated oral health at age 32, and the mean DMFS among those in the 'excellent' maternal oral health status group was less than half that of the 'very poor/edentulous' group (Shearer et al. 2011a). Further findings provided support for continuity in oral health between generations. Early-life social class was found to shape oral health beliefs (which predicted oral health-related behaviours such as toothbrushing and dental service use), and were substantially influenced by parental oral health-related beliefs (Broadbent et al. 2016).

Childhood socio-economic status (SES) had a profound effect on health later in life, particularly so for oral health. The SES of Study members' parents is important for Study members' oral health into the third (Poulton et al. 2002; Thomson et al. 2004) and fourth (Thomson 2012) decades of life. Social class may change (for better or worse) through life, but upward SES mobility in adulthood did not negate the adverse effects of low social class of origin (Poulton et al. 2002). Moreover, what is becoming clear from the Dunedin Study findings is that the SES of destination (that is, in adulthood) has taken on progressively more importance as the cohort ages (Thomson 2012). This is consistent with how chronic, cumulative conditions such as dental caries, periodontitis and incremental tooth loss progress.

Periodontal disease

In the past, periodontitis was considered by many to be a disease of older people, with all considered to be equally susceptible, while gingivitis was thought to inevitably lead to periodontitis and subsequent tooth loss. However, the evidence for this was lacking, and little research had investigated the transition from health to periodontal disease in younger adults, and none had done so with a representative sample. The Dunedin Study began comprehensive periodontal data collection at age 26 years, enabling such investigation.

Periodontitis asserted itself as the second most prevalent oral health problem from as early as the mid-twenties (Thomson, Hashim, et al. 2000) and appears to progress more rapidly with increasing age. From age 26–32, 12% of Study members experienced incident or progressing attachment loss, while 22% experienced this from age 32 and 38 (Thomson et al. 2013). Considerable work has been done through the Dunedin Study to unravel the periodontal health effects of smoking tobacco (Hashim et al. 2001; Hashim et al. 2002; Thomson et al. 2007, 2013) and cannabis (Thomson et al. 2008, 2013) and how the effects of smoking are exacerbated by poor oral hygiene (Broadbent et al. 2011). Host susceptibility also affects risk for periodontitis (Thomson et al. 2001). Smoking cessation before the mid-twenties has marked benefits for ongoing periodontal health (Thomson et al. 2007). The social inequalities observed with caries experience and tooth loss were also seen with periodontitis. Periodontal disease among those of low SES was three times greater than among those of high SES (Poulton et al. 2002).

Quality of life

Those who experience the greatest dental disease are not necessarily those who experience their worst impacts. The traditional approach of defining 'good' oral health through clinically assessed oral health is lacking, because it does not consider or reflect a condition's impact on the sufferer's quality of life. Accordingly, at the 32 years, a 14-item Oral Health Impact Profile (OHIP-14) scale (Slade 1997) was introduced to measure the impact of oral health on quality of life, and it has been used again at ages 38 and 45. It should be noted that a measure of this type was considered for the age-26 assessments but, because all available scales had to that point been validated for use only with older people, that did not proceed.

At age 32, nearly a quarter of Study members reported experiencing impacts on quality of life 'fairly often' or 'very often'. The impacts on quality of life reported most frequently were in the domain of 'physical disability', characterised by impacts on diet or having to interrupt meals due to dental problems (10.7% of Study members). This was followed closely by 'psychological discomfort', characterised by self-consciousness or tension due to dental problems (10.3% of Study members). Problem-oriented users of dental services had over 3 times greater odds of experiencing an impact on OHRQoL. After controlling for confounders, there was no significant association of sex with the prevalence of impacts on quality of life, but females experienced impacts to a significantly greater extent than males (IRR 1.4, 95% CI 1.1–1.6). Those of low SES who utilised dental services episodically had significantly greater risk for experiencing one or more impacts (OR 1.6 and 2.3, respectively), as well as significantly greater extent (IRR 1.3 and 2.1) and severity (IRR 1.1 and 1.5) of impacts (Lawrence et al. 2008). Dental caries, tooth loss due to decay, and periodontal disease were also associated with more frequent, extensive, and severe impacts on oral health-related quality of life.

Psychological characteristics and oral health

The physical and psychological effects of dental anxiety can be serious and this has been an area of research strength for the Dunedin Study. The first report on dental fear from the Dunedin Study described how aversive dental experiences (as measured by caries experience by age 15) were associated with onset of dental fear three years later (Poulton et al. 1997). The late David Locker (1949–2010) made some important contributions to the Dunedin Study research in the field of dental anxiety. In collaboration with Locker, the Dunedin Study team described how early conditioning experiences can lead to dental anxiety in adulthood, and identified a number of psychological traits that can predict dental anxiety (Poulton et al. 2001; Locker, Thomson, et al. 2001; Locker, Poulton, et al. 2001; Thomson et al. 2009). Dental anxiety has a number of oral health consequences, and those with high dental anxiety experienced the greatest tooth loss and dental caries experience (Kruger et al. 1998; Thomson et al. 2009) and were least likely to be routine users of dental services (Thomson, Locker, et al. 2000; Thomson et al. 2009).

Personality characteristics of the Dunedin Study members have been investigated in depth in previous assessments for the wider study (Israel et al. 2014). The role of self-

reported oral health measures (such as the OHIP-14) for research and clinical practice is well recognised, yet it is somewhat unclear how different personality profile affects this. In the Dunedin Study, those with higher scorer for the negative emotionality dimension had a greater risk of reporting 1+ oral health impacts and worse-than-average oral health. They also experienced significantly greater tooth lost due to caries and untreated DS (Thomson et al. 2011).

Recently published findings have also shown gradients by childhood IQ in caries experience, periodontal status, oral hygiene and dental beliefs. Those who had higher child IQ had more favourable oral health and beliefs later in life. This emphasises the need to shape oral health services to ensure that those of poorer cognitive function are not disadvantaged throughout the rest of their lives (Thomson et al. 2019).

Other findings

Other areas of oral health research in the Dunedin Study have been diverse. Examples of this research includes investigation of putative risk factors for dental caries such as dry mouth and asthma, putative outcomes for orthodontic treatment, and impacted 3rd molar teeth in the longer term.

Dry mouth is considered a condition of the 'old'; however, in this birth cohort, about one in ten reported having xerostomia as early as 32 years. Study members taking antidepressants or iron supplements had more than 4 times greater odds of having xerostomia, while those taking narcotic analgesics had more than twice the odds. This strong association between certain medications and the odds of reporting xerostomia was not unexpected, but this research confirmed it can occur from a relatively young age and demonstrates that xerostomia has a nontrivial and significant impact on OHRQoL across all OHIP-14 domains (Thomson, Lawrence, et al. 2006; Thomson, Poulton, et al. 2006).

Asthma has frequently been cited as a possible risk factor for dental caries. A Dunedin Study investigation found no significant differences in caries increment between the asthma-free and asthma-affected Study members, regardless of tooth surface type. The Study findings did not support the idea of asthma as a cause of dental caries (Meldrum et al. 2001).

Orthodontic treatment is one of the only categories of dental care that is not publicly funded for New Zealand children. The Dunedin Study is unique among population-based cohort studies to have data taken at repeated occasions on malocclusion and self-perceived success of orthodontic treatment outcomes. The self-rated dental appearance of those who needed and received orthodontic treatment improved (Thomson 2002), but the experience of those improvements was associated with personality characteristics (Barker et al. 2005).

One study investigated outcomes for third molar (wisdom) teeth. Treatment philosophy means that many third molars are extracted 'prophylactically', in case they become impacted and fail to erupt in the future. However, there is a lack of longitudinal research to have reported on outcomes for third molar teeth that were not removed. Of the teeth observed to be not impacted at age 18 years, 42.2% had erupted by age 26 years and 29.8% had been extracted. Horizontally impacted third molars do not usually erupt, but between 20% and approximately 50% of those with other types of impaction may in fact erupt into the oral cavity (Kruger et al. 2001).

Implications of findings

Implications for clinical practice

The previously-published findings of the Study have many implications for the day-to-day practice of dentistry. In general terms, Dunedin Study findings lend support for the effectiveness of dental care in minimising the impacts of dental diseases on quality of life (Lawrence et al. 2008). Clinicians can use Dunedin Study findings to help understand and manage risks for oral health problems. For example, clinicians should avoid prophylactic extraction of third molar teeth in the absence of clinical indications or symptoms (Kruger et al. 2001). Study findings have implications for patient education about the oral health effects of smoking cannabis (Thomson et al. 2008, 2013) and the importance of plaque control (Broadbent et al. 2011). They can help clinicians understand likely progression of dental caries (Broadbent et al. 2008, 2013) and periodontal disease (Thomson et al. 2013).

The Study can also help identify patients who are at greater risk for oral conditions. For example, dental restorations (placed by dentists) can contribute to risk for periodontal disease at the restoration site (Broadbent et al. 2006). The study can also identify new risk factors for developmental defects of enamel (Suckling et al. 1985, 1987; Broadbent et al. 2005). Clinical management of children affected by dental trauma or early childhood caries should include communication with patients about the long-term implications for developmental defects of the permanent teeth and higher caries risk, and the permanent successors of deciduous teeth affected by trauma should be covered under schemes such as ACC (a no-fault insurance scheme for accidental injuries in New Zealand). The longitudinal data show how ongoing exposure to modifiable risk factors such as smoking (Thomson et al. 2007, 2008, 2013; Broadbent et al. 2013) and poor oral hygiene (Broadbent et al. 2011) affect oral health in the long term, and can help identify targets for preventive interventions.

Implications for health policy

There is no 'perfect' oral health care system, and New Zealand's current system serves the majority of the country's younger people well, but more needs to be done to address inequity in access to dental care among New Zealand adults. Parental oral health is associated with that of the next generation (Evans et al. 1982; Shearer et al. 2011a, 2011b). The argument that efforts to improve the oral health of adults (particularly young mothers) will have benefits for the oral health of children throughout life stands up to both reason and analysis (Broadbent et al. 2016). Changes in the dental health system will not happen without significant shifts in policy at all levels of government, and actions towards this must be universal and proportionate to need.

The problem of low dental service utilisation among young adults remains an enduring problem. The 2017/18 National Health Survey (Ministry of Health 2010, 2019) reported 44% of the NZ population had put off dental care during the past year due to the cost, but among those aged 25–34 the figure was 59%. Dunedin Study findings have shown that, as the responsibility of dental care shifted onto the individuals themselves–especially for those who are socio-economically disadvantaged–poorer oral health outcomes can be expected. Young adulthood tends to be a period of life when disposable income is low and

other priorities (e.g. tertiary study, raising children) mean dental care is beyond reach. It is crucial that we recognise the unmet dental needs of our population and adapt New Zealand's oral health system to have appropriate focus on prevention and primary dental care. More needs to be done such so that the oral healthcare system can help redress the current inequalities in child oral health into and through adulthood.

Research gaps

Early life exposures have profound effects on oral health outcomes in adulthood. Investments in early years (to address social disadvantage) is important, and this is the principle underlying New Zealand's dental care system, which enables access to State-funded care for children and adolescents. However, we still observe that the most disadvantaged children in New Zealand experience the worst oral health. Many of the problems are external to the dental care service: by the time a child accesses the formal dental care system, patterns of poor diet, poor self-care, and even dental caries have often already occurred.

Current dental-related Dunedin Study research includes detailed characterisation of dental plaque and with advances in bacterial genetics, the study has begun to investigate the bacteria collected from different intra-oral sites from age 32. The study can provide insights into the composition of the human plaque, the ecological role that species have in modulating human plaque, and provide a glimpse of its effect in the progression from healthy to periodontitis. Further work is being conducted on the microbiology of dental plaque and how it may affect caries risk and periodontal disease. Digital 3D scans of the Study members' dentitions at age 45 years enable investigation of occlusal features and temporomandibular joint dysfunction, along with dental aesthetics. In future, the digital scans will provide insights into changes to the ageing dentition including crowding and attrition (tooth wear).

Conclusion

Ongoing investigation of the natural history of oral conditions in this and future cohorts is needed to improve oral health in this and future generations. Given New Zealand has successfully invested in with a world-leading lifecourse study of oral health, we feel justified in aspiring to a world-leading dental care system for our country. The Dunedin Study provides useful information supporting the aim of benefiting oral health in New Zealand and beyond.

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Disclosure statement

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ORCID

W. Murray Thomson http://orcid.org/0000-0003-0588-6843

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