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SYSTEMATIC REVIEW

Economic Evaluations of Preventive Interventions for Dental Caries and Periodontitis: A Systematic Review

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Abstract

Objectives To critically examine the methods used for full economic evaluations of preventive interventions for dental caries and periodontitis.

Methods Published literature post-2000 was searched to April 2021. Based on a developed intervention classification framework for dental caries and periodontitis, only universal, selective or indicated interventions were included in this review. The Drummond 10-point checklist was used for quality appraisal.

Results Of 3,007 unique records screened for relevance, 73 studies were reviewed. Most model-based studies (61/73) used cost-effectiveness analysis (49%) or cost-benefit analysis (28%). Trial-based studies (16/73) commonly used cost-effectiveness analysis (59%). Four studies used both economic evaluation methods. Sixty-four papers (88%) were on dental caries, eight papers (11%) focused on periodontitis, and one paper (1%) included both oral diseases; 72% of model-based and 82% of trial-based studies were of good quality. The most frequently investigated dental caries preventive interventions were water fluoridation (universal intervention; cost-saving or cost-effective), fissure sealant and fluoride varnish (selective and indicated interventions; cost-effectiveness outcomes were inconsistent). Supportive periodontal therapy with oral health education (indicated intervention; cost-effective) was the most frequently evaluated preventive intervention for periodontitis. Thirty percent of studies with a time horizon > 1 year did not apply an appropriate discount rate and 26% did not comprehensively discuss other important considerations beyond the technical analysis.

Conclusions Generic health outcome measures should be incorporated for economic evaluations on preventive interventions for dental caries and periodontitis, and an increased focus to prevent periodontitis using economic evaluation methods is needed to inform resource allocation and policy decision-making.

1 Introduction

The major contributors impacting quality of life due to oral disease are predominantly caused by advanced dental caries, periodontitis (gum disease) and advanced periodontitis. Advanced dental caries and advanced periodontitis affecting multiple teeth can lead to edentulism (total tooth loss). The 2017 Global Burden of Disease (GBD) study estimated 2.3 billion people had dental caries in permanent (adult) teeth, 532 million children had dental caries in deciduous (baby) teeth, 796 million people have advanced periodontitis, and 267 million people have edentulism [1]. These statistics correspond to 1.6 million years lived with disability (YLD) for permanent teeth, 0.1 million YLD for deciduous teeth, 5.2 million YLD for severe periodontitis and 7.3 million YLD for edentulism [1].

Dental caries and periodontitis are experienced disproportionately by different populations in society [2–4], and share common risk factors with other noncommunicable diseases (NCDs) [5, 6]. Additionally, periodontitis can have a direct association with other NCDs including cardiovascular disease [7, 8], dementia and cognitive impairment [9, 10], diabetes [11, 12] and obesity [13, 14]. The 2017 GBD study reports that more economically developed countries had the lowest burden of dental caries and advanced periodontitis [1]. The burden of oral diseases

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Key Points for Decision Makers

Methods used for economic evaluations on preventive interventions for dental caries and periodontitis were diverse, including the cost components, the consequences, and health outcomes.

These differences make it difficult to enable comparability between interventions to inform health investment decisions.

Future research in the field should consider how to incorporate generic health outcome measures, increase focus on performing economic evaluations to prevent periodontitis, and consider health equity impacts.

is significant, yet oral health is often excluded from evidence-based public health policy [15–17].

Despite a large body of evidence demonstrating the clinical effectiveness of a broad range of preventive interventions for dental caries and periodontitis, few interventions are translated into routine clinical dental practice or public health programs [18–22]. Dentistry has remained treatment-dominated and a highly specialised area of healthcare, which, as a result, has not successfully tackled the global burden of oral diseases [5].

Evidence for the cost-effectiveness of interventions is also an important consideration to assist decision makers in determining investment decisions. In the past 10 years, seven systematic reviews of economic evaluations were focused on preventive interventions for dental caries and/or periodontitis [23–29]. Six systematic reviews were exclusively focused on dental caries, of which four reviews were on child populations [25–28]. One systematic review assessed interventions for dental caries, periodontitis and oral cancer [29].

When considering the focus of these reviews, five reviews were primarily concerned with investigating the quality of the economic evaluation studies [23–26, 29]. Four reviews provided an overall economic evaluation quality score using various checklists [23, 25, 27, 29], although determining study quality using a scoring system is not a best practice recommendation [30, 31]. One review did avoid reporting an overall score but developed and used a risk of bias grading assessment [24].

The most common preventive interventions that have been economically evaluated include water fluoridation [23, 29], fissure sealant applications [23, 26, 29], and the use of topical fluorides such as fluoride varnish applications and fluoride mouth rinses [24, 26, 28]. Only three out of the six systematic reviews that assessed these preventive interventions reported whether the preventive interventions were cost-effective [24–26]. This is due, in part, to the reviews' primary aim being to determine the quality of economic evaluation studies. In general, preventive interventions found to be cost-effective were water fluoridation, taxation of sugar sweetened beverages (SSBs), and anticipatory guidance inclusive of oral health education. Fissure sealant applications and interventions (with or without dental treatment) incorporating the use of topical fluorides (mouth rinses, gels and fluoride varnish applications) were shown to have mixed cost-effectiveness outcomes (either cost-effective or more costly and more effective). The lack of primary studies on economic evaluations for the prevention of periodontitis continues to be a gap in the literature. In addition, the economic evaluation methodology on prevention interventions for dental caries and periodontitis have not yet been fully explored. Therefore, the aim of this study was to conduct a systematic literature review to critically examine the methods used for full economic evaluations of preventive interventions for dental caries and periodontitis.

2 Methods

The study protocol was registered in May 2020 in PROSPERO (CRD42020186409) and revised in October 2020 to ensure there was contemporary relevance.

2.1 Literature Search

Published literature was searched in May 2020 and updated in April 2021 for publications post-2000 using the following electronic databases: The CRD databases (DARE, NHS EED, HTA), EBSCO databases (CINAHL, ERIC, Global Health, OpenDissertations), EMBASE, Medline and Web of Science. Efforts were made to identify relevant unpublished 'grey' literature and conference proceedings through appropriate websites and databases such as Proquest Dissertations and Theses Global, OpenGrey, and EThOS databases for potentially relevant studies. Google Scholar and government websites were not searched due to the limitations of search replicability. Bibliographic information from identified relevant systematic reviews were examined for potentially applicable studies. Medical Subject Headings (MeSH) and free-text search terms were combined with key concepts relating to dental caries, periodontitis and economic evaluation. The adopted search terms and strategy are specified in Online Supplementary Material (OSM) Appendix 1.

2.2 Study Selection and Eligibility

The study eligibility criteria were based on the population, intervention, comparator and outcome (PICO) framework: P—all ages, I—Preventive interventions for dental caries and periodontitis, C—at least one strategy (the intervention or comparator) must be a preventive intervention or prevention is a primary focus (dental treatment can be a consequence), and O—dental caries or periodontitis and economic evaluation.

In this review, we adapted the intervention framework that has been commonly used in mental health prevention [32, 33] to develop the Intervention Classification Framework for Dental Caries and Periodontitis. The spectrum of interventions illustrated in Fig. 1 classifies six categories according to their descriptors as explained in OSM Appendix 2. Only universal, selective or indicated interventions were included in this review. Universal interventions target the whole population and not people identified based on individual risk for dental caries or periodontitis. Selective interventions target community population subgroups whose risk of developing dental caries or periodontitis is higher than average. Indicated interventions target high-risk individuals or those with initial stages of dental caries or periodontitis.

Other inclusion parameters included full-texts, English language publication, model-based or trial-based full economic evaluations (primary or secondary data), original empirical research, peer-reviewed and non-peer-reviewed publications (e.g., theses, government reports). Full economic evaluation is a systematic framework that allows the incremental analysis of alternative interventions in terms of both costs (resource use) and consequences (outcomes, effects) [34].

Other specific exclusion criteria include:

- Studies published earlier than 2000.
- Partial economic evaluations, where the incremental analysis of alternative interventions was not performed.
- Studies that made comparisons of different dental materials or clinical techniques, investigated the different use of the dental workforce or payment schemes.
- Studies that did not have a primary focus on preventive interventions.

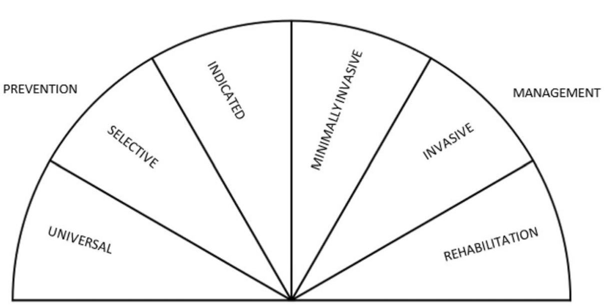

Fig. 1 Interventions classification framework for dental caries and periodontitis, adapted from Mrazek and Haggerty [32]

- Literature/systematic reviews, letters, editorials, conference abstracts and commentaries.

The screening process and quality appraisal were evaluated for their level of agreement according to Cohen's Kappa values whereby a score < 0.40 corresponds to poor, 0.40–0.74 is considered fair to good, and 0.75–1 is defined as perfect agreement [35]. It was agreed that studies pre-2000 would be excluded considering that economic evaluations in oral health research have considerably increased from the year 2000 onwards [36]. Potential papers identified using the literature search strategy were imported and duplicate records removed using Endnote X9.2 (Clarivate Analytics). The remaining papers for screening were imported and managed using Covidence. Two reviewers (TMN and UT) independently screened title/abstract and full-text screening. Any differences in agreement were discussed and a consensus reached.

2.3 Data Extraction

TMN completed the data extraction for studies into Covidence using the following parameters:

A. Publication year, author, classification of preventive intervention, country context, data source (primary/secondary data), economic evaluation study type (model/trial/combination)
B. Type of economic evaluation (e.g., cost-benefit analysis (CBA), cost-consequence analysis (CCA), cost-minimisation analysis (CMA), cost-effectiveness analysis (CEA), cost-utility analysis (CUA) or combination and return on investment (ROI) studies.
C. Economic evaluation characteristics including perspective, reference year, time horizon, discount rate for costs and outcomes, cost categories.
D. Intervention and comparator description.
E. Population characteristics including age of target population, and number of participants.
F. Reported outcomes including:
   - Dental outcomes (e.g., caries free, decayed teeth surfaces (ds/DS), decayed teeth (dt/DT), decayed, missing, and filled surfaces (dmfs/DFMS), decayed, missing, and filled teeth (dmft/DMFT), proportion of bleeding sites, retained-tooth per year, quality-adjusted tooth years (QATYs),
   - Health outcomes (e.g., disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs), and
   - Economic evaluation outcomes (e.g., incremental cost-effectiveness ratio (ICER), cost-benefit ratio (CBR), and ROI.

2.4 Cost-Effectiveness

Value for money judgments were made based on whether the preventive intervention was cost-saving, dominant, or was below a willingness-to-pay (WTP) threshold. For CEA studies that calculated the ICER, where the intervention was more costly and more effective, cost-effectiveness was 'not stated' due to the absence of WTP thresholds for dental outcomes. If a WTP threshold was used to judge cost-effectiveness for CUA studies, as these can differ between countries, this was included in the review.

2.5 Quality Appraisal

The methodological quality of eligible model-based and trial-based studies was appraised using the Drummond 10-point checklist, including the 32 sub-questions, which informed the response of the overarching question (answer options being 'yes', 'no' or 'unsure') [34]. The Drummond 10-point checklist has previously been applied for systematic reviews of economic evaluations on oral health interventions [24, 27, 36, 37]. Quality appraisal was also used to assist in identifying the methodological characteristics of the economic evaluations included in this review. All studies were appraised by one reviewer (TMN), and a second appraisal was provided by two other independent reviewers (50:50; UT and LL). Any differences in the quality appraisal scoring were discussed between the reviewers to reach a consensus, with unresolved issues mediated by the third reviewer. Individual study and overall study quality according to the preventive interventions were classified using Method 1 from the Gonzalez-Perez (2002) criteria [38] for the Drummond 10-point checklist [34]: low quality (0–0.69), moderate quality (0.7–0.89) and good quality (0.9–1.0).

3 Results

The literature search process is summarised using the PRISMA guidelines (Fig. 2) [39]. Of the 5,133 records identified, the duplicate study removal process resulted in 3,007 unique records, with 2,685 records excluded at the title/abstract screening stage (TMN/UT; Cohen's Kappa: 0.605). Four records were identified via bibliographic citation search. Of the remaining 322 records subjected to full-text screening (TMN/UT; Cohen's kappa: 0.430), 29 records were automatically removed since they reported abstracts only or the full-texts could not be retrieved. The final number of studies meeting the inclusion eligibility criteria was 73 full-text articles. Both title/abstract and full-text screening had fair to good agreement between reviewers.

3.1 Findings Summary

A summary of the study characteristics is reported in Table 1, with the individual details presented in OSM Appendix 3. Based on the full-text analysis, 64 studies (88%) were related to dental caries, eight (11%) to periodontitis, and one study (1%) investigated impacts on both dental caries and periodontitis. Most studies (90%) were in high-income countries including the USA (n = 17), Australia (n = 15), and the UK (n = 11). Of the 73 full-text papers, there were 34 categories of preventive interventions for dental caries and/or periodontitis; ten were universal interventions, nine were selective interventions, and 15 were indicated interventions (Table 2).

The most frequently economically evaluated preventive interventions for dental caries were water fluoridation (universal), fissure sealant and fluoride varnish (selective and indicated). For periodontitis, the most common preventive intervention economically evaluated was supportive periodontal therapy with oral health education. The target population for these interventions were mainly only for children (64%) followed by both adults and children (22%).

A summary of the characteristics of included studies is reported in Table 3. The most common economic evaluation approaches used were CEA and CBA (47% and 25%, respectively). Model-based studies were the most common approach for economic evaluation (78%), with a few studies using both model-based and trial-based studies (5%).

Almost half (49%) of model-based studies used the societal perspective and 44% used the healthcare perspective, compared with 35% for trial-based studies that used either the healthcare or the societal perspective. A greater proportion of trial-based studies (29%) compared with model-based studies (5%) performed economic evaluation from both the healthcare and societal perspectives. The most common cost categories were the cost of direct restorations only (33%) and direct treatment costs inclusive of restorations, extractions and other direct costs for dental caries (36%) for model-based studies, where the latter cost category was the most used for trial-based studies. Other direct costs for dental caries include the cost of root canal treatments, crowns, bridges and implant crowns, noting that these dental treatment procedures may be caused by trauma, cracked tooth syndrome, and severe stages of periodontitis rather than because of dental caries.

The most common dental outcome measures for dental caries were dmfs/DMFS, dmft/DMFT averted, ds/DS averted and caries-free proportion of the population, months or persons. The most common dental outcomes for periodontitis were retained-tooth per year and the proportion of teeth with bleeding sites. CUA model-based and trial-based studies (14%) used either DALYs for dental caries and QALYs for dental caries and periodontitis as the health outcome

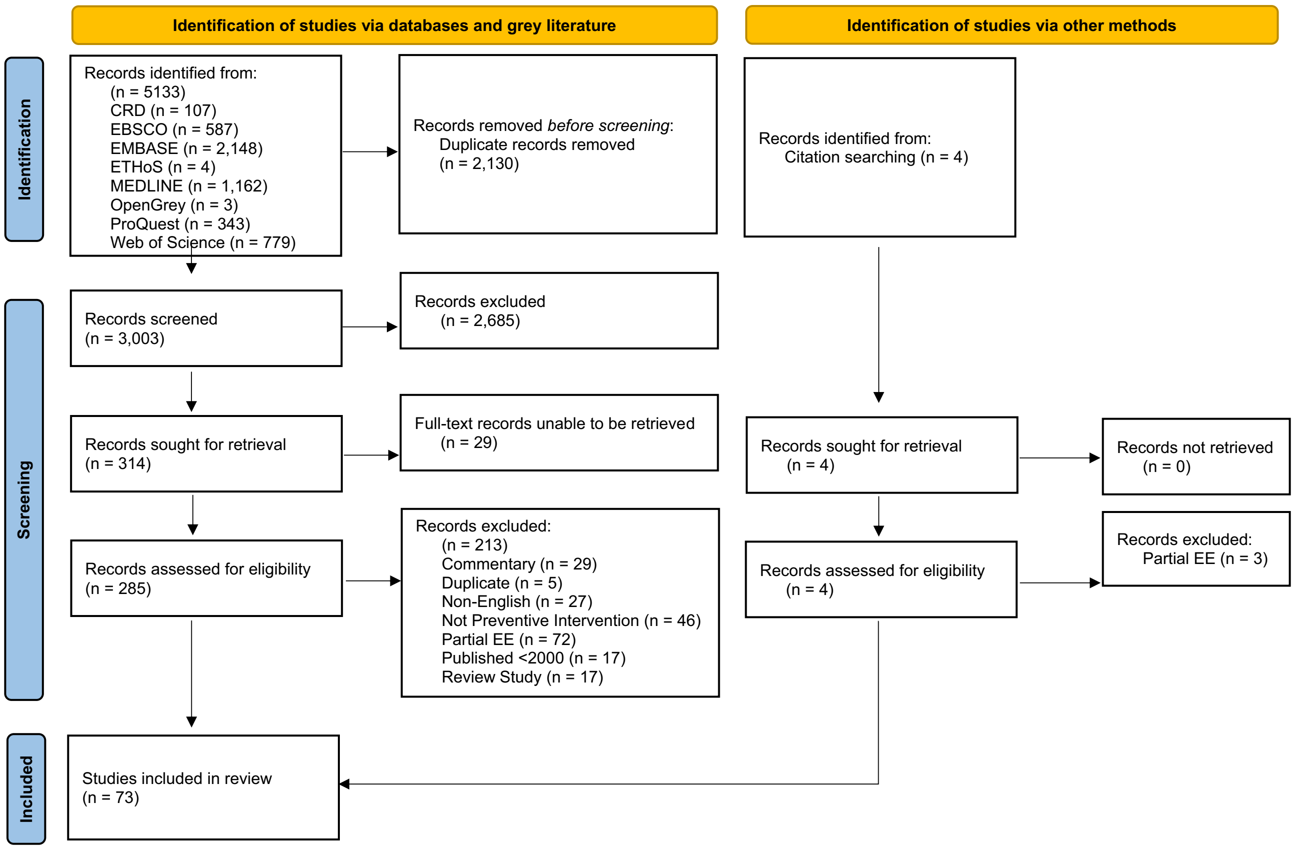

Fig. 2 Results of the systematic review search strategy using the PRISMA guidelines [39]

measures. One study quantitatively used a health equity outcome measure, which evaluated whether the intervention increased access to dental services for children from low-income households [94].

3.2 Derivation of Disability and Utility Weights for General Health Outcome Measures

The use of disability and utility weights in the selected studies to quantify DALY averted and QALY gained was variable. Two studies measured DALY using the disability weight of 0.057 for symptomatic dental caries according to the 2003 Australian Burden of Disease study. It includes two time periods spent with disability, an initial phase where the individual experiences intermittent pain and the terminal phase where the individual experiences constant pain. This approach has later been adopted by the 2017 GBD study [1]. One study used the disability weight of 0.012 for dental caries derived from the 2010 GBD study [51] but did not state if the initial and terminal phase experience of pain was considered.

Except for two studies [52, 53], there were generally two approaches to quantify QALYs: (1) one minus the disability weight used in GBD studies or (2) measured using quality-of-life survey instruments for trial-based studies. One study used the disutility weight of 0.720 for otitis media (middle ear infection) [54], and one study used the disutility weight for different severity of dental caries experience (dmft/DMFT) [55], derived from the New Zealand Burden of Disease study [56]. For trial-based studies, one study used the Child Health Utility Nine-Dimension (CHU-9D) instrument, either completed by the parent/primary caregiver as a proxy measure [57] or via the children directly [40], and another study used the EQ-5D-3L instrument to derive QALY utility weights for adults [58]. One study used 'expert opinion' for the utility weights for periodontitis, and another study represented QALY as the aggregate preference tooth utility weight of eight permanent molar teeth to represent the individual [52].

3.3 Willingness-To-Pay Thresholds

Various hypothetical WTP thresholds for dental outcomes were considered by seven studies [48–50, 59–62]. Two Chilean studies have suggested a WTP threshold of 20,000 Chilean pesos per QATY gained or caries-free person, based on the cost of a restoration from the healthcare

Table 1 A summary of the study characteristics included in the systematic review

Summary	Characteristic	No. of studies $N = 73$ (%)
Country context*	*High income*	
	Australia [52, 57, 63–65, 67, 68, 70, 87, 92–94, 99, 103, 108]	15 (19%)
	Canada [96, 100]	2 (3%)
	Chile [44, 59, 61, 82, 85]	5 (6%)
	Finland [60]	1 (1%)
	Germany [49, 50, 62, 89, 90, 108, 110]	7 (9%)
	Ireland [71, 108]	2 (3%)
	Japan [97, 108]	2 (3%)
	Netherlands [86, 105]	2 (3%)
	New Zealand [55, 73, 79]	3 (4%)
	Norway [109]	1 (1%)
	Spain [108]	1 (1%)
	Sweden [48, 106, 107]	3 (4%)
	UK [40, 54, 58, 84, 95, 102, 104, 108, 111–113]	12 (15%)
	USA [41, 43, 45–47, 53, 69, 74, 76, 88, 91, 98, 101, 102, 108, 123, 124]	17 (21%)
	Subtotal	72 (90%)
	Upper-middle income	
	Brazil [42]	1 (1%)
	Iran [72]	1 (1%)
	Peru [80]	1 (1%)
	South Africa [75, 78]	2 (3%
	Thailand [81]	1 (1%)
	Subtotal	6 (8%)
	Low-middle income	
	Sri Lanka [108]	1 (1%)
	Low income	
	Nepal [83]	1 (1%)
Target oral disease	Dental caries [40–50, 52, 54, 55, 57–65, 67–69, 71–91, 93–101, 103–107, 111, 112, 123, 124]	65 (88%)
	Periodontitis [53, 92, 102, 108–110, 113]	7 (11%)
	Caries and periodontitis [70]	1 (1%)
Target population	Adults [50, 53, 58, 64, 88, 92, 102, 108–110]	10 (14%)
	Children^ [40–49, 52, 54, 57, 59–62, 67–69, 71, 74, 80–85, 90, 91, 93–101, 103–107, 112, 123, 124]	47 (64%)
	Adults + children^ [55, 63, 65, 70, 72, 73, 75–79, 86, 87, 89, 111, 113]	16 (22%)
Economic evaluation study type	Model-based [41, 43–47, 49, 50, 52–55, 57, 59, 61–63, 67–91, 93, 95, 96, 98–101, 103, 105, 108–111, 123, 124]	57 (78%)
	Trial-based [48, 58, 60, 92, 94, 97, 102, 104, 106, 107, 112, 113]	12 (16%)
	Model + trial [40, 42, 64, 65]	4 (5%)
Data source	Primary [40, 42, 48, 58, 60, 63, 64, 92, 94, 97, 102, 104–107, 112, 113]	17 (23%)
	Secondary [41, 43–47, 49, 50, 52–55, 57, 59, 61, 62, 65, 67–91, 93, 95, 96, 98–101, 103, 108–111, 123, 124]	58 (77%)

N total number of studies

*One study reported economic evaluations for eight different country contexts [108]

^Children were defined as < 18 years old

perspective [59, 61], and three studies have referenced AU$3,300 per restoration averted [63–65], derived from a study estimating the average lifetime average costs of probable avoided restoration per person [66]. Two other studies used various WTP thresholds using proposed dental outcomes [48, 60]. The WTP threshold of AU$50,000 per DALY averted [67, 68], £20,000 per QALY gained [40, 58], and the 2014 US gross domestic gross product

Table 2 The categories of preventive interventions that were economically evaluated for dental caries and periodontitis

Preventive intervention description	Number of economic evaluations $N = 100$ (%)		Target oral disease	Economic evaluation outcome	Overall quality of studies*
Universal interventions (N = 28)					
20% sugar-sweetened beverages tax vs. no intervention [86, 87]	2	(2%)	Dental caries	Cost-effective or Cost-saving	Good
Bacterial screening saliva testing vs. standard care [91]	1	(1%)	Dental caries	N/S	Moderate
Ban on sugar-sweetened beverages sales vs. no intervention [88]	1	(1%)	Dental caries	Cost-saving	Good
Fluoridation of toothpastes vs. no intervention [83]	1	(1%)	Dental caries	Cost-saving	Moderate
Front-of-package food labelling vs. no intervention [89]	1	(1%)	Dental caries	Cost-effective	Good
Increasing the use of chewing gum vs. no intervention [90]	1	(1%)	Dental caries	Cost-saving	Good
Interleukin-1 genetic testing vs. standard care [53]	1	(1%)	Periodontitis	N/S	Good
Milk fluoridation vs. no intervention [81, 82, 85]	3	(2%)	Dental caries	Cost-effective	Good
Salt fluoridation vs. no intervention [80, 85]	2	(2%)	Dental caries	Cost-effective	Good
Water fluoridation vs. no intervention [55, 67, 68, 70–79, 84, 85]	15	(12%)	Dental caries and periodontitis[#]	Cost-effective or Cost-saving	Moderate
Selective interventions (N = 29)					
Targeted postage of oral hygiene products vs. no intervention [95]	1	(3%)	Dental caries	N/S	Low
Targeted pre/primary school-based dental check-up vs. standard care [94]	1	(3%)	Dental caries	Cost-effective	Good
Targeted pre/primary school-based fluoride varnish by dental/non-dental primary care providers with/without dental screening [44, 54, 61, 96]			Dental caries		
vs. counselling [44]	2	(7%)		Not cost-effective or N/S	Good
vs. no intervention [54, 61]	2	(7%)		Cost-effective or N/S	Moderate
vs. standard care [96]	1	(3%)		Cost-effective	Moderate
Targeted primary school-based fissure sealant program with/without fluoride mouthrinse (intervention)			Dental caries		
vs. no intervention [59, 84, 85, 97, 98]	5	(17%)		Cost-effective or Cost-saving or N/S	Moderate
vs. standard care [69, 99, 100]	4	(14%)		Cost-effective or N/S	Good
vs. targeted school-based toothbrushing program [42]	1	(3%)		N/S	Good
Targeted primary school-based fissure sealant program (comparator)			Dental caries		
All seal vs. risk-based [98, 101]	2	(7%)		N/S	Moderate
No intervention vs. risk-based [98, 101]	2	(7%)		Not cost-effective	Moderate
Targeted primary school-based fluoride gel vs. no intervention [85]	1	(3%)	Dental caries	N/S	Good
Targeted primary school-based fluoride mouth rinse vs. no intervention [85]	1	(3%)	Dental caries	Cost-effective	Good
Targeted supervised toothbrushing program vs. no intervention [42, 54, 85]	2	(7%)	Dental caries	N/S	Moderate
Targeted telehealth or home visit oral health education vs. standard care [57, 84, 93]	3	(10%)	Dental caries	Cost-saving or Cost-effective	Moderate
Targeted community-based group oral health education vs. chairside oral health education [92]	1	(3%)	Periodontitis	Cost-saving	Good
Indicated interventions (N = 42)					
Artificial intelligence for intra-oral radiographic detection of dental caries vs. no intervention [49]	1	(2%)	Dental caries	Cost-effective	Good
Oral prophylaxis and oral health education vs. fissure sealant and fluoride varnish [103]	1	(2%)	Dental caries	Not cost-effective	Moderate

Table 2 (continued)

Preventive intervention description	Number of economic evaluations $N = 100$ (%)		Target oral disease	Economic evaluation outcome	Overall quality of studies*
Fluoride and xylitol supplement, oral prophylaxis and fluoride/chlorhexidine varnish vs. standard care [60, 107]	2	(5%)	Dental caries	N/S	Good
Fissure sealant vs. no intervention [41, 45–47]	5	(12%)	Dental caries	N/S	Moderate
Fluoride varnish vs. fissure sealant [40, 41]	2	(5%)	Dental caries	Cost-effective or Not cost-effective	Moderate
Fluoride varnish vs. standard care [48, 52, 62, 105, 106, 112]	6	(14%)	Dental caries	N/S	Good
Minimally invasive dentistry (intervention)			Dental caries		
vs. no intervention [104]	1	(2%)		N/S	Good
vs. standard care [63–65, 104, 105]	5	(12%)		Not cost-effective or N/S	Good
Standard care vs. minimally invasive dentistry [104]	1	(2%)	Dental caries	Not cost-effective	Good
Slow releasing fluoride glass devices program [84]	1	(2%)	Dental caries	Cost-saving	Low
Resin infiltration vs. fluoride varnish and/or oral health education [50]	1	(2%)	Dental caries	N/S	Moderate
Varied intervals of dental check-ups e.g., 3-, 9-, 12-, 24-, 36-monthly, risk-based			Dental caries		
vs. standard care [58, 111]	7	(17%)		N/S	Good
24-monthly vs. risk-based [58]	1	(2%)		Cost-effective	Good
Regular supportive periodontal therapy			Periodontitis		
vs. irregular supportive periodontal therapy [109, 110]	2	(5%)		N/S	Moderate
vs. tooth removal and implant crown replacement [110]	1	(2%)		N/S	Good
Supportive periodontal therapy by dental specialist vs. general dental practitioner [108]	1	(2%)	Periodontitis	N/S	Good
Varied intervals of supportive periodontal therapy and standard oral health education (e.g., 12-monthly)			Periodontitis		
vs. standard care [102]	1	(2%)		Cost-saving	Good
Varied intervals of supportive periodontal therapy and tailored oral health education (e.g., 6-monthly, 12-monthly, risk-based)			Periodontitis		
6-monthly vs. standard care [102]	1	(2%)		N/S	Good
12-monthly vs. standard care [102]	1	(2%)		N/S	Good
Risk-based vs. standard care [102]	1	(2%)		N/S	Good

N = total number of economic evaluations, *N/S* not stated, *Standard care* refers to treatment as usual with 6-monthly dental check-ups

#Only one study on water fluoridation economically evaluated dental caries and periodontitis [70]

*Overall quality of studies using the Gonzalez-Perez (2002) criteria [38] for the Drummond 10-point checklist [34]

per capital (US$54,639 per DALY averted) [69] were used for CUA studies in Australia, the UK and the USA, respectively.

3.4 Universal Interventions

The majority of universal interventions were reported to be cost-effective or cost-saving. These universal interventions included various forms of topical fluorides [55, 67, 68, 70–85], interventions targeting the reduction of sugar consumption such as SSBs taxation or ban on selling SSBs at the workplace [86–89], increasing use of chewing sugar-free gum [90], and bacterial screening saliva test for virulent levels of mutans streptococci [91]. For interleukin-1 genetic screening to prevent periodontitis for persons aged 35 years, the ICER was calculated but the cost-effectiveness was not stated [53].

3.5 Selective Interventions

For selective interventions, targeted community-based group oral health education for adults [92], targeted primary school-based fluoride mouth-rinse program [85], targeted telehealth or home visit oral health education for young children [57,

Table 3 A summary of characteristics for model-based and trial-based economic evaluation studies

Characteristics	Model-based Economic evaluations $N = 61^*$ (%)	
Economic evaluation approach		
CBA [55, 70, 72, 74–78, 83, 84, 86–88, 90, 91, 123, 124]	17	(28%)
CEA [41–47, 49, 59, 61–65, 73, 79–82, 85, 93, 95, 96, 98, 100, 101, 105, 108, 109]	30	(49%)
CUA [53, 54, 57, 67–69]	6	(10%)
CBA and CEA [50, 71, 89, 99, 111]	5	(8%)
CEA and CUA [40, 52]	2	(3%)
Perspective		
Healthcare [41, 43, 45–47, 49, 50, 52–54, 59, 61–65, 84, 85, 87, 90, 91, 101, 109–111, 123, 124]	27	(44%)
Societal [42, 44, 55, 57, 67–83, 86, 89, 93, 95, 96, 98–100, 108]	30	(49%)
Healthcare and societal [40, 88, 105]	3	(5%)
Reference year		
N/R [54, 75, 84, 91, 95, 96, 123]	7	(11%)
< 2000 [53, 74, 78, 79, 82, 98, 99]	7	(11%)
2000–2005 [43, 45, 46, 67, 68, 70, 77, 81, 83, 101, 111]	11	(18%)
2006–2010 [64, 65, 80, 85, 100, 108]	6	(10%)
2011–2015 [40–42, 44, 47, 49, 50, 52, 55, 57, 63, 69, 72, 73, 76, 87, 90, 93, 105, 109, 110]	21	(34%)
2016–2020 [59, 61, 62, 71, 86, 88, 89, 124]	8	(13%)
Time horizon		
N/R [73]	1	(2%)
< 5 years [125]	14	(23%)
5–10 years [40, 41, 45, 47, 57, 59, 63, 75, 80, 81, 83, 85, 87, 89, 93, 96, 98–101, 123]	21	(34%)
> 10 years [49, 50, 52, 53, 55, 62, 67, 68, 70, 71, 74, 76, 77, 79, 86, 90, 108–110]	19	(31%)
Mixed (< 5 and 5–10 years) [124]	1	(2%)
Mixed (< 5 and > 10 years) [63, 64]	2	(3%)
Mixed (5–10 and > 10 years) [88, 111]	2	(3%)
Cost categories—healthcare and societal perspective[#]		
Direct treatment costs—N/R [41, 44, 95]	3	(5%)
Direct treatment costs—restorations only [42, 61, 67–69, 72–75, 78, 79, 83, 87, 89, 98–101, 105, 111]	20	(33%)
Direct treatment costs—restorations and extractions only [40, 47, 59, 71, 76, 80–82, 85]	9	(15%)
Direct treatment costs—restorations, extractions and other direct costs for dental caries [43, 45, 46, 49, 50, 52, 54, 55, 57, 62–65, 77, 84, 86, 90, 91, 93, 96, 123, 124]	22	(36%)
Direct treatment costs—restorations, extractions and other direct costs for dental caries and periodontitis [70, 88, 110]	3	(5%)
Direct treatment costs for periodontitis only [53, 108, 109]	3	(5%)
Cost categories—societal perspective		
Direct societal costs—N/R [87]	1	(2%)
Direct societal costs (intervention only) [42, 55, 67, 68, 71, 72, 75, 76, 78, 79, 83, 86, 89, 95, 96, 99]	15	(25%)
Direct and indirect societal costs (productivity costs lost, travel costs, etc.) [40, 44, 57, 69, 70, 73, 74, 77, 80–82, 85, 88, 93, 98, 100, 105, 108]	17	(28%)
Dental outcomes measures		
Decayed teeth surfaces/teeth averted (ds/DS)^ [41, 42, 50, 57, 70, 76–79, 89, 91, 93, 96, 98]	13	(21%)
Decayed, missing and filled teeth surfaces/teeth averted (dmfs/DMFT, dmft/DMFT) [52, 55, 62, 64, 65, 71–75, 80–85, 87, 90, 95, 99, 105, 111, 124]	23	(38%)
Caries free (%/months/person) [40, 43, 44, 61, 86, 95, 100, 101]	8	(13%)
Clinical attachment loss averted [108]	1	(2%)
QATY [40, 46, 59]	3	(5%)
Restorative/extraction/episode of pain/hospital/event averted [43, 47, 63, 95, 123]	5	(8%)
Retained-tooth per year [49, 62, 109, 110]	4	(7%)
Tooth loss averted [108]	1	(2%)

Table 3 (continued)

Characteristics	Model-based Economic evaluations $N = 61$* (%)	
Generic health outcome measures		
DALY [67–69]	3	(5%)
QALY [40, 52–55, 57, 88]	7	(11%)
Characteristics	Trial-based economic evaluations $N = 17$* (%)	
Economic evaluation approach		
CBA [102]	1	(6%
CEA [42, 48, 60, 64, 65, 104, 106, 107, 112, 113]	10	(59%)
CMA [92, 103]	2	(12%)
CBA and CEA [97]	1	(6%)
CBA and CUA [58]	1	(6%)
CEA and CUA [40, 94]	2	(12%)
Perspective		
Healthcare [60, 64, 65, 92, 103, 104]	6	(35%)
Societal [40, 58, 102, 106, 112, 113]	6	(35%)
Healthcare and Societal [42, 48, 94, 97, 107]	5	(29%)
Reference year		
< 2000 [103, 107]	2	(12%)
2000–2005 [60, 97]	2	(12%)
2006–2010 [64, 65, 92, 113]	4	(24%)
2011–2015 [40, 42, 94, 102, 106, 112]	6	(35%)
2016–2020 [48, 58, 104]	3	(18%)
Time horizon		
< 5 years [40, 42, 48, 58, 60, 64, 65, 92, 94, 102–104, 106, 112, 113]	15	(88%)
5–10 years [107]	1	(6%)
Mixed (< 5 and 5–10 years) [97]	1	(6%)
Cost categories—healthcare and societal perspective		
Direct treatment costs—N/R [103, 106]	2	(12%)
Direct treatment costs—restorations only [42, 48, 107]	3	(18%)
Direct treatment costs—restorations and extractions only [40]	1	(6%)
Direct treatment costs—restorations, extractions and other direct costs for dental caries [60, 64, 65, 94, 97, 104, 112]	7	(41%)
Direct treatment costs—restorations, extractions and other direct costs for dental caries and periodontitis [58]	1	(6%)
Direct treatment costs for periodontitis only [92, 102, 113]	3	(18%)
Cost categories—societal perspective		
Direct societal costs (intervention only) [42, 48, 97]	3	(18%)
Direct and indirect societal costs (productivity costs lost, travel costs, etc.) [40, 58, 94, 102, 106, 107, 112, 113]	8	(47%)
Dental outcomes measures		
Decayed teeth surfaces/teeth averted (ds/DS)^ [42, 103, 112]	3	(18%)
Decayed, missing and filled teeth surfaces/teeth averted (dmfs/DMFT, dmft/DMFT) [48, 60, 64, 65, 94, 97, 106, 107]	8	(47%)
Caries free (%/months/person) [40, 112]	2	(12%)
Bleeding sites (%) [92, 102]	2	(12%)
QATY [40, 94]	2	(12%)
Restorative/extraction/episode of pain/hospital/event averted [104, 112]	2	(12%)
Successful case managed for periodontitis [113]	1	(6%)
Generic health outcome measures		

Table 3 (continued)

Characteristics	Trial-based economic evaluations *N* = 17* (%)
QALY [40]	1 (12%)
Other outcome measures	
Per 1% card-holder reached [94]	1 (6%)

N total number of studies/interventions, *N/R* not reported, *CBA* cost-benefit analysis, *CMA* cost-minimisation analysis, *CEA* cost-effectiveness analysis, *CUA* cost-utility analysis, *dmfs/DMFS*[+] number of decayed, missing, and filled teeth surfaces for the deciduous or permanent dentition, *dmft/DMFT*[+] number of decayed, missing, and filled teeth for the deciduous or permanent dentition, *ds/DS*[+] number of decayed teeth surfaces for the deciduous or permanent dentition, *dt/DT*[+] number of decayed teeth for the deciduous or permanent dentition, [+] lower-case letters refer to the deciduous dentition and upper-case letters refer to the permanent dentition, *DALY* disability-adjusted life years, *QATY* quality-adjusted tooth years, *QALY* quality-adjusted life years

*Four studies performed model-based and trial-based economic evaluations [40, 42, 64, 65]

[#]Four studies did not report the intervention costs [54, 87, 88, 90]

^Includes dental outcomes exclusively for occlusal or proximal surfaces

84, 93], and targeted pre/primary school-based dental check-up programs [94], were cost-saving or cost-effective.

The cost-effectiveness was not stated for targeted postage of oral hygiene products [95], targeted primary school-based fluoride gel [85], and targeted supervised toothbrushing program [42, 54, 85]. There were mixed cost-effectiveness results for targeted pre/primary school-based fluoride varnish by dental/non-dental primary care providers with/without dental screening [44, 54, 61, 96] and targeted primary school-based fissure sealant program with/without fluoride mouth rinse [42, 59, 69, 84, 85, 97–101]. In the context of targeted primary school-based fissure sealant programs, no intervention versus risk-based (fissure sealant application was based on the patient's dental caries risk) interventions was not cost-effective [98, 101].

Table 4 The quality appraisal results using the Drummond 10-point checklist [34]

Drummond 10-point checklist question	Publication year								
	2000–2010 *N* = 24			2011–2021 *N* = 49			2000–2021 *N* = 73		
	Yes	No	Can't tell	Yes	No	Can't tell	Yes	No	Can't tell
Q1. Was a well-defined question posed in answerable form?	92%	4%	0%	98%	2%	0%	96%	3%	1%
Q2. Was a comprehensive description of the competing alternatives given? (i.e., can you tell who did what to whom, where and how often?)	92%	4%	4%	100%	0%	0%	97%	1%	1%
Q3. Was the effectiveness of the programmes or services established?	96%	0%	4%	100%	0%	0%	99%	0%	1%
Q4. Were all the important and relevant costs and consequences for each alternative identified?	83%	0%	13%	94%	0%	6%	90%	0%	10%
Q5. Were costs and consequences measured accurately in appropriate physical units prior to valuation (e.g., hours of nursing time, number of physician visits, lost work days, gained life-years)?	96%	0%	4%	96%	2%	2%	96%	1%	3%
Q6. Were costs and consequences valued credibly?	96%	0%	0%	86%	4%	10%	89%	3%	7%
Q7. Were costs and consequences adjusted for differential timing?	67%	25%	8%	71%	20%	8%	70%	22%	8%
Q8. Was an incremental analysis of costs and consequences of alternatives performed?	92%	4%	0%	96%	4%	0%	95%	5%	0%
Q9. Was uncertainty in the estimates of costs and consequences adequately characterised?	79%	21%	0%	90%	10%	0%	86%	14%	0%
Q10. Did the presentation and discussion of study results include all issues of concern to users?	58%	38%	4%	82%	16%	2%	74%	23%	3%

N number of studies

3.6 Indicated Interventions

Under indicated interventions, the use of artificial intelligence for the detection of dental caries on dental intra-oral radiographs was cost-effective [49]. Supportive periodontal therapy and standard oral health education provided 12-monthly versus 6-monthly [102], and the use of slow-releasing fluoride glass devices (glass ionomer cements) for children at high risk for dental caries risk [84] were cost-saving. The economic evaluation outcomes were variable for the remaining studies, either cost-effective, not cost-effective or not stated [40, 41, 45–48, 50, 52, 58, 62–65, 92, 98, 100–113]. Oral prophylaxis and oral hygiene education versus fissure sealant and fluoride varnish application was not cost-saving according to the CMA [103], and standard care versus minimally invasive dentistry was not cost-effective [104].

3.7 Quality Appraisal

The results of the quality appraisal using the Drummond 10-point checklist are reported in Table 4 regarding the sub-questions and Cohen's Kappa values. The study quality according to model-based and trial-based studies is shown in Table 5. Generally, the study quality for economic evaluations improved for studies published after 2010. For all 73 studies, some criteria of the Drummond 10-point checklist were not met, including 30% of studies not applying an appropriate discount rate (question 7) when the time horizon is greater than 1 year and 26% of the studies did not comprehensively discuss other important considerations beyond the technical analysis (question 10). Most model-based (72%) and trial-based studies (82%) were of good quality. In terms of quality appraisal assessment consistency, there was poor inter-rater agreement using the Drummond 10-point checklist (TMN/UT Overall Cohen's kappa: 0.164; TMN/LL Overall Cohen's kappa: 0.148; individual question Cohen's Kappa scores is reported in OSM Appendix 4).

Table 5 A summary of the study quality using the Gonzalez-Perez [38] criteria for the Drummond 10-point checklist for model-based and trial-based studies [34]

Study quality	Model-based studies $N = 61$		Trial-based studies $N = 17$	
Good	44	(72%)	14	(82%)
Moderate	14	(23%)	3	(18%)
Poor	3	(5%)	–	

N number of studies

4 Discussion

This study found that there was a significant number of peer-reviewed publications on the economic evaluation of preventive interventions for dental caries, but there were limited publications on economic evaluation for periodontitis. Most of the studies (90%) were conducted in high-income countries. The choice in the selection of parameters used for economic evaluation was variable throughout the studies, including the time horizon, cost categories, and the chosen dental and health outcome measure(s). In general, universal interventions such as water fluoridation were cost-effective and cost-saving. Selective interventions were either cost-effective or more costly and more effective, and indicated interventions had mixed cost-effectiveness.

Generally, the studies included in the review were demonstrated to be of moderate or good quality. There was generally poor inter-rater reliability using the Drummond 10-point checklist, but this is likely to be influenced by the assessor's interpretation of the question rather than the quality appraisal instrument itself [35]. Two of the three assessors had previous experience using the Drummond 10-point checklist, and two of three assessors have a background in dentistry. The poor level of inter-rater agreement highlights the importance of using at least two assessors, which may have influenced the quality appraisal of each study in either direction.

Our updated review noted there was a diversity of dental and generic health outcomes used in the studies included in this review and identified that there was sparse evidence for cost-effective interventions to prevent periodontitis [29, 114–116], which is a consistent finding from previous reviews [23–29]. Different outcome measures do not allow comparison between interventions or diseases to guide resource allocation. Our review found very few economic evaluations were conducted in low- and low-middle-income countries. Although quantitative outcome measures that capture health equity were not specifically investigated in our review, we found one study [94, 117] that incorporated it in their analysis. The issue of health equity is missing from previous reviews.

4.1 Interpretation and Implication of Outcome Measures

The use of dental outcome measures for economic evaluation has considerable limitations. For example, some authors compared preventive interventions using dental outcomes exclusively for occlusal or proximal surfaces [41, 48, 50, 98, 103], and described them as cavities [42, 96] or caries lesions [49, 57, 86, 89]. There were many studies that used the term caries increment with dental outcomes reported as either ds/DS, dt/DT, dmfs/DMFS and dmft/DMFT [43, 44, 48, 62, 64, 68, 71, 74–76, 85, 86, 89, 98, 105–107]. The nuance of terminology in dentistry to describe dental caries as numbers of tooth surfaces or teeth is distinct, as opposed to dental caries incidence in epidemiology, where an individual develops at least one tooth with dental caries. These measurement differences have implications for intervention comparability. With regards to periodontitis, there were variations in using tooth-specific or individual person measures such as retained-tooth per year, percentage of bleeding sites, and successful case managed.

In addition, the dmfs/DMFS and dmft/DMFT are only composite measures for dental caries since decayed teeth (d/D) is only one component of these indices [118]. Despite the limitations of both indices, the dmft/DMFT index is incorporated in the methodology used by the 2017 Global Burden of Disease study to calculate dental caries incidence given it is the most widely used instrument to measure for dental caries experience [1]. In brief, based on longitudinal studies, the population incremental difference in the dmft/DMFT index for the initial and subsequent dental check-up is accepted as the number of dental caries incidence. These differences in outcomes are a limitation in quantifying the true measure of dental caries incidence. Adding to the complexity, many studies using CEA approaches could not be assessed for cost-effectiveness due to an absent WTP threshold using dental outcomes. This makes it difficult to interpret the cost effectiveness credentials of interventions that have been economically assessed using CEA frameworks. However, if studies use the same outcome measures, then their cost-effectiveness ratios can be compared.

Regarding CUA studies, there are important differences in using general health outcome measures such as DALY and QALY, whereby their results need to be interpreted with caution. This means that preventive interventions for dental caries and periodontitis cannot be directly compared or ranked against each other, nor can they be compared with other health interventions for appraisal and make health policy investment decisions. To date, there is still ongoing research to validate the use of quality-of-life survey instruments for children with dental caries, although the CHU-9D and the EQ-5D-Y instruments show promise, but these have not been tested for face validity [119]. The application of quality-of-life survey instruments for adults have had more extensive research generally [120], but they have not been widely applied in economic evaluations for preventive interventions for dental caries and periodontitis. To date, research using QALY has shown they is not sensitive to oral diseases [125], but since DALY is independent of quality-of-life survey instruments. It may be the only outcome now that can directly allow comparisons between other health interventions.

4.2 Cost-Effectiveness Analysis Methods

There were concerns regarding how the benefits were defined for CEA studies. For example, three studies (model-based and trial-based studies) performed an economic evaluation for the cost-effectiveness of fissure sealants and fluoride varnish [40, 41], or fissure sealant and a school-based toothbrushing program [42]. In this context, fissure sealants have a clinical benefit for the occlusal surfaces of posterior molar teeth, where they are applied, whereas the clinical benefit of fluoride varnish and regular toothbrushing with fluoride toothpaste can have a spill-over benefit to other surfaces and numbers of teeth for an individual. i.e., the clinical effectiveness of each strategy was not fully incorporated and consistent.

Other studies used effectiveness data based on older studies (>20 years ago), perhaps as no recent studies were applicable [43, 44]. Other model-based studies have made assumptions for the consequences of an intervention using panel datasets of dental services, such as for the effectiveness of fissure sealants [45–47], which may or may not have a preventive effect as smooth surfaces of teeth are not protected by the fissure sealant. Similarly, three studies (model-based and trial-based studies) investigated the cost-effectiveness of fluoride varnish interventions against standard care, where the effectiveness was evaluated for surfaces in between teeth (proximal) and not smooth surfaces [48–50]. These methodological issues on effectiveness indicate potential bias and limitation of the results.

4.3 Strengths and Limitations

One of the key strengths of the present systematic review is the breadth of the study, which includes populations of all age groups and periodontitis as one of the target oral diseases. We articulated an intervention framework to classify prevention interventions for dental caries and periodontitis according to the existing classifications for the oral disease severity. i.e., the Intervention Classification Framework for Dental Caries and Periodontitis. The framework can be useful for future systematic reviews of economic evaluations in oral health and dentistry. Given most model-based and trial-based studies were of moderate or good quality, the decision to not exclude lower quality studies is unlikely to influence the results. Method 1 from the Gonzalez-Perez (2002) study quality criteria [38] was used in preference to Methods 2 and 3 given the Drummond 10-point checklist does not include the 11th criteria question 'Is the paper relevant for the NHS and are the results sufficiently transparent for them to be replicated in an NHS setting?'

Our review expands on previous reviews by clearly articulating whether the prevention interventions were cost-effective and discussed in detail the interpretation and limitation of dental and generic health outcomes. Although dental caries is highly prevalent, their burden of disease measured by YLDs is considerably less than for periodontitis and signifies the importance for prevention efforts needed beyond dental caries.

We are aware that some publications excluded at the full-text screening stage were of partial economic evaluations, such as the 20% sugar-sweetened beverages tax intervention [121, 122], which could be informative in the present analysis. Our review may be biased since it was restricted to publications after 2000 (inclusive), papers had to be reported in English, a limited search of databases for relevant grey literature was conducted, and relevant full-text may be excluded given the lower inter-rater reliability value of 'fair to good' agreement according to the Cohen's Kappa assessment. It is apparent that many of the studies included in our review referred to dental caries using other descriptions such as cavities and caries lesions, which could potentially result in relevant publications being excluded from our systematic review search strategy. These concerns were not observed for economic evaluations of preventive interventions for periodontitis. Finally, it is important to consider how the economic evaluation studies were validated. We did not explicitly review this as part of the a priori review protocol, and, therefore, this is essential to capture and discuss in future reviews in the field according to the ISPOR-SMDM Modeling Good Research Practices Taskforce [126].

4.4 Recommendations

We recommend three key essential considerations for future research, which can accelerate oral health policy investment: (1) use generic health outcomes to facilitate the assessment for cost-effectiveness, (2) conduct economic evaluation research to prevent periodontitis, and (3) make considerations for health equity.

5 Conclusion

Universal interventions, in particular water fluoridation, were generally demonstrated to be cost-effective, while the cost-effectiveness for selective and indicated interventions were mixed. Other universal interventions that had at least more than one study demonstrating cost-effectiveness include taxation on sugar-sweetened beverages, milk and salt fluoridation. The disparate selection of the cost components, the consequences, and the choice for measuring health outcomes, meant that it was difficult to make investment decisions for preventive interventions for dental caries and periodontitis. We propose future research on economic evaluation for the oral health context using generic health outcome measures to determine cost-effectiveness outcomes. In addition, there is an increasing need to conduct research on the cost-effectiveness of preventive interventions related to periodontitis and to reflect on health equity considerations. These recommendations will enable comparability with mainstream economic evaluations of health interventions to inform policy decision making.

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Declarations

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RESEARCH ARTICLE

Modeled health economic and equity impact on dental caries and health outcomes from a 20% sugar sweetened beverages tax in Australia

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Abstract

Dental caries is the most prevalent oral disease across the life course. This study modeled the population health and economic impact of a 20% sugar sweetened beverages tax (SSB) for preventing dental caries compared to no intervention (societal and healthcare perspective). A cost-effectiveness analysis according to quintiles of area-level socioeconomic disadvantage was performed for the 2020 Australian population (0–100 years old) using a closed cohort Markov model. A qualitative assessment of implementation considerations (e.g., acceptability, equity, sustainability) was undertaken. Health outcomes were modeled as decayed teeth prevented and disability-adjusted life years (DALYs) averted. The 10-year and lifetime scenarios were modeled with probabilistic sensitivity analysis (Monte Carlo simulation, 2000 cycles). The 10-year scenario from a societal perspective yielded cost-savings of AUD\$63.5M, healthcare cost-savings of AUD\$42.2M, 510,977 decayed teeth averted and 98.1 DALYs averted. The lifetime scenario resulted in societal cost savings of AUD\$176.6M, healthcare cost-savings of AUD\$122.5M, 1,309,211 decayed teeth averted and 254.9 DALYs averted. Modeling indicated 71.5% and 74.5% cost-effectiveness for the 10-year and lifetime scenarios, respectively. A three-fold health benefit for the least advantaged was found compared to the most advantaged. A 20% SSB tax in Australia is cost-effective and promotes health equity.

KEYWORDS
cost-effectiveness analysis, dental caries, economic evaluation, public policy, sugar sweetened beverages, taxes

1 | INTRODUCTION

Dental caries is responsible for 70% of all tooth loss (Ling & Tao, 2016) and is the most prevalent oral disease affecting 29.5% of global population (GBD 2017 Oral Disorders Collaborators et al., 2020). Excessive tooth loss affects masticatory efficiency and can lead to less healthy food choices and impacts general health and wellbeing (Cascaes et al., 2022; Zelig et al., 2019). Excess free sugars is the primary cause of dental caries (Sheiham & James, 2015). Free sugars include all monosaccharides and disaccharides added to foods and those naturally present in honey, syrups, fruit juices and fruit juice concentrates; it excludes those naturally present in liquid milk, milk products, in whole fruits, vegetables and grains (Moynihan, 2016; Moynihan et al., 2018).

The World Health Organization's (WHO's) guideline on intake of sugars recommends free sugars should not exceed 10% of the total daily energy intake per day in order to prevent overweight/obesity and dental caries in both children, adolescents and adults (Moores et al., 2022; Moynihan, 2016). A further reduction of sugars intake below 5% of the total daily energy intake would prevent dental caries throughout the life-course (Moores et al., 2022; Moynihan, 2016). More than half of the Australian population exceeds the WHO's 10% threshold for free sugars consumption, especially among children and adolescents (Lei et al., 2016), and about 90% of Australian adults exceed the 5% threshold (Gupta et al., 2018).

In Australia, 35% of the total daily energy is consumed from ‘discretionary foods’ with the highest proportion consumed amongst 14–18 year olds (41%) (Boylan et al., 2017). Sugar-sweetened beverages (SSB) are one of the leading contributors to free sugar intake for most Australians (Australian Institute of Health and Welfare, 2018). A single serve of a SSB (375 mL) has a wide range of sugar content, but contains an average of 39g of free sugars (Food Standards Australia & New Zealand, 2019). As a relative reference, about 27.5g of free sugars per day is the threshold to meet the 5% of energy intake for an adult (Moynihan et al., 2018).

It has been estimated that the impact of free sugars consumption on dental caries was attributable to the loss of approximately 4.1M disability-adjusted life years (DALYs) globally (Meier et al., 2017). A linear-dose relationship between the amount and frequency of sugar intake and incidence of dental caries has been established (Bernabé et al., 2016). Similarly, there is a linear dose-response relationship between SSB consumption and dental caries incidence (Bernabé et al., 2014). The case to reduce the consumption of free sugars in order to reduce the burden of dental caries based on epidemiological evidence is compelling (Meyer & Lee, 2015; Sheiham & James, 2015).

Sugar-sweetened beverages taxes can increase prices, leading to a decrease in the purchase of SSB. Sugar-sweetened beverages taxes have been implemented in over 50 countries, and real-world evaluations have demonstrated effectiveness in reducing SSB purchases and consumption (Teng et al., 2019). For example, two volumetric SSB tax policies have resulted in a reduction in SSB sales in the Seattle, USA (Powell & Leider, 2021) and Mexico (Sánchez-Romero et al., 2020). Thus, a tax on SSB consumption is a practical strategy for reducing free sugar consumption in the Australian context (Dry & Baker, 2021). Evidence indicates that a SSB tax can reduce consumption of unhealthy products if the tax results in price increases of 20% or more (Wright et al., 2017).

Despite the successful implementation of SSB taxation internationally, there remains political barriers for its implementation in Australia (Allen & Allen, 2020). Previous Australian simulation modeling studies have shown interventions that reduce SSB consumption, such as a SSB tax, has varied impact on SSB consumption, body weight and tax burden by different household income groups (Sharma et al., 2014) and obesity-related diseases (Lal et al., 2017, 2020). The cost-effectiveness analysis (CEA) of a 20% SSB tax for the prevention of obesity in Australia across socioeconomic groups, found greater health benefits for more disadvantaged quintiles and healthcare cost savings of $1733 million over the population's lifetime (Lal et al., 2017).

An Australian population-level study that modeled the impact of a 20% tax on dental caries reported 3.89 million units of decayed, missing and filled teeth (DMFT) could be prevented, and AUD$666M in cost-savings over 10 years (Sowa et al., 2019). However, studies have reported limited details on the model validation process, and more importantly, they did not include the cost associated with the implementation of a SSB tax on dental caries outcomes (Briggs et al., 2017; Jevdjevic et al., 2019; Schwendicke et al., 2016; Sowa et al., 2019).

The aim of this study is to perform a CEA for the implementation of a 20% SSB tax across socioeconomic groups, and to explore other considerations important to policy-decision makers for intervention implementation. The 20% SSB valoric tax (flat sales tax) was selected as the intervention because of its greater ease of implementation in Australia compared with the alternative 20 cents/liter volumetric tax (Sharma et al., 2014).

This work is guided by a Project Steering Group (PSG) (refer to Acknowledgments) as part of a broader priority-setting study called the Assessing Cost-Effectiveness of Oral Health Preventive Interventions (ACE-Oral Health Prevention). Assessing Cost-Effectiveness methods were developed in Australia to inform resource allocation in a range of health areas (Carter et al., 2008). The 20% SSB tax intervention was selected as one of six interventions for modeling by the PSG. The PSG includes academics, dental practitioners, consumers, health professional association and policy-decision maker representatives.

2 | METHODS

2.1 | Effect of the 20% sugar-sweetened beverages tax on volume consumption

The model logic pathway of how the 20% SSB tax intervention impacts dental caries outcomes and DALYs is representation in Appendix 1 (Supplementary File). The 20% SSB tax was compared to the no intervention scenario. The model logic shows that the intervention increases SSB prices, which impacts on consumers to decrease SSB purchases. The amount of SSB purchase reduction results in reduced sugar intake and translates to preventing dental caries incidence and DALYs averted.

The current amount of sugar intake from SSB consumption was estimated using updated data from the Australian Health Survey 2017-18 (Australian Bureau of Statistics, 2018) for males and females aged: 2–4, 5–9, 10–14, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50-44, 55–59, 60–64, and 65+ years. This dataset included the average cups of SSB consumption per week and the proportion of the population who were SSB consumers for each Index of Relative Socio-economic Disadvantage (IRSD) quintile. Sugar-sweetened beverages included sugar sweetened soft drinks, cordials, sports drinks and energy drinks but excluded fruit juice (Australian Bureau of Statistics, 2018). Since no data is available regarding SSB consumption for the 0–1 year age cohort, an assumption of no impact on SSB consumption was made until the cohort reached age 2 years. Sugar content of one cup of SSB was derived from the Australian Food, Supplement and Nutrient Database (Food Standards Australia and New Zealand, 2016).

The total net reduction in SSB consumption based on the Australian study on own- and cross-price elasticities for implementing the 20% SSB tax is 11.52% (SD 9.62) (Sharma et al., 2014).

2.2 | Modeling approach

The CEA for implementing a 20% sugar tax on dental caries outcomes was modeled from a societal and healthcare perspective. Modeling was performed for the 2020 Australian population according to the IRSD quintiles. The IRSD is an area-level of socioeconomic disadvantage index used in Australia, which reflects a range of information on socioeconomic status, such as income, level of qualification and skill occupations (Australian Bureau of Statistics, 2017). Quintile one is the most socioeconomic disadvantaged group. Each IRSD quintile and the total population were modeled separately using the Markov model decision tree structure shown in Appendix 1 (Supplementary File). For this study, an assumption was made that people do not move between the IRSD quintiles within the time horizon of the evaluation.

Figure 1 shows the relationship between the four health states. Each age cohort enter the health state based its prevalence to simulate the real-world scenario. They either have no caries (i.e., caries free), have dental caries, or have complete tooth loss (edentulism), with the exception for the dead health state due to background mortality as the absorbing state. Toothache due to dental caries was not considered as a separate health state due to its short duration. A summary of the model key parameter inputs is shown in Table 1.

2.3 | Population

The 2020 Australian population was modeled using single age cohorts for 0–100 years old (Australian Bureau of Statistics, 2022b). Background mortality for Australia reported by the 2019 GBD was incorporated (Institute for Health Metrics

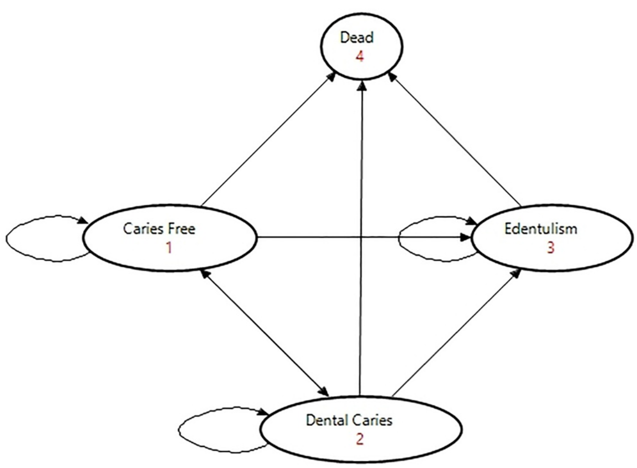

FIGURE 1 The health state transition diagram visualizing the relationship between the four health states for dental caries.

TABLE 1 Description of key parameter inputs according to the quintile subgroups with the 95% uncertainty intervals (UI).

Data inputs	Quintile 1 (95%UI)	Quintile 2 (95%UI)	Quintile 3 (95%UI)	Quintile 4 (95%UI)	Quintile 5 (95%UI)	Total population (95%UI)
Target population[a]	Australian population 2020, aged 0–100 years					
Proportion of SSB intake by population (%)[b]	44.7 (42.6; 46.8)	41.2 (38.8; 43.6)	38.3 (36.1; 40.5)	34.2 (31.8; 36.6)	29.0 (26.6; 31.4)	37.2 (36.2; 38.2)
Mean daily SSB consumption (cups)[b]	1.41 (1.25; 1.57)	1.18 (1.07; 1.30)	0.94 (0.84; 1.05)	1.02 (0.87; 1.16)	0.72 (0.63; 0.81)	1.07 (1.02; 1.13)
Intervention effectiveness decay	Intervention effectiveness applied at 100% for all cycles					
Type of model used	Closed cohort Markov model					
Costs included	Patient travel costs, time costs for travel and dental treatment, dental examination, restorations, full upper and lower dentures, and replacing dentures					
Intervention costs (AUD$)[c]	First year - 5.8M (SD 0.679) Subsequent years - 4.47M (SD 0.679)					

Note: Detailed model parameter inputs are presented in Appendix 2 and 3 (Supplementary File).

Abbreviations: AUD$, 2020 Australian dollars; SD, standard deviation; UI, uncertainty interval.

[a]Data from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2022b).

[b]Data from the 2017–2018 National Health Survey (Australian Bureau of Statistic, 2018).

[c]Data from an Australian modeled study (Lal et al., 2017).

and Evaluation, 2021) based on age and sex. Modeling was performed using TreeAge Pro 2022 with one-year cycle lengths (TreeAge Software, LLC.).

2.4 | Time horizon

The time horizons were 10-year and lifetime (100 years) to enable comparability to the previous Australian studies (Lal et al., 2017; Sowa et al., 2019).

2.5 | Epidemiology of dental caries

Dental caries incidence and edentulism (complete tooth loss) for each age cohort was derived from the 2019 GBD study datasets (Institute for Health Metrics and Evaluation, 2021) (Appendix 2; Supplementary File), which is derived from changes in DMFT. Decayed, missing and filled teeth is a cumulative measure of dental caries experience (Lewis, 1996). It is defined as the number of teeth affected by dental caries, tooth decay, previously extracted or filled (restored) due to tooth decay, in an individual.

Edentulism was incorporated in the model to exclude persons who are no longer susceptible to dental caries. For children aged 6–14 years, dental caries incidence incorporated the probability of cohort specific mixed dentition (Nelson & Wheeler, 2020). Each new case of dental caries had dental caries severity having a mean number of 1.64 (SD 1.262) decayed teeth (Hummel et al., 2019).

2.6 | Health benefit modeling

The established linear relationship between sugar consumption and DMFT among adults has been reported to be 0.010 (SD 0.028) per 10g of sugar per day during an 11-year prospective study (Bernabé et al., 2016) which were used by previous studies (Briggs et al., 2017; Jevdjevic et al., 2019; Schwendicke et al., 2016; Sowa et al., 2019). This was used to estimate the impact of reduced SSB consumption on DMFT for deciduous (primary) and permanent teeth with conversion into one-year probabilities by using the in-built Treeage Pro 2022 software function. The ΔDMFT is equivalent to a reduction in dental caries incidence (GBD 2019 Diseases and Injuries Collaborators, 2020). that is, the ΔDMFT of 0.10 is the equivalent of a reduction in dental caries incidence by 10%.

2.7 | Estimating disability-adjusted life years

The disability weights for symptomatic dental caries (0.010; SD 0.004) and edentulism (0.067; SD 0.008) from the 2019 GBD study was used (GBD 2019 Diseases and Injuries Collaborators, 2020). Disability-adjusted life years were estimated using similar methods from the 2019 GBD. For dental caries, the symptoms were characterized by two phases of toothache: (1) the 'initial phase' where there is intermittent pain occurring at an average of 1 hour per day, and the 'terminal phase' where individuals experience constant pain before receiving dental treatment. The duration of symptoms for dental caries was estimated to be 28 days for children aged 2–16 (Mason et al., 1997), and 55 days for individuals 17 years and older (Whyman et al., 1996). The disability weight for edentulism was constantly applied.

2.8 | Costs

2.8.1 | Perspective

The societal perspective includes costs related to the intervention cost of the 20% SSB tax (intervention arm only), other societal costs such as travel costs, and opportunity time cost of travel to complete dental treatment, and healthcare costs. Under the healthcare perspective, the intervention costs were included since it is a critical component of the economic evaluation. All costs were adjusted to 2020 prices (Reserve Bank of Australia, 2021).

2.8.2 | Intervention costs

The costs for passing legislation and implementation of the 20% SSB tax were assumed to be approximately AUD$5.8M (SD 0.679) in the first year and AUD$4.47M (SD 0.679) for the following years with ongoing administration costs, which is the inflated price from a previously published Australian study (Lal et al., 2017).

2.8.3 | Other societal costs

The opportunity costs of time taken off work to travel and attend dental appointments for dental treatment were calculated to be AUD$49.22 per hour based on the mean weighted costs of paid and unpaid adult hourly rate, and average weekly earnings (Australian Bureau of Statistics, 2021, 2022a, 2022c). The time required to travel with return trip and its translation to opportunity costs lost were estimated to be 60 min (Curtis et al., 2007). The total time taken to treat dental caries was estimated to a one visit 60-min appointment, which included a dental check-up and restorations. For patients with edentulism, it was assumed that to make a full upper and lower removable denture, it would require three appointments totaling 60 min (visit 1: dental check-up and impressions, visit 2: try-in and fabrication, visit 3: fitting of a pair of removable full upper and lower dentures). The patient time costs were assumed to be the same for adults as for one parent/guardian who accompanied the child for dental treatment, and patient time costs for children due to no data source available.

The travel costs to and from a dental clinic for one dental appointment were estimated to be AUD$20.71 (Vos et al., 2010).

2.8.4 | Healthcare costs

All patients experiencing toothache were assumed to have dental caries restored (Do & Spencer, 2016; The Australian Research Centre for Population, 2019), and return to the caries free health state. For the remainder of the population, individuals who reported to have visited a dental practitioner in the last 12 months was assumed to have dental caries restored for both intervention and no intervention arms (Do & Spencer, 2016; Harford & Luzzi, 2013; The Australian Research Centre for Population, 2019).

Treatment costs were estimated from the Australian healthcare perspective (both provider and patient), with different costs incurred since 85% of dental care is assumed to be provided in private practice (Tennant & Kruger, 2014). Fees at private dental clinics were estimated from the average fees paid by private health insurers (Private Healthcare Australia, 2021) and the public sector costs were based on the federal government fee schedule (Department of Veterans' Affairs, 2020).

Using the above price schedules, the Australian Dental Associations' (ADA) coding and description of dental services (The Australian Dental Association, 2022) was used as a reference to identify the mean healthcare costs. The weighted average costs for restorations included a dental check-up costing AUD$54.69 (SD 3.19) (item code 013, 012, and 011), the cost for posterior restorations AUD$189.61 (SD 17.95) (item code 531, 532 and 533) given that dental caries typically affect posterior teeth). The cost to replace missing teeth due to edentulism was for a pair of removable full upper and lower dentures costing AUD$2798.08 (SD 433.37). Denture replacement was included based on denture survival of 0.41 (SD 0.064) over 10 years, and converted into 1-year probabilities (Taylor et al., 2021).

Patients accrued dental treatment costs for the three health states except for dead. The costs applied to those who developed caries and had toothache, those who developed caries without having toothache and reported a dental attendance in the last 12 months, and those with edentulism who perceived they needed dentures (Harford & Islam, 2013; Harford & Luzzi, 2013; The Australian Research Centre for Population, 2019).

2.9 | Discount rate

A discount rate of 3% was applied for costs and outcomes incurred in year 2 onwards and expressed in 2020 values, consistent with previous Australian model-based studies modeling (Ananthapavan et al., 2020; Lal et al., 2017).

2.10 | Willingness-to-pay threshold

The willingness-to-pay (WTP) threshold of AUD$50,000 per DALY averted was chosen. This value was used by two previous studies (Ciketic et al., 2010; Cobiac & Vos, 2012) identified by the systematic review on economic evaluations of prevention interventions for dental caries and periodontitis (Nguyen et al., 2022).

2.11 | Sensitivity analysis

Probabilistic sensitivity analysis was performed through Monte Carlo simulation with 2000 cycles with within cycle correction. Summary statistics were analyzed using Stata 12 IC (StataCorp). The model parameters and data source used in the Markov model are reported in Appendix 2 and 3 (Supplementary File). Given the intervention effectiveness decay rate is unknown, that is, reduced effectiveness of the intervention over time, a threshold analysis was performed to estimate this minimum value for the intervention to remain cost-effective.

2.12 | Model validation

The CEA Markov model was validated according to The Professional Society for Health Economics and Outcomes Research and Society for Medical Decision Making (ISPOR−SMDM) Modeling Good Research Practices Task Force (Eddy et al., 2012). Face validity was achieved through shared agreement on the model structure by key authors (TMN, UT, AS, LL, HC, CM), and was made transparent for interrogation by the PSG for ACE-Oral Health Prevention. Model verification was made through regular meetings amongst core authors leading the modeling (TMN, UT, AS, LL) to confirm model parameters, including the formula calculations and values for uncertainty analysis. Cross-validation was undertaken by comparing the results with similar studies (Briggs et al., 2017; Jevdjevic et al., 2019; Schwendicke et al., 2016; Sowa et al., 2019). Lastly, dental caries incidence and DALYs accrued from the 2019 GBD study were compared with our Markov model to ensure significant under- or over-estimation did not occur. Predictive validation is not possible given data inputs are unavailable from clinical trials or cohort studies.

2.13 | Implementation considerations

In addition to the technical analysis of the CEA approach, the PSG discussed other implementation considerations that are important to key stakeholders that are enablers and barriers for policy adoption. Criteria for the assessment of implementation considerations is reported in Appendix 4 (Supplementary File). Where relevant, a subjective analysis of the implementation consideration criteria was discussed with an agreed consensus.

3 | RESULTS

The outcomes for no intervention, the 10-year and lifetime scenarios according to each IRSD quintile and total population is presented in Table 2. Undiscounted values are reported in Appendix 5 (Supplementary File).

The 10-year scenario for the total population had societal cost-savings of AUD$63.5M (95%UI 59.4M; 67.6M), healthcare cost-savings of AUD$42.2M (95%UI 38.7M; 45.7M), 510,977 (95% uncertainty intervals (UI) 489,146; 532,808) decayed teeth averted and 98.1 (95%UI 94.3; 101.9) DALYs averted.

Under the lifetime scenario, the modeling yielded societal cost-savings of AUD$176.6M (95%UI 166.2M; 186.6M), healthcare cost-savings of AUD$122.5M (95%UI 113.6M; 131.5M), 1,309,211 (95% UI 1,253,273; 1,365,149) decayed teeth averted and 254.9 (95%UI 245.0; 264.8) DALYs averted.

For both scenarios, the intervention was dominant (cost saving and health promoting). The intervention was cost-effective 71.5% of the time for the 10-year scenario, and 74.8% for the lifetime scenario. Largest benefit was observed for IRSD Quintile 1 (most disadvantaged quintile) followed by IRSD Quintile 2. Index of Relative Socio-economic Disadvantage Quintile 1 had at least a three-fold health benefit compared to IRSD Quintile 5. The results were robust to sensitivity analysis (Refer to cost-effectiveness acceptability curve, Appendix 6; Supplementary File).

The threshold analysis showed that the intervention would not be cost-effective if the intervention effectiveness was smaller than 82.9% per year over 10 years. This is compared to a higher threshold of 91.5% for the lifetime scenario against the WTP threshold.

The implementation considerations rated by the PSG are reported in Table 3. The main findings were that the assessment for acceptability to government and industry was stated to be 'Low'. There was a 'Medium' rating for the strength of evidence and acceptability by the general public criteria. The acceptability by other stakeholders, feasibility and sustainability considerations were rated 'High'. Equity, environmental impact, and other considerations were rated 'Positive' except for some concerns regarding possible product substitution with non-nutritive sweeteners of unknown consequences (Popkin & Ng, 2021) with a rating 'Neutral'.

4 | DISCUSSION

This study estimated impacts of the 20% SSB tax on dental caries of different socioeconomic groups. The overall findings is consistent with the previous studies showing that the policy is likely to be dominant (Ananthapavan et al., 2020; Lal et al., 2017; Sowa et al., 2019). that is, the intervention is cost-saving and health promoting compared to no intervention. Based on more contemporary data on SSB consumption of the Australian population, our model showed there was greater health benefits on dental caries outcomes for groups of higher socioeconomic disadvantage. Our findings corroborate the potential health equity benefits from models that have estimated the obesity-related health impacts of a SSB tax (Ananthapavan et al., 2020; Lal et al., 2017). Regarding the threshold analysis, the intervention can be less effective for the 10-year time horizon for it to remain cost-effective given most of the cost and health benefits accrue earliest 10 years in the lifetime scenario.

Our modeling approach incorporated important enhancements compared to previous studies related to dental caries (Briggs et al., 2017; Jevdjevic et al., 2019; Schwendicke et al., 2016; Sowa et al., 2019), particularly with the adoption of best practice approaches to model validation. We included the intervention cost within the societal perspective, which were absent in previous studies, incorporating the health transition state for edentulism and its associated costs, including the relationship between dental caries incidence cases and dental caries severity, and using DALYs averted as the health outcome measure. The present study estimate for the 10-year scenario showed considerably lower societal cost-savings and less health benefit compared to the previous Australian study (Sowa et al., 2019). It is plausible that the authors overestimated the dental caries reduction impact by using an unadjusted sugar-dose relationship with decayed teeth from the 11-year study (Bernabé et al., 2016), compared to our study, where we converted the data source to an annual probability. In our view, our dental model may be more realistic, and more closely aligns with lower health benefits relative to the population found in other studies (Briggs et al., 2017; Jevdjevic et al., 2019; Schwendicke et al., 2016).

The impact of 254.9 DALYs averted for the lifetime scenario in our dental model is relatively small, largely because there is a low proportion of the Australian population who self-report toothache, the experience of pain is of short duration, and

TABLE 2 The results of the 10-year and lifetime scenarios for the dental caries impact for implementing the 20% sugar-sweetened beverages (SSB) tax according to the quintile subgroups and the total population, with cost and outcomes discounted at 3%.

Results	Quintile 1 (95%UI)	Quintile 2 (95%UI)	Quintile 3 (95%UI)	Quintile 4 (95%UI)	Quintile 5 (95%UI)	Total population (95%UI)
10-Year scenario						
Total societal costs accrued (AUD$)	3.4B (3.3B; 3.4B)	3.4B (3.3B; 3.5B)	3.4B (3.4B; 3.5B)	3.5B (3.4B; 3.5B)	3.5B (3.4B; 3.5B)	16.8B (16.5B; 17.1B)
Total healthcare costs accrued (AUD$)	2.7B (2.6B; 2.8B)	2.7B (2.7B; 2.8B)	2.8B (2.7B; 2.8B)	2.8B (2.7B; 2.8B)	2.8B (2.7B; 2.8B)	13.5B (13.2B; 13.8B)
Total decayed teeth accrued	15.6M (15.3M; 16.0M)	15.8M (15.5M; 16.2M)	16.0M (15.7M; 16.4M)	16.2M (15.8M; 16.5M)	16.0M (15.7M; 16.4M)	79.0M (77.3M; 80.7M)
Total DALYs accrued	213,694 (212,525; 214,863)	209,880 (208,733; 211,028)	202,773 (201,665; 203,881)	196,716 (195,642; 197,791)	200,103 (199,009; 201,196)	1,014,517 (1,008,970; 1,020,063)
Total societal cost savings (AUD$)	23.4M (22.1M; 24.7M)	17.0M (16.0M; 18.0M)	10.7M (10.0M; 11.5M)	10.5M (9.7M; 11.2M)	2.6M (2.1M; 3.0M)	63.5M (59.4M; 67.6M)
Total healthcare cost savings (AUD$)	24.5M (23.2M; 25.8M)	11.8M (10.9M; 12.6M)	6.8M (6.1M; 7.5M)	6.6M (5.9M; 7.2M)	0.3M[a] (0.7M; −0.1M)	42.2M (38.7M; 45.7M)
Total decayed teeth averted	161,042 (154,159; 167,924)	125,439 (120,079; 130,799)	94,484 (90,447; 98,520)	93,319 (89,332; 97,305)	54,078 (51,768, 56,387)	510,977 (489,146; 532,808)
Total DALYs averted	30.8 (29.6; 32.0)	24.2 (23.2; 25.1)	18.0 (17.3; 18.7)	17.9 (17.2; 18.6)	10.2 (9.8; 10.6)	98.1 (94.3; 101.9)
Mean ICER						Dominant
Probability of being cost-effective for societal and healthcare perspectives[b]						71.5%
Intervention effectiveness decay threshold when the intervention is cost-effective						82.0%
Lifetime scenario						
Total societal costs accrued (AUD$)	6.1B (5.0B; 6.2B)	6.2B (6.1B; 6.3B)	6.3B (6.2B; 6.4B)	6.3B (6.2B; 6.4B)	6.3B (6.2B; 6.4B)	30.6B (30.1B; 31.1B)
Total healthcare costs accrued (AUD$)	4.9B (4.8B; 5.0B)	5.0B (4.9B; 5.1B)	5.1B (5.0B; 5.1B)	5.1B (5.0; 5.2B)	5.1B (5.0B; 5.2B)	24.7B (24.2B; 25.2B)
Total decayed teeth cases accrued	27.3M (26.7M; 27.9M)	27.6M (27.0M; 28.2M)	28.1M (27.5M; 28.7M)	28.4M (27.8M; 29.0M)	28.1M (28.1B; 28.7B)	138.1M (135.1M; 141.1M)
Total DALYs accrued	404,710 (402,496; 406,925)	406,913 (404,687; 409,140)	403,987 (401,777; 406,196)	400,541 (398,3501; 402,731)	404,345 (402,133; 406,557)	1,997,538 (1,986,609; 2,008,467)

TABLE 2 (Continued)

Results	Quintile 1 (95%UI)	Quintile 2 (95%UI)	Quintile 3 (95%UI)	Quintile 4 (95%UI)	Quintile 5 (95%UI)	Total population (95%UI)
Total societal cost savings (AUD$)	65.7M (62.4M; 69.0M)	46.6M (44.1M; 49.2M)	30.3M (28.4M; 32.2M)	30.0M (28.1M; 31.9M)	9.2M (8.1M; 10.3M)	176.6M (166.2M; 186.6M)
Total healthcare cost savings (AUD$)	48.6M (45.8M; 51.4M)	33.4M (31.3M; 35.6M)	20.4M (18.8M; 22.0M)	20.1M (18.5M; 21.8M)	3.7M (2.7M; 4.6M)	122.5M (113.6M; 131.5M)
Total decayed teeth averted	413,740 (396,056; 431,424)	321,052 (307,332; 334,771)	239,788 (229,543; 250,033)	239,295 (229,072; 249,519)	134,626 (128,876; 140,377)	1,309,211 (1,253,273; 1,365,149)
Total DALYs averted	81.4 (77.9; 84.2)	62.6 (60.2; 65.1)	46.3 (44.5; 48.1)	46.5 (44.7; 48.3)	25.9 (24.9; 26.9)	254.9 (245.0; 264.8)
Mean ICER						Dominant
Probability of being cost-effective for societal and healthcare perspectives[b]						74.8%
Intervention effectiveness decay threshold when the intervention is cost-effective						91.5%

Note: Dominant: the intervention is cost-saving and health promoting.

Abbreviations: AUD$, 2020 Australian dollars; B, billion; DALY, disability adjusted life year; ICER, incremental cost effectiveness ratio; M, million; UI, uncertainty interval.

[a]Negative value indicates net incremental cost.

[b]Willingness-to-pay threshold of AUD$50,000 per DALY averted.

dental caries has a low disability weight. The lifetime societal cost-savings of AUD$176.6M in our dental model is also a small fraction of the lifetime healthcare savings of AUD$1,733M modeled for preventing obesity-related diseases (Lal et al., 2017).

However, our estimated DALYs averted in addition to the cost-savings is likely to be a significant underestimation, given dental caries accounts for 70% of tooth loss (Ling & Tao, 2016). Thus, any dental caries averted would prevent individuals from experiencing severe tooth loss, which has a disability weight of 0.067 (GBD 2019 Diseases and Injuries Collaborators, 2020). Severe tooth loss is also experienced over longer durations compared with toothache due to dental caries since it has a high cost for dental rehabilitation. Modeling severe tooth loss was not possible in our analysis due to a lack of data informing the transitional probability from dental caries to severe tooth loss health state. In our model, only restorative treatment for dental caries was considered.

Two major barriers for intervention implementation: (i) the non-supportive stance of the federal government policy position (Allen & Allen, 2020; Backholer & Martin, 2017), and (ii) industry pushback (Allen & Allen, 2020). The ratings determined by the PSG slightly differed from the ratings reported from previous research (Ananthapavan et al., 2020), that felt acceptability to government was ‘Low’ rather than ‘Medium’ and that the impact on equity was ‘High’ rather than ‘Medium’. Previous research showed that the potential household expenditure cost impact is higher for most disadvantaged consumers by AUD$3.80 per capita compared to the least disadvantaged (Ananthapavan et al., 2020). However, it was felt on balance that the associated health benefits and cost-savings evaluated in our study illustrated a three-fold cost-saving and health benefit between IRSD Quintile 1 and IRSD Quintile 5, indicating improvement in health equity.

Dental caries is a significant public health issue and has an increasing impact on low-income and middle-income countries due to under-resourcing for primary prevention and treatment (Peres et al., 2019). However, attempts to curb dental caries through the provision of dental care in high-income countries such as Australia, have largely remained treatment-orientated, highly technical and individual-centric to those who can afford it (Watt et al., 2019). Radical upstream approaches to dental

TABLE 3 The rating for the implementation considerations for the 20% tax by the Project Steering Group (PSG).

Considerations	Details	Assessment
Strength of evidence	Moderate certainty effects between dose-response relationship sugar consumption and dental caries (Bernabé et al., 2014).	Medium
	Systematic review and meta-analysis of non-randomized control trial studies reported dose-response relationship between higher consumption of SSB with dental caries (Valenzuela et al., 2021).	
	Systematic review and meta-analysis reported SSB tax intervention showed reduction in SSB intake (Andreyeva et al., 2022; Teng et al., 2019).	
	Narrative review identified the SSB tax intervention showed consistent results for modeled effects for reducing dental caries (Alhareky, 2021).	
Safety	The intervention has no safety concerns.	High
Acceptability		
Government	Major political parties and the federal government has previously stated that they do not support a tax on SSBs at this time (Allen & Allen, 2020; Backholer & Martin, 2017).	Low
Industry	The beverage and sugar industries have stated their opposition to taxes on SSBs (Allen & Allen, 2020).	Low
Other stakeholders	All major stakeholders such as peak health professional associations, consumer advocacy groups, etc. Support a SSB tax (Cancer Council Victoria, 2017).	High
General public	Scoping review report general public support never reached more than 50% unless revenue from the tax was used to subsidize health programs or subsidize healthy food (Cullerton et al., 2021).	Medium
Equity	The ACE obesity policy study showed the potential household expenditure would impact would cost AUD$3.80 per capita more for the most disadvantaged compared with the least disadvantaged (Ananthapavan et al., 2020).	Positive
	The subgroup population in IRSD quintile 1 has at least three times the cost-savings and DALYs averted due to preventing dental caries compared with the subgroup population in IRSD quintile 5.	
Feasibility	Over 50 countries have implemented policy intervention for a SSB tax (Dry & Baker, 2021).	High
Sustainability	Regulatory interventions are likely to be maintained and potentially attractive if revenue is generated from a SSB tax. that is, no SSB tax has been repealed to date.	High
Environmental impacts	Reduction in SSB consumption reduces consumer demand and may result in reduction in manufacturing of products, including packaging (plastics) and raw material (sugar production).	Positive
	Reduction in dental caries leads to reduced consumption of dental treatment services such as restorations and extractions, resulting in less use of disposal products for infection control.	
	Replacement of SSB consumption with alternative products may generate similar environmental impacts, although real-world evidence for countries with an SSB tax found there was no substitution for untaxed beverages (Andreyeva et al., 2022).	
Other considerations	There are potential concerns regarding product substitution and the increased consumption of non-nutritive sweeteners of unknown consequences (Popkin & Ng, 2021).	Neutral
	There are 'spill-over' positive effects on obesity-related chronic diseases that have been previously modeled (Ananthapavan et al., 2020; Lal et al., 2017).	Positive

Note: Green = High/Positive, Orange = Medium/Neutral, Red = Low/Negative.

Abbreviations: DALY, disability-adjusted life years; IRSD, Index of Relative Socio-economic Disadvantage; SEIFA, Socio-Economic Indexes for Areas; SSBs, sugar-sweetened beverages.

public health are necessary to address oral health inequities (Watt et al., 2019). Limiting the availability of dietary free sugars through legislation such as the 20% SSB tax has a degree of certainty for it being a cost-effective strategy, but current causal effects are yet to be evaluated in the real-world. Advocates for a tax recommend any revenue from a SSB tax, estimated to be AU$642.9M annually (Lal et al., 2017), should be redirected to preventive health interventions (Australian Council of Social Service, 2019; Public Health Association of Australia, 2020).

4.1 | Limitations

The estimated total societal and healthcare cost-savings modeled in our CEA is likely underestimated. We did not include any direct and associated direct treatment costs due to dental caries given the lack of available data on the consequences associated with dental treatment (e.g., repeat restorations, root canal treatment, extractions, etc.). Dental treatment cost can include cost of treatments performed under general anesthesia, and the cost of hospital-related services, retreat restorations, root canal treatment, dental extractions, dental implants, dental bridge, or dentures to replace tooth loss.

In addition, we did not disaggregate whether some of the healthcare costs were borne by individuals. Given, on average per person, that oral healthcare is the second most costly out-of-pocket health expense ($240) just after non-subsidized medications ($429) (Australian Institute of Health and Welfare, 2020), there is likely greater increased equity outcomes, which cannot be captured under the present CEA. Furthermore, we used a closed cohort Markov model, which meant any cost-savings and health benefits to prevent dental caries were not captured for population growth.

Our dental model has several other key limitations. Firstly, we assumed the sugar-dose relationship applied for both deciduous and permanent teeth. Realistically, there is evidence that deciduous teeth are more susceptible to dental caries than permanent teeth, largely due to their thin enamel tooth structure (Lynch, 2013). In addition, our dental model is limited by whether the sugar-dose relationship for DMFT reported by the Finnish study (Bernabé et al., 2016) is appropriate, although there are no compelling reasons why the results would differ for Australia. There are also problems using the IRSD being a measure of area-level socio-economic disadvantage rather than individual socioeconomic disadvantage. Both the sugar-dose relationship and the IRSD SSB consumption profile have potential effect modification in the relative risk by levels of socioeconomic disadvantage.

It has been reported in Australia that increases in the price of SSBs may affect different subgroups, and high SSB consumers were less sensitive to changes than less frequent consumers (Blake et al., 2019), which conflicts with a previous modeled study showing higher income groups were less sensitive to a 20% SSB tax (Sharma et al., 2014). Real-world evidence from the SSB tax in Philadelphia, US, indicate the intervention was not associated with the reduction of dental caries outcomes in the general population, but were observed for adults and children who were recipients of the Medicaid program, which targets low-income households (Petimar et al., 2023). Differences in SSB consumption by IRSD quintiles could not be modeled in our CEA due to limited data availability according to the IRSD quintile profiles. Therefore, we limited our CEA approach to primarily only account for the equity impact according to the differential SSB volume intake by the IRSD quintile groups. Additionally, we did not incorporate the substitution effect because other substitute drink products had minimal consumption effects, with the exception of fruit drinks (Sharma et al., 2014). The data source did not include fruit drinks intake, and therefore was not modeled. Lastly, unavailable cohort studies on the impact of a 20% tax on dental caries outcomes constrained model validation.

Our study demonstrates a 20% tax is cost-effective to prevent dental caries and is likely to increase health equity. Despite favorable ratings on the implementation considerations, a major barrier is the low acceptability to government and industry. Advocacy efforts should be directed with the Australian government with a health equity lens, and with industry stakeholders. Future research should consider measuring the intervention effects on dental caries outcomes when implemented in the real world.

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CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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ORIGINAL PAPER

Economic evaluation on dental caries preventive interventions for Australian children using a priority-setting approach

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Abstract

This study aims to economically evaluate three preventive interventions for dental caries among Australian children from low household income. The interventions included: (1) anticipatory guidance provided by oral health therapists via 1a) home visits or 1b) telehealth consultations; (2) school-based dental screening and fluoride varnish program delivered by 2a) dental practitioners or 2b) non-dental health professionals (no screening); and (3) school-based fissure sealant program. The base-case scenario included intervention and dental treatment costs, with six-year (1a and 1b) and two-year (2a, 2b and 3) time horizons. Sensitivity analysis included other healthcare costs (e.g. pulp therapy, extractions, etc.). Additionally, extrapolation modelling extended the 12-year time horizon (all interventions). Probability for cost-effectiveness applied AUD$50,000 per disability-adjusted life year (DALY) averted, and AUD$28,033 per quality-adjusted life year (QALY) gained willingness-to-pay thresholds. Under the base-case scenario, none of the interventions were cost-effective. Cost-effectiveness results were sensitive when including other healthcare costs and the 12-year time horizon. Probability for cost-effectiveness (DALYs averted/QALYs gained) with extrapolation modelling in order of ranking were: (1) 91.5%/94.7% for fluoride varnish, (2) 43.9%/48.6% for dental screening and fluoride varnish, (3) 28.7%/29.8% for anticipatory guidance via telehealth, (4) 17.1%/20.0% for fissure sealant, and (5) 2.2%/2.2% for anticipatory guidance via home visits.

Keywords Dental caries · Children · Fluorides · Economic evaluation · Resource allocation

Introduction

Globally, oral diseases affect over 3.5 billion people, with dental caries being the most prevalent health condition (Watt et al. 2019). It has been estimated that there were 0.1 million (95% CI 0.006; 0.3) years lived with disability (YLDs) due to dental caries in the deciduous (baby) teeth and 1.6 million (95% CI 0.7; 3.1) YLDs affecting the permanent (adult) teeth (GBD 2017 Oral Disorders Collaborators et al. 2020). There is increasing inequity from oral diseases. Between 1990 and 2017, reductions in YLDs for all oral disorders were observed for high- and upper-middle-income countries, yet such disorders increased in low- and lower-middle-income countries (GBD 2017 Oral Disorders Collaborators et al. 2020).

In Australia, there was an increase of 5.8% in the age-standardised disability-adjusted life year (DALY) rate for oral disorders between 2003 and 2022 (Australian Institute of Health and Welfare 2022). However, the profile of oral disorders has markedly changed, with a 34.5% decrease for severe tooth loss, while there were increases of 16.7% for dental caries and 40.3% for periodontal disease (Australian Institute of Health and Welfare 2022). High prevalence of oral disease disproportionately impacts people from lower socioeconomic status (Do and Spencer 2016; The Australian Research Centre for Population 2019) and other priority populations including Aboriginal and Torres Strait Islander

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people, people living in rural and remote areas and people with additional or specialised health care needs (COAG Health Council 2015).

Although dental caries impact populations across the life course, many countries tend to prioritise child populations and people experiencing financial hardship, in their resource allocation decisions within this context (Vernazza et al. 2021; Winkelmann et al. 2022). At a population level in Australia, expenditure for oral healthcare is predominantly incurred via private services with minimal public funding subsidisation, with limited government funding committed to oral healthcare (Nguyen et al. 2023). Dental caries remains one of the most common childhood health conditions and has significant financial burden on families and society (Chen et al. 2021). Therefore, implementing cost-effective dental caries preventive interventions based on rigorous evidence is imperative to improve population oral health.

Economic evaluation on dental caries preventive interventions targeting children have shown mixed results (Nguyen, Tonmukayakul, Le, Calache, et al., 2023). The most common economically evaluated interventions include the application of fissure sealants and fluoride varnish in school-based settings or fixed dental clinics. The variations in study protocol, country context, cost components and outcome measures used make it challenging to identify the best government funding investment decisions. A key limitation, particularly related to economic evaluation of preventive interventions for dental caries, is the commonly used health outcome using the decayed, missing and filled teeth index (DMFT) (Nguyen et al. 2024). The DMFT index measures dental caries experience and is only a 'proxy' measure for dental caries. In addition, the diversity of other dental outcome measures used for economic evaluation (Nguyen, Tonmukayakul, Le, Calache, et al., 2023) has meant that making comparisons between oral health interventions are difficult.

The aim of this study is to undertake an economic evaluation of preventive interventions for dental caries targeting Australian children using a population health approach. The three oral health preventive interventions to be evaluated target children from families with low household income and include: (1) anticipatory guidance provided by oral health therapists, (2) school-based fluoride varnish program, and (3) school-based fissure sealant program.

Methods

For this study, the previously published dental caries economic model from the 20% sugar-sweetened beverages tax intervention was adapted (Nguyen et al. 2023) The present study forms part of the priority-setting study called the Assessing Cost-Effectiveness of Oral Health Preventive Interventions (ACE-Oral Health Prevention) (Nguyen et al. 2023).

Based on our own evidence review on the effectiveness of different preventive interventions for oral health, the three preventive interventions investigated in this study were selected by the Project Steering Group. These dental caries preventive interventions were prioritised using predetermined selection criteria (Supplementary File, page 1) and were of most relevance to the Australian context. Amongst other factors the criteria included strength of evidence according to the National Health and Medical Research Council evidence hierarchy (Merlin et al. 2009).

This study was reported following the Consolidated Health Economic Evaluation Reporting Standards 2022 (Husereau et al. 2022) (Supplementary File– CHEERS Checklist).

Effectiveness of dental caries preventive interventions

The clinical effectiveness for the three broad categories of oral health prevention interventions for dental caries relevant to the Australian context were selected and modelled. All interventions were compared against the no intervention comparator (base-case scenario) to reflect the potential impact of these interventions if implemented extensively in the real-world.

Modelling was performed for the appropriate age groups corresponding to the following three interventions.

Anticipatory guidance provided by oral health therapists

Anticipatory guidance for oral health involves providing oral health education and supporting behaviour change to prevent dental caries (Nation et al. 2023). Anticipatory guidance is the process of providing practical and developmentally appropriate information about children's health to prepare parents for significant physical, emotional, and psychological milestones (American Academy of Pediatric Dentistry 2022). The modelled intervention includes the provision of oral health education, dietary advice and tooth brushing instructions. The mode of delivery (i.e. community-based, home visits or telehealth) can vary, including the provider of the service (health professional). For anticipatory guidance interventions, effectiveness to prevent dental caries for deciduous teeth was based on the Australian trial provided by oral health therapists via home visits (Intervention 1a) and telehealth (via phone call) (Intervention 1b) (Koh et al. 2015). The intervention was implemented every six months for children starting at 6 months, to age 5 years old (a total of 11 anticipatory guidance consultations).

School-based fluoride varnish program

Traditionally, fluoride varnish is used in dental settings (clinic-based) as a dental medicine, which consists of a high concentration of fluoride to prevent dental caries and is applied at least every six months (Marinho et al. 2013). The demonstrated effectiveness for dental caries prevention is applicable for both deciduous and permanent teeth, is based on the Cochrane systematic review and meta-analysis study Marinho et al. 2013) and was provided through outreach school-based settings. Fluoride varnish is easy to apply to teeth and has very minimal adverse effects across all age (Mascarenhas 2021).

Regular applications of fluoride varnish can be provided by non-dental health professionals (e.g. medical practitioners, nurse practitioners, Aboriginal and Torres Strait Islander health practitioners, dental assistants, etc.) (Nguyen 2017; Nguyen et al. 2023a; Ummer-Christian et al. 2024). In the United States of America, fluoride varnish is provided by non-dental health professionals under the Medicaid program with a step-down reimbursement fee (Kranz et al. 2022), but the practice is limited in Australia due to existing drugs and poisons regulations and government funding arrangements (Skinner et al. 2020, 2021). For this study, two different modes of delivery were modelled, six-monthly fluoride varnish provided by dental practitioners in primary schools (Intervention 2a), and six-monthly fluoride varnish applied by appropriately trained non-dental health professionals (Intervention 2b), for all school children aged 6–12 years old from low socioeconomic household.

School-based fissure sealant program

Fissure sealants are a thin protective layer of dental material (the same resin-based restorative material used for white restorations of teeth), which is applied to the deep fissures within the chewing surfaces of the first and second permanent molar teeth. The sealant on the chewing surfaces of the molar teeth prevents the ingression of oral bacteria, food and debris into the fissures of the chewing surfaces of the molar teeth, resulting in prevention of the progression of dental caries on the chewing surfaces of those teeth. In this study, the school-based fissure sealant program was modelled for dental practitioners undertaking outreach school-based settings in primary schools (Intervention 3) for first permanent molars (children aged 6 years and second permanent molars (children aged 12 years). i.e. two cohorts of children aged 6 and 12 years, corresponding to when the first and second permanent molars erupt into the mouth. Intervention effectiveness was derived from the Cochrane systematic review and meta-analysis study (Ahovuo-Saloranta et al. 2017).

Other intervention components for school-based programs

Typically, school-based dental programs delivered by dental practitioners in Australia include dental screening (Nguyen et al. 2015, 2017). Although there is no evidence for the effectiveness for dental screening to improve oral health outcomes (Arora et al. 2022), the costs for dental screening to identify dental caries risk and referral (first visit only) were included for Intervention 2a and 3 to reflect the real-world scenario. Dental screening is a brief assessment of the teeth, and is differentiated from a dental examination, which includes a thorough evaluation of the teeth, gums and oral cavity. A summary description of the modelled dental caries preventive interventions is reported in Table 1, and key data inputs are reported in Table 2. Detailed parameters that were varied from the dental caries model (Nguyen et al. 2023) can be found in the Supplementary File (Table 1).

Population

Single age cohorts relevant to the interventions (Table 2) were developed and modelled using TreeAge Pro 2023 with one-year cycle lengths (TreeAge Software, LLC.) for the 2020 Australian population (Australian Bureau of Statistics 2022a). Australian background mortality according to age and sex was incorporated using data from the 2019 Global Burden of Disease (GBD) study (Institute for Health Metrics and Evaluation 2021).

The three preventive interventions for dental caries modelled in this study, includes the child population using the 2021 Australian Census dataset (household income < AUD$60,000/year) (Australian Bureau of Statistics 2022b), which corresponded to the higher prevalence of dental caries among children from low household income (Do and Spencer 2016). Modelled interventions were compared against the ‘status quo’ scenario (i.e. no intervention).

Time horizon

Two separate time horizons in the base case (Table 2) were selected to reflect the duration on the evidence of effectiveness for the dental caries preventive interventions: (1) six years for anticipatory guidance in early childhood delivered by oral health therapists (Koh et al. 2015) and (2) two years for school-based dental screening with fluoride varnish (Marinho et al. 2013) and school-based fissure sealant program (Ahovuo-Saloranta et al. 2017).

Table 1 Intervention effectiveness and the cost parameter inputs for the three dental caries preventive intervention targeting children at higher risk in Australia

	Country	Study design	Intervention description	Health provider	Population	Effectiveness	Data source
Intervention 1a	Australia	Case-control study	Anticipatory guidance and dental screening provided by oral health therapists during home visits 30-minute consultations (11 visits)	Oral health therapist	6 months	-0.15 mean caries incidence*	Koh et al. 2015
Intervention 1b			Anticipatory guidance provided by oral health therapists via telehealth 20-minute consultations (11 visits)	Oral health therapist	6 months	-0.18 mean caries incidence*	
Intervention 2a	International	Cochrane systematic review and meta-analysis	Six-monthly fluoride varnish (four visits)	Dental practitioner	6–12 years	0.37 preventive fraction for dmft	Marinho et al. 2013
Intervention 2b				Non-dental health professionals	6–12 years	0.43 preventive fraction for DMFT	
Intervention 3			Fissure sealant of first or second permanent molars (one visit)	Dental practitioner	6 and 12 years	0.12 odds ratio caries incidence	Ahovuo-Saloranta et al. 2017

dmft/DMFT = decayed, missing and filled teeth (lower case: deciduous dentition / upper case: permanent dentition).

*Clinical effectiveness was based on crude mean value difference from the standard care comparator. Given the authors did not perform statistical analysis for the effectiveness difference, intervention effectiveness was derived using normal distribution parameters generated in the TreeAge Pro 2023 using trial data (Koh et al. 2015).

Health benefit modelling

The research expands on the existing economic evaluation evidence on dental caries prevention by using generic health outcomes as measured using decayed teeth prevented (DT prevented) disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs). Although methodologies to economically model dental caries interventions using DALYs are well established, the use of QALY outcomes in this context are still emerging (Nguyen, Rogers, et al., 2023). QALYs are however the preferred metric to use in many national health technology assessment agencies (National Institute for Health and Care Excellence 2013) including Australian health technology assessment agencies (Commonwealth of Australia 2024).

Modelled health states included dental caries free, dental caries, edentulism (complete tooth loss) and dead (Nguyen et al. 2023). Although edentulism among children is rare, this health state is retained for modelling consistency (Nguyen et al. 2023). Any impacts from edentulism were excluded because edentulism incidence only accrue for age 20+ years (GBD 2019 Diseases and Injuries Collaborators 2020). In order to determine DALYs, disability weights were assigned for dental caries as per the 2019 GBD study (0.010; SD 0.004) (GBD 2019 Diseases and Injuries Collaborators 2020).

Based on the 2019 GBD study, the Australian incidence rate for dental caries for the general population were used (Institute for Health Metrics and Evaluation 2021). Dental caries incidence is derived from the mean number of teeth affected by dental caries (decayed), previously extracted or filled (restored) in the population, also known as DMFT (Lewis 1996). i.e. an increase of 0.10 DMFT represents 10 new cases (individuals) developing dental caries per year.

Dental caries incidence was adjusted based on the higher prevalence of dental caries among children from low household income (Do and Spencer 2016). Differences in dental caries incidence for deciduous and permanent teeth were included for cohort specific mixed dentition for age 6–14 years (Nelson and Wheeler 2020). For each new case of dental caries, there was on average 1.64 (SD 1.262) decayed teeth (Hummel et al. 2019).

Quality of life utility gain, required to calculate QALYs, to prevent dental caries was derived from the Australian trial on anticipatory guidance provided by oral health therapists, which was previously economically evaluated (Koh et al. 2015). The difference between healthy (score of 1) and the baseline health utility for dental caries of 0.9 (SD 0.120) was used (Koh et al. 2015). Health utility was measured using the modified Child Health Utility 9 Dimensions paediatric quality of life multi-attribute instrument (Stevens 2012), with Australian utility population norm being less than 1 (Catchpool et al. 2019; Le et al. 2021). To reflect a more realistic health utility gain as applied in the Australian trial (Koh et al. 2015), we considered a utility gain of

Table 2 Key data inputs for the three dental caries preventive interventions modelled in this study

Data inputs	Intervention 1a	Intervention 1b	Intervention 2a	Intervention 2b	Intervention 3
^Target child population from low household income	45,677 (of 303,407 aged < 1 year old)		333,651 (of 2,236,730 aged 6–12 years old)		94,025 (of 638,445 children aged 6 and 12 years old)
Start age	6 months		6–12 years		6 and 12 years
Time horizon	6 years		2 years		
Intervention effectiveness decay	Intervention effectiveness applied at 100% for all cycles				
Type of model	Closed cohort Markov model				
+Intervention mean costs	First year - $1.6 M Subsequent years - $3.2 M	First year - $0.7 M Subsequent years - $1.5 M	First year - $34.6 M Subsequent years - $24.6 M	First year - $18.9 M Subsequent years - $18.9 M	First year - $21.2 M Subsequent years - $0 M
+Healthcare costs included	Dental check-up and restorations (AUD$)				
Sensitivity analysis					
+Other healthcare costs included	*Potentially preventable hospitalisation (D40Z), ~dental general anaesthesia and yearly other healthcare costs relevant to dental caries (Supplementary File, page 4)				
Extrapolation modelling					
Extended time horizon	12 years				

Intervention 1a: anticipatory guidance provided by oral health therapist via home visits; Intervention 1b: anticipatory guidance provided by oral health therapist via telehealth; Intervention 2a: school-based fluoride varnish program provided by dental practitioners; Intervention 2b: school-based fluoride varnish program provided by non-dental health professionals; Intervention 3: school-based fissure sealant program provided by dental practitioners; ^Data from the Australian Bureau of Statistics (2022); +2020 Australian dollars (AUD$); D40Z: Dental Extractions and Restorations classification by the Australian Refined Diagnosis Related Groups (AR-DRG) Version 10 (Independent Health and Aged Care Pricing Authority 2021); ~trial data costs only applied to children < 7 years old (Koh et al. 2015)

0.1 was optimistic and halved this when the 'dental caries' health state moved to 'healthy'.

Perspective

The Australian government healthcare perspective (intervention and dental caries treatment costs) was adopted in this study given these interventions are reliant on the public healthcare system for implementation.

Intervention costs

All costs were adjusted to 2020 (AUD$) prices (Reserve Bank of Australia 2024) based on the consumer price index, consistent with the same reference year for the 20% sugar-sweetened beverages tax intervention to enable comparability between studies consistency (Nguyen et al. 2023).

Table 2 and the Supplementary File (Table 1) reports the intervention costs and all resource inputs, including trial data costings (Koh et al. 2015) for interventions 1a and 1b, or relevant government dental fee-for-service items for children and adults (Department of Veterans' Affairs 2020) for interventions 2a, 2b and 3.

Anticipatory guidance provided by oral health therapists via home visits (Intervention 1a) included five visits of AUD$23.33 consultation costs and AUD$12.34 (SD 0.92) travel costs (Koh et al. 2015).

Anticipatory guidance provided by oral health therapists via telehealth (Intervention 1b) included 11 visits of AUD$16.04 consultation costs (Koh et al. 2015).

The school-based fluoride varnish program provided by dental practitioners (Intervention 2a) included AUD$29.25 dental screening cost (first visit only) and AUD$36.80 for six-monthly fluoride varnish applications (a total of four visits).

The school-based fluoride varnish program provided by non-dental health professionals practitioners (Intervention 1b) included six-monthly fluoride varnish applications. A 76.9% step-down reimbursement rates of fluoride varnish were applied for non-dental health professionals (Virginia Health Catalyst 2021). Travel costs were excluded due to unknown cost estimations per child, and consistent with previous economic evaluation of a school-based dental program (Nguyen et al. 2017).

The school-based fissure sealant program provided by dental practitioners (Intervention 3) included AUD$29.25 dental screening cost (first visit only) and the cost to apply fissure sealants at AUD$49.00 each to all four first or second permanent molars completed in one visit (four teeth at age six and age 12 years).

Healthcare costs

The cost consequences due to dental caries included the costs of a dental check-up costing AUD$54.69 (SD 3.19) and the cost of a dental restoration per tooth of AUD$189.61 (SD 17.95) (Nguyen et al. 2023).

Discount rate

A discount rate of 3% was applied for both costs and outcome measures, consistent with the previous published dental caries model (Nguyen et al. 2023).

Willingness-to-pay threshold

For the Australian context, the willingness-to-pay (WTP) threshold for dental outcomes is yet to be elicited. Thus, cost-effectiveness was not assessed for preventing decayed teeth. For generic health outcome measures, the WTP of AUD$50,000 per DALY averted (Ciketic et al. 2010; Cobiac and Vos 2012) and AUD$28,033 per QALY gained (Edney et al. 2018) were used.

Uncertainty analysis

Monte Carlo simulation with 2,000 cycles using within cycle correction was performed in TreeAge Pro 2023 to conduct probabilistic sensitivity analysis. Summary statistics and the incremental cost-effectiveness ratio (ICER) were analysed using Stata 18 BE (StataCorp). Key parameters varied in the model structure were the start age, number of children in the single age cohorts, intervention effectiveness and intervention cost parameters (Supplementary File, Table 1).

Sensitivity analysis

Other healthcare costs

Given the assumptions used in the modelling, an alternative scenario was evaluated that also included other selected healthcare costs relevant to prevent and treat dental caries (e.g. pulp therapy, extractions, etc.) (Supplementary File, page 4). Costs were weighted according to 15% of dental services provided in the public and 85% of dental services provided in the private sector (Tennant and Kruger 2014).

In addition for Intervention 1a and 1b only, the alternative scenario analysis included the costs for potentially preventable hospitalisations due to dental caries based on the trial data (Koh et al. 2015). These costs were estimated according to the Australian Refined Diagnosis Related Groups classification system code D40Z - Dental extraction and restorations (Independent Health and Aged Care Pricing Authority 2021) and the cost for dental general anaesthesia (Koh et al. 2015). Only children aged < 7 years old and those experiencing toothache accrued the costs for potentially preventable hospitalisations due to dental caries and the costs for dental general anaesthesia.

Extrapolation modelling

To estimate the economic impact in the longer term, all interventions were modelled with a 12-year time horizon, inclusive of other healthcare costs. The 12-year time horizon was selected to reflect the health impacts according to the ages in which children attended primary and secondary school. This meant that all children in Intervention 1a and 1b would have completed primary school (extended by six years), and for Intervention 2a, 2b and 3, all children would have completed secondary school (extended by 10 years). Intervention effectiveness was assumed to be the same when extrapolated to 12 years, assuming the intervention costs remained fixed to six years for anticipatory guidance provided by oral health therapists (Intervention 1a and 1b; intervention effectiveness only applied to deciduous teeth), and two years for the school-based interventions (Intervention 2a, 2b and 3). A 0% intervention effectiveness decay rate was applied in the absence of existing evidence to inform it.

Model validation

Details for the model validation process is described in the previously published dental caries model (Nguyen et al. 2023) and that is the basis for this study, which followed the ISPOR-SMDM Modeling Good Research Practice guidelines (Eddy et al. 2012).

Implementation considerations

Following previous methodology, other implementation considerations were rated by the members of the PSG according to the pre-defined criteria (Nguyen et al. 2023), which were informed by the relevant literature, wherever possible.

Results

Base-Case scenario

For anticipatory guidance via home visits, the cost difference was AUD23.0 million (SE < 0.1 million), which corresponds to 7,649 DT-prevented (SE 93), 0.4 DALYs averted (SE < 0.1) and 2.4 QALYs gained (SE 0.1). Anticipatory guidance via telehealth had a cost difference of AUD$18.5 million (SE < 0.1 million) and yielded 8,927 DT-prevented (SE (113), 0.5 DALYs averted (SE < 0.1) and 2.8 QALYs gained (SE < 0.1).

The dental screening and fluoride varnish program had a cost difference of AUD$57.5 million (SE 0.2 million).

Table 3 The healthcare cost difference, effectiveness differences, the ICER values and the probability for cost-effectiveness for the three dental caries preventive intervention targeting children at higher risk in Australia (discounted)

Base-Case Scenario	Δ Healthcare Costs* AUD$ (SE)	Δ DT Effective-ness* (SE)	Δ DALY Averted* (SE)	Δ QALY Effective-ness* (SE)	Incremental Cost-Effectiveness Ratio				
					AUD$ / DT Prevented	AUD$ / DALY Averted	CE	AUD$ / QALY Gained	CE
Home Visits	23.0 million (<0.1 million)	7,649 (93)	0.4 (<0.1)	2.4 (0.1)	3,010	54.5×10^{6}	0%	9.5×10^{6}	0%
Telehealth	18.5 million (<0.1 million)	8,927 (113)	0.5 (<0.1)	2.8 (<0.1)	2,067	37.2×10^{6}	0%	6.6×10^{6}	0%
Dental screening and fluoride varnish	57.5 million (0.2 million)	65,198 (728)	5.0 (<0.1)	28.7 (0.6)	882	11.4×10^{6}	0%	2.0×10^{6}	0%
Fluoride varnish (non-dental health professionals)	34.7 million (0.2 million)				532	6.9×10^{6}	0%	1.2×10^{6}	0%
Dental screening and fissure sealant	10.5 million (<0.1 million)	1,860 (20)	0.1 (<0.1)	0.7 (<0.1)	5,651	82.2×10^{6}	0%	14.4×10^{6}	0%
Sensitivity Analysis^ Including Other Healthcare Costs									
Home Visits	12.8 million (<0.1 million)	7,649 (93)	0.4 (<0.1)	2.4 (0.1)	1,680	30.4×10^{6}	0.1%	5.3×10^{6}	0.1%
Telehealth	6.5 million (<0.1 million)	8,927 (113)	0.5 (<0.1)	2.8 (<0.1)	733	13.2×10^{6}	7.2%	2.3×10^{6}	7.3%
Dental screening and fluoride varnish	50.7 million (0.2 million)	65,198 (728)	5.0 (<0.1)	28.7 (0.6)	778	10.1×10^{6}	0%	1.8×10^{6}	0%
Fluoride varnish (non-dental health professionals)	27.9 million (0.2 million)				428	5.6×10^{6}	0.1%	1.0×10^{6}	0.1%
Dental screening and fissure sealant	10.3 million (<0.1 million)	1,860 (20)	0.1 (<0.1)	0.7 (<0.1)	5,544	80.6×10^{6}	0%	14.1×10^{6}	0%
Sensitivity Analysis^ 12 Year Time Horizon									
Home Visits	9.6 million (<0.1 million)	18,303 (221)	1.1 (<0.1)	6.3 (0.1)	523	8.7×10^{6}	2.2%	1.5×10^{6}	2.2%
Telehealth	2.8 million (<0.1 million)	21,129 (265)	1.3 (<0.1)	7.2 (0.1)	132	2.2×10^{6}	28.7%	0.4×10^{6}	29.8%
Dental screening and fluoride varnish	<0.1 million (0.6 million)	296,834 (3,316)	39.5 (0.3)	225.6 (4.4)	~0	1,988	43.9%	348	48.6%
Fluoride varnish (non-dental health professionals)	-25.0 million (0.6 million)				-84[#]	-663,657[#]	91.5%	-110,984[#]	94.7%
Dental screening and fissure sealant	3.0 million (<0.1 million)	28,942 (323)	4.1 (<0.1)	23.3 (0.5)	104	737,176	17.1%	129,035	20.0%

^ includes costs of potentially preventable dental hospitalisation and general anaesthesia for children<7 years old and other healthcare costs related to dental caries;

AUD$ = 2020 Australian dollars; Δ = change; *3% discount rate was applied; DT=decayed teeth; DALY=disability-adjusted life years; QALY=quality-adjusted life years; CE=probability intervention is cost-effective (AUD$50,000 per DALY averted and AUD$28,033 per QALY gained); ~ approximately; [#] dominant.

The fluoride varnish program provided by non-dental health professionals yielded a cost difference of AUD$34.7 million (SE 0.2 million). Both fluoride varnish interventions generated 65,198 DT-prevented (SE 728), 5.0 DALYs averted (SE<0.1) and 28.7 QALYs gained (SE 0.6).

The dental screening and fissure sealant program had a cost difference of AUD$10.5 million.

(SE<0.1 million) and resulted in 1,860 DT-prevented (SE 20), 0.1 DALYs averted (SE<0.1) and 0.7 QALYs averted (SE<0.1) compared to no intervention.

The healthcare cost difference, effectiveness difference and the ICER values are reported in Table 3 (undiscounted results reported in Supplementary File, Table 2), which included the base-case scenario and sensitivity analysis. All modelled interventions were not cost-effective (0% probability) under the base-case scenario.

Sensitivity analysis

Other healthcare costs

The probability for cost-effectiveness was not sensitive when including other healthcare costs related to dental caries for both DALY outcomes (0-7.2%) and QALY outcomes (0-7.3%) (Table 3).

Extrapolation modelling

When the model was extended to the 12-year time horizon, anticipatory guidance via home visits remained not cost-effective (2.2% for DALYs averted and 2.2% QALYs gained). The probability for cost-effectiveness increased for anticipatory guidance via telehealth at 28.7% for DALYs averted and 29.8% for QALYs gained.

The dental screening and fluoride varnish program had increased probability for cost-effectiveness (approximately cost-neutral; 43.9% for DALYs averted and 48.6% for QALYs averted). Evaluation with the 12-year time horizon demonstrated the fluoride varnish program provided by non-dental health professionals was cost-effective (dominant; 91.5% for DALYs averted and 94.7% for QALYs gained).

The dental screening and fissure sealant program had increased probability for cost-effectiveness at 17.1% for DALYs averted and 20.0% for QALYs gained.

Implementation considerations

The rating for other implementation considerations is reported in the Supplementary File (Table 3). School-based interventions were considered more favourable when compared to anticipatory guidance interventions. The utilisation of oral health therapists to deliver anticipatory guidance via home visits or telehealth were rated as having low feasibility and sustainability, largely due to constrained workforce supply and state/territory funding mechanism that typically is not flexible to deliver outreach-based interventions.

Discussion

The findings from this study demonstrates that the three dental caries preventive interventions targeting children from low household income were not cost-effective for the base-case scenario. The ranking for the most to least cost-effective interventions according to the base-case scenario were: (1) school-based fluoride varnish program provided by non-dental health professionals, (2) school-based dental screening and fluoride varnish program, (3) anticipatory guidance via telehealth, (4) anticipatory guidance via home visits, and (5) school-based dental screening and fissure sealant program. The economic evaluation results were sensitive only under extrapolation modelling using the optimistic 12-year time horizon.

The original economic evaluation study on anticipatory guidance via home visits and telehealth provided by oral health therapists, showed they were cost-effective interventions (Koh et al. 2015). This differed from our study, possibly due to two key factors. Firstly, there is potentially selection bias where the chosen comparator were children who were users of public dental services. i.e. children accessing public dental services have more severe levels of dental caries, higher dental caries prevalence (Do and Spencer 2016), and consequently would incur higher costs. Secondly, we used a more conservative value for 0.050 utility gains for each dental caries case prevented within one year because this reflects the unrealistic likelihood a child would be in 'perfect' health if they remained free of dental caries (Le et al. 2021). This appears reasonable given the mean QALYs gained for school children was 0.05 (95% -0.01; 0.12) in an economic evaluation of community water fluoridation in Cumbria, UK (Whittaker et al. 2024).

The rankings for the school-based dental caries prevention interventions would appear logical given that the intervention effectiveness for fluoride varnish is applicable to the entire dentition, compared to fissure sealants, which only have a preventive effect for the chewing surfaces of permanent molar teeth. Previous economic evaluation of fissure sealant and fluoride varnish interventions has had mixed cost-effectiveness results (Nguyen, Tonmukayakul, Le, Calache, et al., 2023). It should be noted that it is ethically problematic to explicitly target individual children from low household income for school-based interventions given the diversity of student enrolment. School-based oral health interventions would be implemented by selecting schools based on the most disadvantaged score using the Index of Community Socio-Educational Advantage (ICSEA) classification. The ICSEA provides a relative description of school according to the indication of the socio-educational backgrounds of students (Australian Curriculum, Assessment and Reporting Authority 2013).

Critically, our study results differed from the economic evaluation of the school-based fissure sealant program for the United States context that reported the intervention was cost-effective (cost-saving) (Griffin et al. 2016). Both this study (Griffin et al. 2016) and our study applied the same intervention effectiveness for fissure sealants from the Cochrane review (Ahovuo-Saloranta et al. 2017) and the use of DALYs averted for outcomes. Critically though, the US modelled study applied DALYs averted for 72.1% of children who qualified for Medicaid (a proxy measure for low household income) and had symptomatic dental caries for the entire year (Griffin et al. 2016). This is likely to overestimate health benefits when compared to our dental caries model, which applied DALYs averted for symptomatic dental caries for a shorter duration (28 days) and for a lower proportion of children experiencing symptoms of pain which ranged from 8.4 to 21.0% (Do and Spencer 2016; Nguyen et al. 2023b).

Our DALY estimates are more reasonable given symptoms due to dental caries ranges from 9.0 to 52.1% used in the 2019 GBD study for deciduous and permanent teeth (GBD 2019 Diseases and Injuries Collaborators 2020). Additionally, our study more realistically accounted for the specificity of health benefits for fissure sealants by applying the intervention effectiveness only at the occlusal tooth surface-level (and not the whole tooth) with the two-year time horizon compared to the four-year (base-case) and nine-year (sensitivity analysis) time horizon in the US study (Griffin et al. 2016). i.e. we assumed dental caries incidence for in the school-based fissure sealant program is only attributed to dental caries developing on the occlusal surfaces of the first and second permanent molars.

With the base-case scenario, the fluoride varnish interventions we modelled were not cost-effective, which is in contrast to the Australian economic evaluation of six-monthly fluoride varnish applied for adolescents (Nguyen et al. 2020). A key difference is the choice for the 70-year time horizon with no intervention effectiveness decay, and how the health outcome was valued. The previous study derived QALYs gained as the mean utility gain of eight molars as measured in quality-adjusted tooth years (Nguyen et al. 2020), which is inconsistent with other approaches in valuation of QALYs gained in the literature (Nguyen, Tonmukayakul, Le, Calache, et al., 2023). International studies on school-based fluoride varnish interventions have also reported mixed-evidence for cost-effectiveness (Nguyen, Tonmukayakul, Le, Calache, et al., 2023). Methodological concerns were identified. The choice for the usual care comparator in the Canadian study (Norrie and Pharand 2020) is likely to inflate healthcare costs for the comparison group (i.e. greater prevalence and severity of dental caries) and bias the cost-effectiveness result (cost-saving). The UK threshold analysis study valued QALYs using utilities related to ear infections requiring hospitalisation (acute otitis media) and a longer duration of 84 days with disability experience (Kay 2018). Our study demonstrated that non-dental health professionals are preferred for implementing school-based fluoride varnish interventions, largely due to their lower cost. Whilst our modelled fluoride varnish interventions were shown to be not cost-effective within two years, they may be in the longer term. Further research is warranted to confirm whether fluoride varnish interventions are effective and cost-effective (≥12-year time horizon).

Implications for policy and practice

The assessment for implementation considerations of the five oral health preventive interventions investigated in this study were generally more favourable for school-based interventions, which are currently implemented under various models by the Australian states and territory programs (Lara Mayze 2015; Tasmanian Department of Health 2021; Victorian Department of Health 2024). Low ratings were given by the Project Steering Group on feasibility and sustainability for anticipatory guidance provided by oral health therapists either via home visits or telehealth consultations. The low rating reflects the existing funding mechanism of the state and territory programs, which are funded to provide service delivery rather than outreach population oral health interventions. The long-term effectiveness of anticipatory guidance provided by oral health therapists either via home visits or telehealth consultations showed negligible differences when compared to each other (Harrison-Barry et al. 2022) and suggests the least costly intervention to implement (i.e. telehealth) is preferable.

In Australia, preventive health assessments are commonly delivered by maternity and child.

health services in the early years (Schmied et al. 2011). Therefore, it seems logical to train registered non-dental health professionals to implement anticipatory guidance interventions that include oral health, noting it was cost-effective with the base-case scenario. Anticipatory guidance interventions for young children can be augmented with the regular application of fluoride varnish as demonstrated in previous trials among Aboriginal communities with demonstrated significant difference for dental caries prevention (Jamieson et al. 2018, 2019; Slade et al. 2011). The systematic review on economic evaluation on fluoride varnish application in preschoolers did not find ‘convincing evidence’ that the intervention is cost-effective due to methodological issues or restricted to specific settings limitations (Dhyppolito et al. 2023). The review is consistent with the previous systematic review critiquing methodological limitations, making it difficult to interpret their credentials for cost-effectiveness (Nguyen, Tonmukayakul, Le, Calache, et al., 2023).

Our study provides important insights into the relative cost-effectiveness of different dental caries preventive interventions for children. A similar Chilean study showed that dental sealant interventions were more costly and more effective (Mariño et al. 2012), but it could not be assessed for value against a willingness to pay as it did not express outcomes as DALYs or QALYs. However, cost-effective interventions included community-based interventions such as water fluoridation and salt fluoridation, and school-based milk fluoridation and fluoridated mouthrinses, as they were cost-saving and more effective (called dominant interventions) (Mariño et al. 2012). Although fluoride varnish was not investigated in the Chilean study, its clinical effectiveness to prevent dental caries is comparable to fluoride mouthrinses (Marinho et al. 2004; Twetman and Keller 2016). Thus, our study builds on existing economic evaluation methodologies of dental caries preventive interventions, whereby probably for cost-effectiveness can be highly sensitive to longer time horizons.

Key limitations

Given our study was modelled-based, its results should be interpreted with caution. The main limitation is that our economic evaluation approach relied on intervention effectiveness for dental caries prevention based on differences in dmft/DMFT, which does not accurately measure dental caries (Nguyen et al. 2024). i.e. dmft/DMFT specifically measures dental caries experience. However, we have reported costs per DT prevented as a way to make comparisons between oral health interventions.

A valid way to convert health benefits using dmft/DMFT to quality of life remains challenging. The use of QALYs, which was derived from the Child Health Utility 9D instrument (Stevens 2012) as applied in our study, is likely not sensitive enough to measure dental caries as demonstrated in previous research (Foster Page et al. 2015; Rogers et al. 2022; Weerasuriya et al. 2023). However, existing health technology assessment processes in Australia uses QALYs as the preferred health outcome measure (Commonwealth of Australia 2024), which informed our decision to include it our study.

Our study excluded other healthcare costs from the base-case scenario analysis due to its relative uncertainty, which would result in less rigour. Therefore, it was included under sensitivity analysis, although it still did not significantly change the probability for intervention cost-effectiveness. Additionally, the exclusion of travel costs for school-based fluoride varnish and school-based dental sealant programs would contribute to an underestimate of the true costs, which would have decreased the probability for their cost-effectiveness in the present analysis. Furthermore, the extrapolation of the intervention effectiveness of the three dental caries preventive interventions under the sensitivity analysis may not be realistic when considered in the real-world scenario.

Conclusion

Our study demonstrated that anticipatory guidance provided by oral health therapists via home visits and telehealth, school-based fluoride varnish programs provided either by dental practitioners or non-dental health professionals or fissure sealant programs were not cost-effective interventions. The probability of cost-effectiveness increased with a 12-year time horizon, but longer-term effectiveness studies are required to reduce uncertainty to offer definitive findings.

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Declarations

Ethics approval This study was declared exempt from review by Deakin University Human Research Ethics Committee ID 2020−238.

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ISSUES BRIEF
No 59

Universal access to essential oral healthcare through a priority-setting approach

30 July 2024

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Cost continues to be the most frequently reported barrier to accessing oral healthcare. Addressing this challenge will require reforms to payment models and pricing structures to improve affordability and equity in access.

While current funding models offer a strong foundation for reform, government support is presently directed toward low-income and priority populations. There is an opportunity to build on these targeted programs and progress toward a more integrated, population-based approach to oral healthcare.

The absence of a nationally agreed definition of what dental services should be government funded, limits the ability to allocate resources effectively. Adopting the WHO's concept of essential oral healthcare would provide a clear, evidence-based framework for defining service coverage.

By building upon the priority-setting approach, the Australian Government can work towards integrating oral health into the public health system with incremental funding changes. This should be enabled by including dental practitioners and dental services using the Australian health technology assessment (HTA) process

Recommendations

- Define essential oral healthcare in Australia: Establish a clear, evidence-based definition of essential oral healthcare in Australia, aligned with the WHO framework, to guide resource allocation and ensure equitable access.
- Implement a formal priority-setting approach: A structured framework, such as the Assessing Cost Effectiveness of Oral Health Preventive Interventions (ACE-Oral Health Prevention) should be adopted, to support funding policy decision-making in oral healthcare, as successfully applied in other health areas.
- Integrate oral healthcare into HTA processes: To enable oral healthcare funding decisions and ensure investments are evidence-based, the priority-setting approach must be taken and its outcomes consider by existing HTA process mechanisms.

AHHA acknowledge the Aboriginal and Torres Strait Islander peoples as Australia's First Nation Peoples and the Traditional Custodians of this land. We respect their continued connection to land and sea, country, kin, and community. AHHA also pays our respect to their Elders past, present, and emerging as the custodians of knowledge and lore.

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Deeble Institute for Health Policy Research

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Key messages

- Cost continues to be the most frequently reported barrier to accessing oral healthcare. Addressing this challenge will require reforms to payment models and pricing structures to improve affordability and equity in access.
- While current funding models offer a strong foundation for reform, government support is presently directed toward low-income and priority populations. There is an opportunity to build on these targeted programs and progress toward a more integrated, population-based approach to oral healthcare.
- The absence of a nationally agreed definition of what dental services should be government funded, limits the ability to allocate resources effectively. Adopting the WHO's concept of essential oral healthcare would provide a clear, evidence-based framework for defining service coverage.
- By building upon the priority-setting approach, the Australian Government can work towards integrating oral health into the public health system with incremental funding changes. This should be enabled by including dental practitioners and dental services using the Australian health technology assessment (HTA) process.

Recommendations

1 **Define essential oral healthcare in Australia**: Establish a clear, evidence-based definition of essential oral healthcare in Australia, aligned with the WHO framework, to guide resource allocation and ensure equitable access.

2 **Implement a formal priority-setting approach**: A structured framework, such as the Assessing Cost Effectiveness of Oral Health Preventive Interventions (ACE-Oral Health Prevention) should be adopted, to support funding policy decision-making in oral healthcare, as successfully applied in other health areas.

3 **Integrate oral healthcare into HTA processes:** To enable oral healthcare funding decisions and ensure investments are evidence-based, a priority-setting approach must be taken and its outcomes considered by existing HTA process mechanisms.

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Background

Dentistry is expensive

In Australia, dentistry is expensive. Unlike accessing elective surgery or seeing a cardiologist in a public hospital, services typically covered by Medicare, most oral healthcare in Australia falls outside the universal healthcare insurance scheme.

For example, over the 2022-23 financial year, $12.5 billion was spent on oral healthcare (AIHW, 2024a); with approximately 61% of this expenditure attributable to spending by individuals and families (non-government) (AIHW, 2024a)[1].

In this regard, consumers bear a significant share of dental care costs through out-of-pocket payments, making dental services one of the highest individual health expenses, averaging $291 per person, second only to non-government subsidised medications at an average of $569 per person (AIHW, 2024a). This is also in contrast to out-of-pocket spending for referred and unreferred medical services at $238, and hospital services at $132 (AIHW, 2024a).

Compared to other health services, more people are reporting cost as a barrier to seeing a dental practitioner (ABS, 2024). This challenge is not only limited to low-income individuals or households, but is being experienced across all levels of socioeconomic disadvantage, with the most significant impact felt by those in the lowest socioeconomic group (ABS, 2024).

- The most common reason people aged 15 and over delay or avoid seeing a dental practitioner is due to cost (ABS, 2024).
- Of Australians aged 15 and over, 18% of people reported costs as a barrier to oral healthcare when needed (ABS, 2024)[2].
- One in ten people in the least socio-economically disadvantaged group report costs as a barrier to accessing oral healthcare, compared to one in three people in the most disadvantaged group (ABS, 2024).

[1] Individuals contributed $7.6 billion of the total health expenditure for dental health services in 2022-23 (data table A6; AIHW 2024a).

[2] Of 13,467 people surveyed, 2,376 individuals stated that the cost was reason to delay or did not see a dental practitioner (data table 14.1; ABS, 2024)

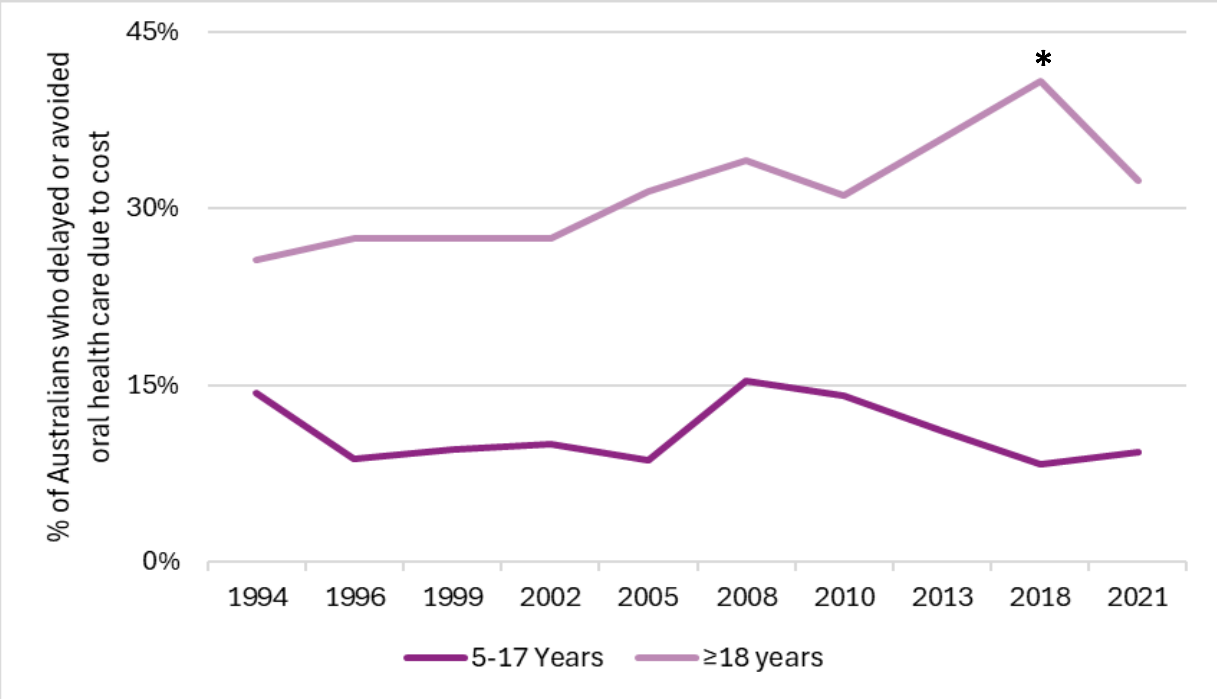

*Figure 1. Delayed or avoided oral health care due to cost: the National Dental Telephone Survey (AIHW, 2024). Financial barriers to accessing oral healthcare increased significantly for adults between 2010 and 2017, and for children between 2005 and 2008 (AIHW, 2024). * The decline in adults (>18 years) delaying oral healthcare due to costs may be attributed to growth in real household disposable income during this period (2018-2021) (Beckers et al., 2024).*

Impact of high oral healthcare costs

Among adults (≥18 years), trends in financial hardship related to oral healthcare have only continued to increase over time (AIHW, 2024) (Figure 1).[3] In 2021, for example, 32% of Australian adults delayed or avoided oral healthcare due to costs, compared to 26% in 1994 (AIHW, 2024).[4]

In contrast, the proportion of children aged 5–17 years who delayed or avoided oral healthcare due to cost decreased over the same period, from 14% to 9% (AIHW, 2024) (Figure 1).[5]

The disparity between adults and children likely reflects the limited financial protection for essential oral healthcare[4] which is not only vital for meeting Australians' health needs but also considered essential for quality of life (Brennan et al., 2020; Srivastava et al., 2017; Naidoo et al., 2024).

For example among those most severely deprived, that is those lacking at least three essential items (e.g. items for children,

[3] Cost interactive 7.

[4] Cost interactive 7.

[5] Cost interactive 5.

emergency savings, home insurance), 47% continue to express concerns about accessing dental treatment when needed (*Material Deprivation in Australia: The Essentials of Life* report ; Naidoo et al., 2024).

If not addressed, ongoing oral health issues can become risk factors for chronic conditions such as diabetes (Fu et al., 2020), or result in visible dental deterioration that affects social confidence and psychological wellbeing (World Dental Federation, nd). These impacts can create further barriers to improving financial circumstances.

For example, difficulties in gaining or keeping employment due to oral health related stigma, or reduced productivity through absenteeism caused by untreated dental problems (Sanders and Spencer, 2004; Singhal et al., 2013).

Consistent, preventative dental care is the most effective way to avoid the escalation of oral health conditions into more complex and costly problems. However, with cost remaining a major barrier, many Australians are forced to seek alternative ways to fund essential dental care, often at a point when their needs are more urgent and treatment is more expensive (Figure 2).

Superannuation is being used to fund dental treatment

Issues of affordability may have led to an increase in the number of consumers accessing superannuation to fund dental treatment under compassionate grounds. The number of applications increasing six-fold over the five year period from 2018/19 to 23/24 (financial years) (ATO, 2024). From 2021 to 2023, around half of the proportion of superannuation released for medical treatment was for dental treatment (Figure 2), indicating a marked increase in unmet oral health needs (ATO, 2024).

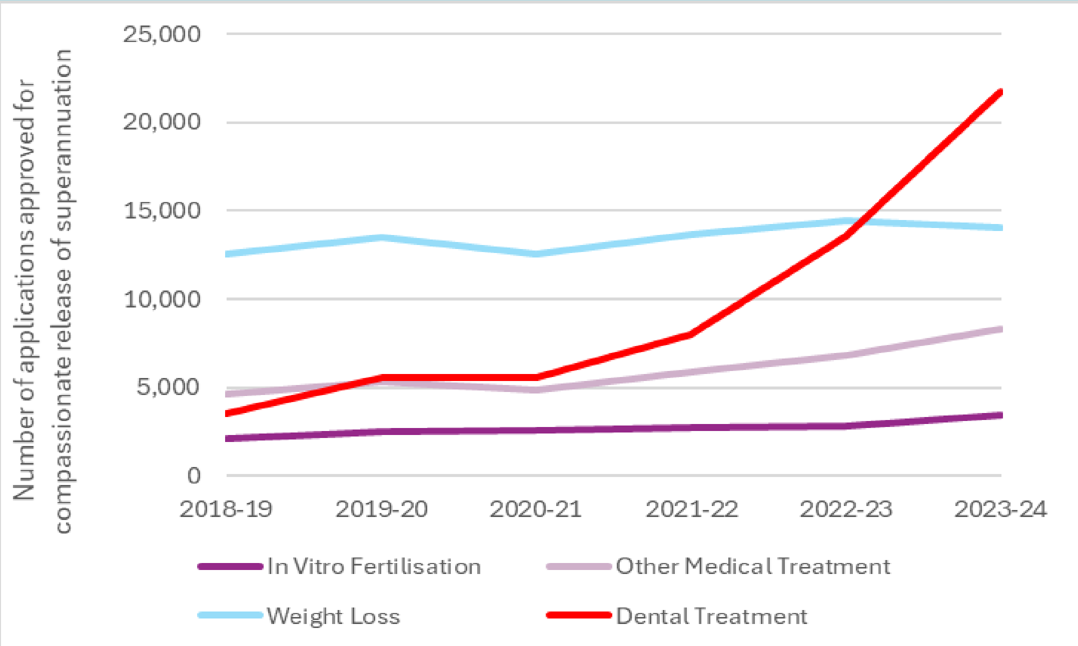

Figure 2. Growth in the number of applications approved by the Australian Tax Office for compassionate release of superannuation (2018-19 to 2023-24) (ATO, 2024).

Universal access to oral health care

To ensure equitable access to essential oral healthcare, reduce out- of- pocket costs and address long standing disparities, Australia must consider shifting to a universal approach to oral healthcare delivery; one that ensures access to oral healthcare across three dimensions (Winkelmann et al., 2022):

- the population covered,
- the proportion of costs covered, and
- the services covered.

To date, oral healthcare in Australia has been delivered through a free market model and estimates to implement a universal dental scheme have been projected in the excess of $5 billion annually (Duckett et al., 2019; PBO, 2024).

However, modelled universal dental schemes are underpinned by a dental fee schedule that has not been formally evaluated for cost-effectiveness, creating uncertainty about its value as an investment (Nguyen et al., 2025).

Nevertheless, despite the inertia seen in Australia towards developing a universal oral healthcare system, interest is growing internationally. The World Health Organization (WHO) has developed, and is implementing, the Global Oral Health Strategy and Action Plan 2023-2030 to support a global oral health policy agenda (WHO, 2024).

This strategy has identified financial protection and improving access to oral healthcare as an output measure to monitor the integration of oral health with universal health coverage (WHO, 2024).

Within this context, the WHO has called for Member States, which includes Australia, to develop a nationally tailored oral healthcare package; supported by a stakeholder engagement process to identify-cost effective oral health interventions for inclusion in the country's universal health coverage framework (WHO, 2024).

This Issues Brief outlines recommendations to support a fiscal incremental approach to achieving universal access to essential oral healthcare in Australia.

Financial barriers to affordable oral healthcare

In 2021-22, Australia ranked sixth out of 31 countries in the OECD in terms of oral healthcare funding; with the majority of spending occurring through out-of-pocket costs to consumers ($6.67B) and health insurance funds ($2.16B) (Hopcraft, 2024). Of the government spending allocated for oral healthcare (Federal $1.3B / State $0.96B), one third was directed towards subsidising private health insurance (Hopcraft, 2024).

Over time, this limited government investment has impacted the provision of public dental services in Australia (Holden, 2018; Holden et al., 2022), resulting in high costs for consumers and inequities of access.

Free market dentistry in Australia

In Australia, dentistry operates largely within a free-market system. Dental services are delivered by private practitioners operating outside government price regulation, with over 77% of oral healthcare provided by the for-profit private sector (Gnanamanickam et al., 2018).

The market is largely shaped by dynamics between consumer demand and service availability (ADVOCATE Consortium et al., 2020), pricing out those unable to afford services. As a result, only around half of Australian adults attend a regular dental checkup at least once a year (AIHW, 2024c).

Dentistry free market in Australia

Predominantly Private System:

- Most dental care is delivered through private dental clinics.
- Patients typically pay out-of-pocket or use private health insurance (extras cover) to help with costs.

Limited Public Dental Services:

- Publicly funded dental care is available, but mainly to eligible groups, such as children (e.g. through the Child Dental Benefits Schedule)

Low-income adults and concession card holders

- Public dental services often involve long wait times and limited scope of care.

Fee-For-Service Model:

- Dentists set their own prices—there is no government regulation of fees.
- This leads to significant price variation between providers and regions.

Market Competition:

- Dental clinics compete for patients through pricing, reputation, technology, and service offerings.
- Consumers can choose their provider, but price transparency is often lacking.

Insurance and Out-of-Pocket Costs:

- Private health insurance offers some coverage for dental, but usually with caps and limits.
- Many Australians pay significant out-of-pocket expenses, making cost a barrier to access.

Oral healthcare policy misalignment

Successive Australian Government policies have aimed to improve access to oral healthcare by disrupting the dentistry free market, however these have been ad hoc and targeted to specific Australian populations, without clear evidence that targeted populations are more appropriate than addressing the needs of the general population (Akers et al., 2017; Nguyen et al., 2023; Wright and List, 2012).

In general, these approaches have been short-term in focus, leading to funding policies that ultimately undermined their intended oral health outcomes. For example, the Chronic Disease Dental Scheme (CDDS).

The Chronic Disease Dental Scheme (CDDS).

The CDDS (2008-2012) was introduced by the government to improve access to oral healthcare. Under this scheme the private sector was able to deliver government subsidised oral healthcare to consumers. Eligible consumers could claim up to A$4,250 per person over a two-year period for dental services (Akers et al., 2017). However, access to the scheme also required approval from a general medical practitioner and a diagnosis of a chronic disease adversely affecting oral health (Crocombe et al., 2015).

The CDDS' focus on disease, rather than on oral disease prevention, resulted in expenditure incentivised for expensive non-preventive complex dental treatments (Crocombe et al., 2015; Lam, 2012) with some general practitioners reporting that they felt pressured to provide dental referrals to consumers who may not necessarily benefit, and even by dentists as a way to drive personal remuneration (Lam, 2012; Weerakoon et al., 2014).

Additionally, as the CDDS was non-means tested it was found to be generally confusing for general practitioners, dentists, and consumers alike (Weerakoon et al., 2014). The cost of the CDDS over the five year period it was implemented was $2.8 billion (Crocombe et al., 2015).

Not only was the CDDS expensive to taxpayers (Crocombe et al., 2015; Lam, 2012), but it also drove geographic inequities across the country, with uptake clustered in urban areas and higher income regions. Particularly in NSW with two thirds of the schemes coming from the state, raising questions about the scheme's integrity and over-servicing (Crocombe et al., 2015; Kraatz et al., 2014; Lam, 2012; Palfreeman and Zoellner, 2012; ANAO, 2014).

Challenges related to the policy design (e.g. lack of targeting and misuse) and concerns relating to the financial sustainability of the scheme contributed to its discontinuation in 2012 (Akers et al., 2017; Lam et al., 2015, 2014).

Since its closure, there have been no concerted efforts to reform the free-market structure of adult dental care in Australia and as a result, access to oral healthcare remains challenging for many adults and barriers to essential services for vulnerable populations are perpetuated.

Fee-for-service funding payment models

Oral healthcare in Australia is predominately remunerated using the fee-for-service payment model, rewarding inputs rather than outcomes (Hegde and Haddock, 2022; Nguyen, 2017) and creating issues of equity and accessibility. For example, fee-for-service payment models are associated with higher risk of overtreatment and 1.5 times the rate of dental caries (Conquest et al., 2021).

Fee for service payment models, combined with free market competition and a growing supply of dentists has also been linked with rising costs, per dental visit (Grytten, 2017).

In Australia, the number of registered dental practitioners is trending upwards (DBA, 2020). However, the geographic distribution of the workforce remains problematic (Veginadu and Haddock, 2024) and there has been no concerted efforts to improve oral healthcare efficiencies through, for example, the optimal utilisation of oral health therapists (Nguyen et al., 2019; Nguyen and Hall, 2024).

The Australian Schedule of Dental Services and Glossary (ADA, 2022) has influenced the structure of government dental programs by supporting a fee-for-service payment model (Commonwealth of Australia, 2023a). However, this model presents challenges for advancing towards outcome-focused funding approaches, as there is currently no available data linking fee-for-service payments to patient outcomes (Productivity Commission, 2017).

Review of fee-for-service dental programs

In Australia, a number of the fee for service dental programs have been reviewed, yet the release of findings has been delayed or not released at all, undermining government responses to the population's oral health needs. For example, The Department of Veterans' Affairs dental program underwent review in 2020; however, as of 2025, the findings have not yet been released (DVA, 2022).

Without access to findings, opportunities for evidence-informed improvements, such as enhancing access, ensuring/improving the provision quality of care or funding arrangements, may be missed. In another example, the means-tested Child Dental Benefits Schedule (CDBS) dental program has been reviewed five times since its implementation in 2014, with recommendations often taking a long time to implement or even failing to be implemented before subsequent reviews take place (Bastani et al., 2022).

A review of eight independent Australian state and territory public dental programs, delivered by salaried dental practitioners, has identified significant challenges linked to the continued use of fee-for-service payment models (Productivity Commission, 2017), including:

- higher rates of dental extractions being performed in the public dental programs, and
- lower rates of preventive dental services, when compared to the private sector under government subsidised oral healthcare (Brennan et al., 2008, 1997; Nguyen et al., 2022).

To better align dental services with consumer needs, Australian governments should develop an evidence-based dental fee schedule that prioritises prevention and early intervention.

This schedule should be tailored to reflect individuals' oral health risks and needs, supporting more targeted and effective care delivery (Productivity Commission, 2017).

There is a prevailing assumption that consumers are generally equipped to make informed decisions about their dental care (Grytten and Sørensen, 2000; Moeller and Quiñonez, 2020). However, this is not always the case and low levels of oral health literacy are not only associated with increased economic barriers to accessing oral health care, but also poorer oral health outcomes (Alzahrani et al., 2025; King et al., 2023).

Cost-effectiveness of oral healthcare

In Australia, the growing burden of oral disease likely reflects systemic inefficiencies in healthcare, partly driven by the high costs of dental services.

The 2024 Australian Burden of Disease Study indicates that the lack of timely access to oral healthcare has contributed to an increased burden of dental caries and periodontitis between 2003 and 2024 (AIHW, 2024c), as measured in disability-adjusted life years (DALYs) (Figure 3).[6] These inefficiencies occur against a backdrop of considerable progress in our understanding of oral disease prevention and advances in technologies in dentistry worldwide (Watt et al., 2019).

Within the Australian context, there are significant knowledge gaps in our understanding of the cost-effectiveness of oral health preventive interventions (Eow, 2019; Nguyen et al., 2023b; Rogers et al., 2019; Tonmukayakul et al., 2015). This potentially hinders efforts to increase investment in oral healthcare.

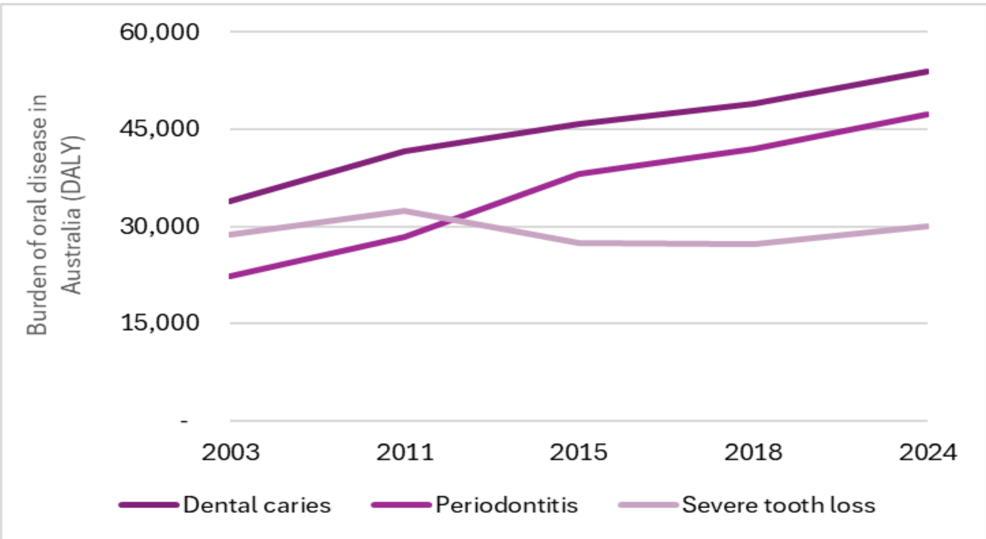

Figure 3: Burden of oral disease in Australia; trends in disability-adjusted life years (DALY) on the three most common oral conditions, (2003-2024) (AIHW, 2024a).

[6] Figure 3.1 interactive for Australian Burden of Disease Study 2024.

For example, six-monthly dental check-ups and professional teeth cleaning continue to be widely practiced internationally, including in Australia, despite limited evidence supporting their cost-effectiveness (Fee et al., 2020; Lamont et al., 2018). This practice, while maintaining a preventative focus, may not always be clinically necessary and therefore represents low-value care when applied universally. Avoidable, unnecessary oral healthcare costs, such as overtreatment and missed opportunities to reorient health services that generate high value for consumers and funders exacerbate this issue (Innes and Schwendicke, 2017; Keys et al., 2019; Lin et al., 2023; Vujicic and David, 2023).

Some progress towards value-based care has been achieved through the adoption of health outcome measures that support policy efforts to prioritise prevention (Nguyen et al., 2023).

For example, the economic evaluation of expanding community water fluoridation in Australia, which supports its implementation in communities with populations of at least 1,000 people has strengthened advocacy efforts and informed public health planning (Cobiac and Vos, 2012; Nguyen et al., 2025).

The modelled impact of a 20% sugar-sweetened beverages tax in Australia (Nguyen et al., 2023a) has demonstrated an almost 10-fold cost-saving benefit ($23.4 million vs $2.6 million) and three-fold health benefit (30.8 DALYs averted vs 10.2 DALYs averted) to populations who were most socioeconomically disadvantaged compared to the least socioeconomically disadvantaged (Nguyen et al., 2023a).

Although a sugar-sweetened tax has been implemented in over 130 jurisdictions in 120 countries and territories (Cancer Australia, 2025), this public health intervention is yet to be adopted in Australia.

Targeted funding: Government subsidised oral healthcare

The exclusion of dentistry from Australia's universal health coverage has led to a fragmented and inequitable approach to oral healthcare access (Parliament of Australia, 2023; Nguyen et al, 2025). In response, funding has largely been targeted to address specific gaps in affordability and availability.

However, this approach has introduced further complexity and inconsistency, as individual oral health needs are shaped by personal preferences and circumstances, making it difficult for targeted interventions to deliver equitable and coordinated care at a system level.

This is highlighted in the 2024 Mirror, Mirror Commonwealth Fund report that compares healthcare system performance across high-income countries.[7] Although Australia ranks first overall, it performs poorly (9th out of 10 countries) in cost-related access to healthcare, which, includes dental care (Blumenthal et al., 2024).

This position in oral healthcare affordability contrasts with countries, such as Germany, Denmark, Finland, France, Sweden, and the United Kingdom which have implemented universal health coverage models that explicitly include oral health services (Winkelmann et al., 2022). In these settings, government subsidised oral healthcare is consistently linked to improved oral health outcomes at the population level (Nguyen et al., 2023; Raittio and Suominen, 2022).

However, variation between countries around what type of dental services are covered, the composition of the oral health workforce, and the cost-sharing models of financing make it difficult to compare between systems to understand the 'ideal' oral healthcare funding model.

Among a broad set of aggregated performance indicators, including unmet needs for dental care, OECD countries with a greater share of government funded healthcare expenditure tend to demonstrate high system efficiency (Molander, 2025).

Targeted oral healthcare for children

In Australia, efforts to expand universal access to oral healthcare have primarily focused on targeted funding for children. A key example being the Australian School Dental Program (ASDP: 1974-1982), a cost-shared initiative between the Commonwealth, state, and territory governments that supported the development and delivery of school-based dental services (Akers et al., 2017).

Despite the program's demonstrated success, evidenced by reductions in the number of decayed, missing, and filled teeth, as well as improvements in children's oral hygiene (Carr, 1982), the ASDP was discontinued following shifts in federal policy priorities under a change in Commonwealth government (Wright and List, 2012).

[7] Canada, France, Germany, Netherlands, New Zealand, Sweden, Switzerland, United Kingdon and United States.

Since the closure of the Program, reforms to children's oral health funding in Australia have been largely piecemeal and reactive, lacking a sustained and strategic approach.

Initiatives such as the means-tested Commonwealth Dental Health Program, the Private Health Insurance Rebate Scheme, the Medicare Teen Dental Plan, and the Child Dental Benefits Schedule have each aimed to improve access (Figure 4), but none have provided a comprehensive or universal solution to financial protection.

Commonwealth Dental Health Program (1994-1997)

The Commonwealth Dental Health Program (CDHP), delivered through state and territory public dental services, aimed to provide comprehensive oral healthcare to low-income populations, including children. The program was discontinued following a change in Commonwealth government (Wright and List, 2012) and was subsequently replaced in 1997 by the Private Health Insurance Rebate Scheme (PHIRS), which shifted the focus toward subsidising private dental care.

Private Health Insurance Rebate Scheme (1997-present)

The means-tested PHIRS provided government subsidies for oral healthcare, but only to individuals who could afford private health insurance. The scheme offers tiered rebate levels based on household income thresholds, reinforcing inequities in access to care (Robson and Paolucci, 2012).

Medicare Teen Dental Plan (2008-2013)

Introduced in 2008 alongside PHIRS, the Medicare Teen Dental Plan (MTDP) provided an annual dental benefit of $150 as a bundled capitation payment for preventive services—such as check-ups, cleaning, radiographs, fissure sealants, and fluoride application, targeted at children aged 12–17 years.

However, government evaluations revealed inequitable utilisation. Children from the most advantaged areas accessed the program at nearly twice the rate (29%) of those from the least advantaged areas (16%) (ANAO, 2015; Commonwealth of Australia, 2009).

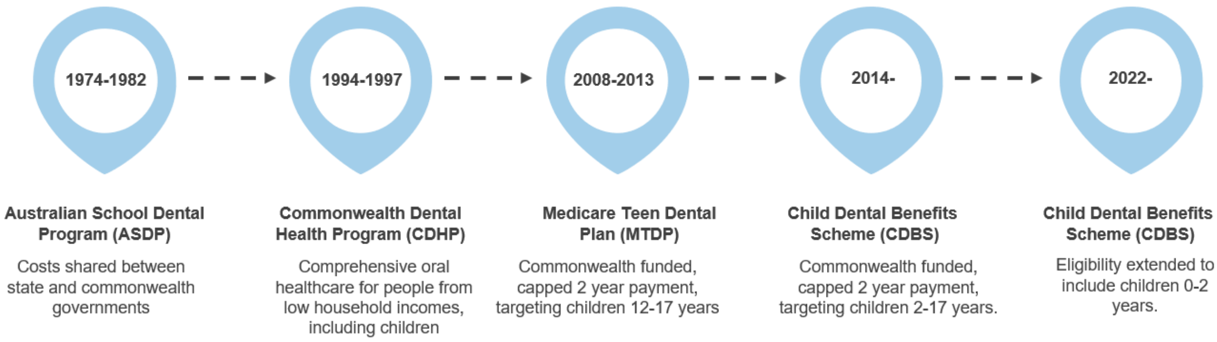

Figure 4: Government subsidised oral healthcare for children in Australia (Akers et al., 2017; Wright and List, 2012).

Geographic disparities were also evident, with uptake ranging from 20–25% across New

Universal access to essential oral healthcare

South Wales (Skinner et al., 2012). While comparable data for other states is limited, national evaluations indicate that children in more advantaged regions consistently accessed the program at higher rates than those in disadvantaged or remote areas (ANAO, 2015).

These patterns reflect broader social determinants of oral health, where barriers extend beyond financial cost to include geographic, cultural, and systemic factors (Bastos and Borde, 2023; Fisher-Owens et al., 2007; Stormon et al., 2022; Stormon and Sowa, 2023).

In 2013, the MTDP was ceased in order to implement the Child Dental Benefits Scheme (CDBS), which arose from recommendations from the National Advisory Committee on Dental Health (ANAO, 2015; NACDH, 2012).

Child Dental Benefits Scheme (2014-present)

The Child Dental Benefits Schedule (CDBS) was introduced to extend the scope of the Medicare Teen Dental Plan (MTDP), aligning more closely with services traditionally delivered by state and territory public dental programs but now funded by the Australian Government. The CDBS expanded eligibility to children aged 0–17 years and broadened the range of services to include general dental treatments, excluding orthodontics (Bastani et al., 2022). To support this expanded coverage, the benefit cap was increased to $1,132 over two calendar years (Services Australia, 2025).

Despite these enhancements, the CDBS has consistently underperformed against its original utilisation target of 78% set in 2014. Current budget projections estimate utilisation at just 44% for the 2024–25 financial year (Commonwealth of Australia, 2024; Nguyen et al., 2021).

While there is some evidence of improved access among children from low-income households, estimated at a 6–8% increase (Nguyen et al., 2025; Stormon et al., 2022), comprehensive evaluations of the program's effectiveness and cost-effectiveness in improving oral health outcomes remain limited.

Fragmented and inequitable funding undermines efficiency

Australia's oral healthcare system is characterised by overlapping responsibilities between federal, state, and territory governments, leading to duplication in service delivery and inefficiencies in funding allocation (NACDH, 2012; Productivity Commission, 2017). The effectiveness of these fragmented arrangements remains unclear.

Additionally, eligibility criteria for public dental services vary significantly across jurisdictions, particularly for adults, while most states and territories offer broader coverage for children (Table 1) (Duckett et al., 2019; Nguyen, 2017).

This inconsistency contributes to inequitable access and complicates national efforts to improve oral health outcomes. This complexity has created confusion among consumers, primarily those from lower socioeconomic backgrounds, when seeking access to government subsidised oral healthcare in a timely manner (Commonwealth of Australia, 2023b).

Table 1: Government subsidised oral healthcare and population eligibility (Duckett et al., 2019; Nguyen, 2017).

Government subsidised oral healthcare	Funding source	Target Population		Dental service coverage
		Children	Adults	
State and territory dental programs	• Federal and state/territory • Department of Health and Aged Care • Federal Financial Agreement	Yes - variable eligibility based on age and may be means-tested	Yes - means tested	Comprehensive dental care following state and territory dental program clinical guidelines
Child Dental Benefits Schedule	• Federal • Department of Health and Aged Care • Dental Benefits Act 2008	Yes - means-tested	No	Comprehensive dental care except for orthodontic services
Public hospital admitted and outpatient services	• Federal and state/territory • Department of Health and Aged Care • National Health Reform Agreement	Yes	Yes	Limited dental care - acute dental conditions
Private health insurance	• Federal • Treasury	Yes - means-tested	Yes - means-tested	Comprehensive dental care
Royal Flying Doctors Service	• Federal • Block funding	Yes*	Yes*	Variable, targeted to rural and remote areas
Department of Veterans' Affairs	• Federal • Department of Veterans' Affairs	Yes*	Yes*	Comprehensive dental care Targeted to individuals who have served in the military, and family members
MBS, Cleft Lip and Palate Services	Federal Department of Health and Aged Care Health Insurance Act 1973	Yes*	No*	Comprehensive dental care Targeted to individuals who are diagnosed with a cleft lip and palate

While eligible children are typically exempt from public dental waitlists, adults often face delays of up to three years before receiving comprehensive care through state and territory programs (Productivity Commission, 2017). These delays contribute to a growing reliance on emergency dental services and preventable high-cost treatments.

In 2022–23 alone, there were 87,410 potentially preventable dental hospitalisations—representing an estimated $1.6 billion in avoidable healthcare costs (IHACPA, 2025). Timely access to oral healthcare through primary care settings could significantly reduce this burden. Across all age groups, children aged 5–9 years experience the highest rate of potentially preventable dental hospitalisations, at 12.3 per 1,000—more than three times the national average of 3.4 per 1,000 (AIHW, 2024e).

The majority of these hospitalisations are due to untreated dental caries, a largely preventable condition (Rogers et al., 2018).

These figures highlight a critical gap in early intervention and access to preventive oral healthcare for young children (see Figure 5)

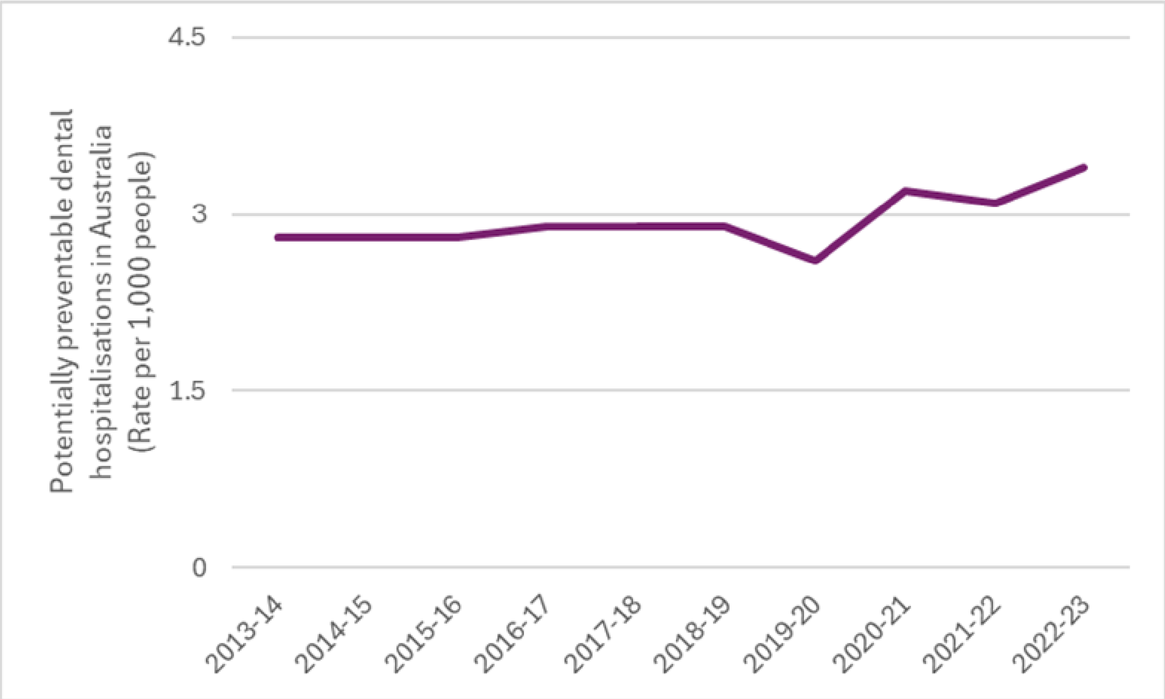

Figure 5: The trends in potentially preventable dental hospitalisations, 2013-14 to 2022-23 financial years (AIHW, 2024e). The reduced rate of potentially preventable dental hospitalisations in the 2019/20 financial year is likely due to COVID-19 pandemic restrictions to oral healthcare in Victoria (Nguyen et al., 2021)

Underfunding limits access and care quality

Government-subsidised oral healthcare in Australia remains under-resourced, limiting its capacity to meet growing consumer demand and making timely access unaffordable for many Australians (Commonwealth of Australia, 2023b).

Chronic underfunding of state and territory dental programs has resulted in a system that prioritises broad access over consumer-centred, evidence-based care. This has led to limited capacity for regular follow-ups and tailored treatment for individuals at higher risk of oral disease (Productivity Commission, 2017; VAGO, 2016).

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For example, in 2011, approximately one-third of Australian adults were eligible for public dental services, yet around 200,000 adults remained on waiting lists (Dudko et al., 2017).

Despite multiple program evaluations, there remains limited visibility into who is benefiting from subsidised care and whether it is reaching those most in need (Productivity Commission, 2017; TAO, 2024; VAGO, 2016).

Inefficiencies in public spending through private health insurance

Compared to European oral healthcare systems, Australia provides limited government-funded dental coverage (Winkelmann et al., 2022). A significant portion, 61%, of the Australian government public oral health budget is directed toward private dental insurance rebates (AIHW, 2024a), despite growing evidence that this model is inefficient and inequitable (Duckett et al., 2019; Law et al., 2014; Yang, 2014).

These rebates are tiered by income, disproportionately benefiting higher-income households with the means to purchase private insurance (Duckett et al., 2019; Hopkins et al., 2013; Teusner et al., 2015).

Moreover, private dental insurance operates under a fee-for-service model that has not been evaluated for cost-effectiveness. This model may incentivise low-value care and overtreatment, potentially leading to physical or financial harm for consumers (Fee et al., 2020; Lamont et al., 2018; Nguyen and Worthington, 2023).

For example, dentists vary widely in their use of dental restorations, applying them in 12% to 74% of cases, despite evidence favouring non-invasive, preventive approaches (Innes and Schwendicke, 2017). Such variation contributes to unnecessary costs for both consumers and taxpayers and undermines the efficiency of public investment in oral healthcare (Holden et al., 2021).

International comparisons show that Australia ranks poorly in terms of affordable access to adult oral healthcare, regardless of the funding model in place (Winkelmann et al., 2022).

Only Portugal, which also has limited oral healthcare coverage similar to Australia, ranks worse at 34% (2019) of the adult population reporting unmet needs for dental care due to cost (Winkelmann et al., 2022), compared to Australia at 32% (2021) (AIHW, 2024).

Lessons from European oral healthcare systems highlight the importance of clearly defining the scope and cost-sharing structure of services within a universal dental care framework (Winkelmann et al., 2022). For Australia, this means explicitly outlining which dental services are considered essential and what proportion of costs will be publicly funded.

These critical design elements have been largely absent from previous proposals for universal dental schemes, limiting their feasibility and long-term sustainability (Clarke and Cutler, 2024; Duckett et al., 2019; Parliamentary Budget Office, 2024).

Recommendations

The adoption of a staged approach to implementing a universal oral healthcare system (Figure 6) would strengthen financial protection, improve health outcomes, and support the development of a sustainable and equitable healthcare system that fully integrates oral health.

This should include: development of an evidence-based definition of essential oral healthcare; a priority setting framework approach to guide oral healthcare funding and integration of oral health into HTA processes.

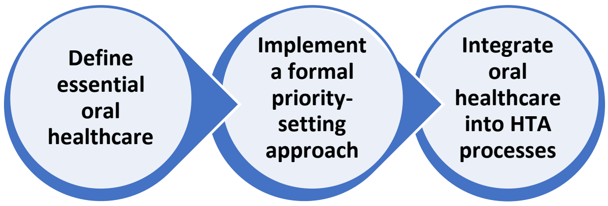

Figure 6: Staged approach to financial protection and enabling universal access to essential oral healthcare in Australia.

Recommendation 1: Define essential oral healthcare in Australia

In Australia, the absence of a nationally agreed, evidence-based definition of essential oral healthcare presents significant challenges in effective resource allocation and determining which dental services should receive government subsidies. This lack of consensus hampers efforts to establish a comprehensive and equitable oral healthcare framework.

To address this issue, Australia should adopt the WHO approach as the foundation for developing a national dental schedule that clearly defines essential oral healthcare services (Benzian et al., 2022; WHO, 2024).

The definition of universal oral healthcare coverage and the WHO framework for essential oral healthcare (Benzian et al., 2022; WHO, 2024).

Universal oral healthcare coverage

Definition and selection of essential interventions based on priorities, burden, resources available, feasibility of interventions, etc.

Agreement on coverage: population access and financial coverage, service arrangement and quality assurance

Essential oral healthcare

Interventions for the most prevalent oral health problems comprising:

An agreed set of safe, quality, and cost-effective interventions at the individual and community level

Promoting and protecting oral health, as well as preventing and treating common oral diseases appropriate rehabilitative services

Goal: maintain health, productivity, and quality of life

The WHO advises member states to undertake a structured national stakeholder engagement process to review scientific evidence, assess workforce capacity, and identify cost-effective oral health interventions (WHO, 2024).

Establishing a nationally agreed definition will enable the Australian Government to make informed resource allocation decisions, ensuring financial protection and equitable access to care within the framework of universal health coverage.

This proposal could be further supported through coordinated action across state and territory jurisdictions, to oversee service delivery and workforce planning that enables flexible care models to be adapted locally, but meet national equity and quality standards

Historically, proposed universal dental schemes in Australia have primarily focused on services delivered by dental practitioners, often neglecting the critical role of non-dental health professionals in preventive oral healthcare (Han et al., 2024). Expanding the involvement of primary care providers, community health workers, and allied health professionals in preventive oral health strategies will enhance accessibility, affordability, and better health outcomes, particularly in rural and remote regions.

Given that primary healthcare professionals are the main providers of health services in rural and remote communities in Australia, they are well-positioned to offer dental services to prevent oral disease (e.g., screening for risk factors and application of topical fluorides). Therefore, it is crucial to include non-dental health practitioners in any framework for providing essential oral healthcare (Table 2).

This is aligned with the recommendations of the Independent Scope of Practice Review (DoHAC, 2024). Further work will be needed to explore how other dental services such as artificial intelligence, tele-dentistry and emerging technologies may meet the definition of essential oral healthcare.

Table 2: Proposed essential oral healthcare in Australia (Nguyen et al., 2025).

Description of services	Health practitioner service provider
Oral health screening and referral Oral health behaviour changes interventions Professional tropical fluoride therapy Oral health consultation (including oral examination, shared decision-making and oral healthcare plan) Periodontal maintenance Course of non-surgical periodontal therapy	Dental practitioners, medical practitioners, nurse practitioners and midwives, pharmacists and Aboriginal and Torres Strait Islander health practitioners working in non-dental primary health settings
Removal of tooth Repair of tooth with direct restorations Repair of tooth with indirect restorations Course of endodontic therapy Course of endodontic therapy Course of orthodontic treatment Course of orthodontic treatment with orthognathic surgery	Dental practitioners

Recommendation 2: Implement a formal priority -setting approach

To address persistent gaps in public funding and access to oral healthcare, Australia should establish a formal priority-setting framework to guide investment decisions in oral health services (COAG Health Council, 2015; Seixas et al., 2021).

A structured priority-setting approach enables policymakers to direct limited resources toward interventions that deliver optimal health outcomes based on agreed criteria, including cost-effectiveness, quality, and feasibility (Carter et al., 2008; Robinson et al., 2012; Teerawattananon et al., 2016).

Priority-setting mechanisms typically follow two interconnected steps (Carlsson, 2004):

- Filtration: Narrowing down health fields to identify priority areas.
- Selection: Choosing specific health fields or technologies for formal assessment.

In Australia, the MSAC and the PBAC serve as HTA bodies for evaluating health services and technologies under the Medicare Benefits Schedule (MBS) and Pharmaceutical Benefits Scheme (PBS), respectively. These HTA processes focus primarily on the assessment of individual health services or pharmaceutical products for national funding inclusion (Angell et al., 2016; Whitty and Littlejohns, 2015).

By contrast, the Assessing Cost-Effectiveness (ACE) approach provides a broader, system-level framework for evaluating multiple health interventions simultaneously.

Through its structured six-step process (Figure 7), the ACE methodology is able to integrate technical economic analysis with stakeholder engagement, ensuring transparency, accountability, and policy relevance (Carter et al., 2008; Mihalopoulos et al., 2013).

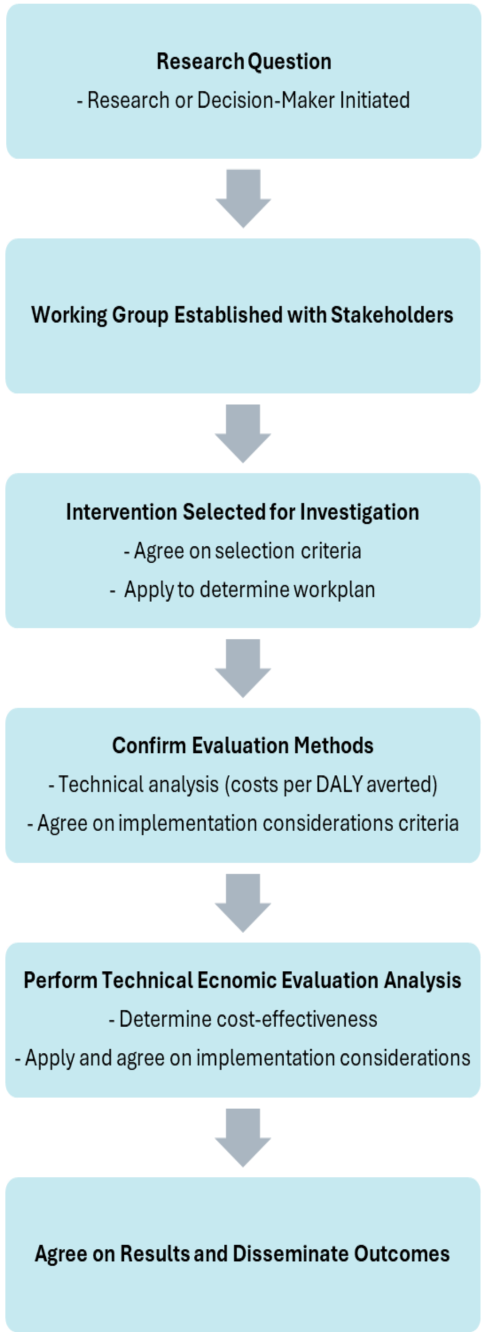

Figure 7: Six steps using the ACE priority-setting approach (adapted from Carter et al., 2008).

The ACE methodology extends beyond individual service assessments by incorporating key considerations such as cost-effectiveness, equity, and feasibility, supporting strategic investment decisions across health policy domains.

The ACE approach is particularly relevant to oral healthcare, where service delivery remains fragmented, the evidence base is inconsistent, and funding decisions must account for long-term population health impact and sustainability.

The ACE approach has been successfully applied in several health domains, including cancer (Carter et al., 2000), mental health (Vos et al., 2005 The ACE framework has been successfully applied in various health domains, including:

- Cancer care (Carter et al., 2000),
- Mental health (Vos et al., 2005),
- Obesity prevention (Carter et al., 2009),
- Public health initiatives (Ananthapavan et al., 2018; Le et al., 2020; Vos, 2010).

Application of ACE in oral health policy

The ACE–Oral Health Prevention study has assessed the cost-effectiveness and population-level impact of preventive interventions targeting dental caries and periodontitis (Bernabe et al., 2025; Nguyen et al., 2023b). Findings indicate that the ACE approach provides a consistent and evidence-based method for modelling and comparing oral health interventions, making it an ideal framework for guiding investment in essential oral healthcare services.

Given the significant fiscal implications associated with the implementation of universal dental care (Clarke and Cutler, 2024; Duckett et al., 2019; PBO, 2024), the ACE–Oral Health Prevention model offers a scalable and pragmatic approach to incrementally expanding public investment in oral health.

Its emphasis on evidence-based decision-making, equity, and cost-effectiveness makes it a valuable policy instrument for advancing universal access to essential oral health services.

Alignment with Value-Based Healthcare (VBHC)

While not synonymous with value-based healthcare (VBHC), the ACE methodology is closely aligned with VBHC principles. It supports high-value service identification, ensuring that investments maximise health benefits relative to cost, while flagging interventions of limited or uncertain value. The ACE methodology incorporates economic evaluation, which compares one intervention with another to determine whether the intervention is cost-effective and resource allocation.

This contrasts with VHBC, which centres on focusing on outcomes that matter most to consumers, relative to cost-efficiency. Given existing knowledge gaps in the cost-effectiveness of oral health prevention, applying ACE methodologies can inform strategic prioritisation, optimising healthcare resource allocation and service delivery.

In jurisdictions such as Victoria, where oral healthcare is increasingly being aligned with VBHC principles (Hegde et al., 2024; Lin et al., 2023; Nguyen et al., 2023), the ACE methodology provides a robust, evidence-based framework to enhance oral healthcare prioritisation and oral health funding policy sustainability.

Recommendation 3: Integrate oral healthcare into HTA processes

The Australian Government should enable dental services and dental practitioners into existing HTA processes to ensure evidence-based resource allocation and equitable access to essential oral healthcare.

International experience highlights the important role of HTA in guiding evidence-based investment in oral healthcare. For example, HTA agencies in Canada and the United Kingdom have demonstrated how economic evaluations can be used to inform decisions about the value, cost-effectiveness, and prioritisation of government subsidised oral healthcare.

Integrating oral health into national HTA processes can help optimise funding by focusing investment on high-value, evidence-based services that improve outcomes and reduce health inequities.

Canada's Drug Agency

Conducted evaluations on the effectiveness and economic value of interventions such as water fluoridation, school-based dental programs, and fluoride varnish application, helping to guide public funding decisions that balance cost with population health impact (Bhatia et al., 2023).

National Institute for Health and Care Excellence UK

Developed clinical guidelines and conducts economic evaluation of dental services, including recall intervals and preventive care, leading to more consistent, cost-effective service provision across the NHS (Coulthard et al., 2015; Pepper et al., 2016).

By enabling funding decisions for dental services and dental practitioners in Australia's existing HTA mechanisms, the Australian Government can adopt similar approaches from overseas, ensuring oral healthcare is evaluated alongside other health interventions for its contribution to value, equity, and sustainability within universal health coverage.

As a first step, the Health Technology Assessment Review Implementation Advisory Group (DoHAC, 2024b) could explore reforms that support the inclusion of dental practitioners in HTA decision-making, ensuring oral healthcare is appropriately prioritised within universal health coverage.

The Child Dental Benefits Schedule and state and territory dental programs should be reviewed through the lens of essential oral healthcare and health economics, to assess their effectiveness, equity, and value for public investment.

Aligning oral healthcare funding decisions with the Health Technology Assessment Policy and Methods Review (DoHAC, 2024c) will promote more equitable access and financial protection for all Australians.

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