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Quality Appraisal of Economic Evaluations done on Oral Health Preventive Programs-A Systematic Review

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Abstract

Objectives: If economic evaluations are to be used by decision makers, such evidence has to be robust so that the relevant policy maker use them. This study was undertaken with the purpose of identifying economic evaluations done on oral health preventive programs and to assess the standard of economic evidence in this field.

Methods: A systematic search was conducted using four major electronic databases in order to search for economic evaluations done on oral health preventive programs. This included economic evaluations that were published between January 1975 and May 2018 on preventive interventions for periodontal disease, oral cancer screening, and other common oral health conditions. To avoid duplications with previous studies, for dental caries interventions, this review included studies from April 2012 and May 2018. “Guidance to undertaking reviews in health care”, developed by York University, was used to assess the quality of reporting in the evaluations, using which strengths and shortcomings were identified.

Results: A total of 2026 records were initially found. After title and abstract screening, and elimination by full text review, 33 relevant economic evaluations were identified. Majority of the economic evaluations included were conducted on dental caries prevention; a few were done on oral cancer screening, periodontal disease, and general preventive dentistry (health promotion, oral hygiene etc.).

Conclusions: In comparison to the findings observed in previous reviews, there has been improvements in the quality of reporting in economic evaluations. Several areas still in need

for improve were identified (e.g., productivity costs, currency and prices, generalizability issues).

Keywords:

Systematic review, Economic evaluation, oral health, preventive measures

Background

Although effective individual, community, and clinical preventive measures can successfully avert oral diseases and conditions, conventional therapeutic oral health care imposes a significant economic burden on many countries, with over ten percent of the public health expenditure being spent on oral health (1). For the individual, oral health care is expensive and not universally available (2). Furthermore, objectives in oral health care cannot be achieved by providing treatment only. This highlights the importance of prevention. Over the last few decades, there has been a shift of focus towards prevention resulting in a lower prevalence of oral diseases and conditions (1).

Public health decision-making is reliant on evidence and restricted by a budget. Resource scarcity demands for an informed decision before allocation of manpower and money for any health intervention (3). Allocation of resources among competing health treatments can be emotionally and politically charged, therefore decision makers prefer to turn to rational and consistent methods of evaluation designed to maximize the efficient use of health expenditure. Economic evaluation (EE) is a tool developed to serve this need. EE enables comparisons between different options using systematic analysis of costs, benefits and outcomes, to help make an objective decision regarding the allocation of resources (3,4).

Valid data and effective use of economic evaluations provide sound evidence, which is accessible to policy makers, researchers, practitioners, and community leaders (5). This evidence needs to be of sound quality in order to assist policy and decision makers (6,7). Economic evaluations are commonly used in decision making processes about health programs; however, comparatively, less examples exist in the oral health literature, since the

emphasis of EE in oral health has been on treatment, rather than preventive programs. Furthermore, significant limitations have been highlighted in the quality of reporting economic evaluations done on oral health interventions. A systematic review of dental caries preventive interventions concluded that the existing economic evaluations did not provide concrete data to draw evidence from (8,9). Furthermore, it suggested that, although there has been an increase in the number of economic evaluations conducted in oral health in the last decade; their standard still needs improvement (9). Similar conclusions were reached by Tonmukayakul et al. (10), who used a very broad category to assess both partial and complete cost analyses done in the area of oral health programs, involving both prevention and treatment. These reviews suggested that improvements could be achieved by including additional information on adjustments for discounting in addition to sensitivity analyses.

A recent systematic review of decision analytic models for prevention and treatment of caries, also concluded that the methodological quality is unsatisfied and recommended that future modelling studies should adhere to good practice guidelines, especially with respect to data quality evaluation, utility values incorporation, and uncertainty analysis (11).

Building on these reviews, the objective of this study was to assess the methodological quality of studies relating to economic evaluations of preventive oral health interventions. This will expand the focus from dental caries only to oral cancer, periodontal disease, dental trauma, and oral diseases and conditions, to provide guidance and recommendation to improve reporting for future EE. In this study, the quality of the reporting of economic evaluations will be related to quality of reporting rather than the actual results of economic evaluation as the outcome measure. This has been referred as one of the uniqueness of the present approach

(5). In addition, it was also an objective to update the systematic review done by Mariño and his collaborators on dental caries prevention and assess whether there has been an improvement in the quality of EE over time (9). Hence, the study aimed at systematically review available economic evaluations on prevention of oral diseases and conditions and provide a narrative synthesis of existing EE to provide guidance and recommendation to improve reporting to research for future EE. It was not the aim of this review to present economic findings for individual studies or draw conclusions from the findings of individual studies; or synthesize findings across studies.

Methodology

This systematic review was done in accordance with the Centre for Review and Dissemination's "*Guidance for undertaking reviews in health care*" developed by the York University in 2009 (12) and we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (13) for the reporting of this systematic review. A comprehensive, systematic literature search was conducted in order to identify economic evaluations done on oral health preventive programs. Primary searches were done in Embase, PubMed, Web of Science and EconLit. Additionally, NHS Economic Evaluation Database (NHS EED), Literatura Latino- Americana e do Caribe em Ciências de Saúde (LILACS) and Scientific Electronic Library Online (SciELO) were also searched for citations. Since EE in the field of oral health are scarce, we designed a sensitive search strategy to find all EE related to oral health. The details of the search strategy used are listed in supplementary data (See Appendix 1).

As this systematic review is an update of a previously conducted review on dental caries prevention – for dental caries prevention, it only included articles published from April 2012 to May 2018. However, for all other areas of preventive dentistry such as periodontal disease, cancer screening and oral hygiene etc., the time frame included articles published from January 1975 to May 2018.

A set of inclusion criteria was constructed, similar to the one used in the systematic review by Mariño et al. (9). Inclusion criteria were:

- Only preventive interventions were searched for and included for evaluation.
- It included articles in English, Spanish, Italian, French or Portuguese.
- Only complete economic evaluations done using randomized control trials, community trials, cross sectional studies or models were considered for inclusion. Complete economic evaluations compare, at least two, relevant alternatives in terms of both cost and outcome (3).

Reviews, conference papers, expert opinions, treatment interventions, literature reviews and research protocols were excluded from the review.

Titles, abstract and full text articles were selected independently by two investigators (GR and RM) to verify their eligibility. A third reviewer resolved the discrepancies (CZ).

Data extraction and methodological quality assessment of the studies were also conducted by independently by two reviewers (GR and either RM or CZ). A random sample of 5 articles were selected in order to conduct a standardization of criteria exercise before starting data analysis. The remaining of the papers were assessed and marked following the same principles

that were discussed during this exercise. Consequently, the studies were independently marked by two reviewers using the York University's evaluative framework (12). All discrepancies and differences were discussed and resolved by consensus until 100% agreement was reached.

An Excel spreadsheet was prepared to categorize the studies by author, country, year, intervention category and type of economic evaluation used and the source of effectiveness estimates. In order to evaluate and assess the key elements of an economic evaluation that are likely to influence the strength of the study results, a comprehensive evaluative tool was used (12) (See Appendix 2). This was a 36-point checklist that grouped the important methodological qualities of economic evaluation into three main categories based on study design (7 items), data collection (14 items) and data analysis (15 items) (12). Each category examines key elements necessary to conduct a good and reliable economic evaluation. The answers were in the categories: "Yes", "No", "Can't tell" and "Not applicable". Three scores were generated for each major category on the checklist, thereby synthesizing a 'Study design' score, a 'Data collection method' score and a 'Data analysis' score. The sum of these scores provided an overall assessment score for each study included.

Results

Study selection

The PRISMA diagram (13) for the process of identification of relevant economic evaluations is shown in Figure 1. The initial search identified 2026 records; PubMed (n=917), Embase (n=981), Web of Science (n=94), EconLit (n=1), Lilacs (n=25), SciELO (n=8). Duplicates

(n=176) were removed primarily using Endnote bibliographic management software, following which, the unidentified ones were removed manually, leaving 1850 unique references. This was followed by an exclusion based on title and abstract (n=1802) leaving 48 publications to be assessed by full text. Of the full-text articles reviewed, four were excluded as they were not economic evaluations (reviews, congress abstract or protocol), eight because were partial economic evaluation and five were treatment-based economic evaluations. Additionally, three studies were identified by reviewing reference lists. The 34 articles identified correspond to 33 studies, because one study was reported in more than one article. Finally, 33 complete economic evaluations were included for data extraction and analysis (6, 14-45).

Study characteristics

Economic evaluations included in this study were from fourteen countries. The majority was conducted either in the United States of America (n=9), or United Kingdom (n=4); or Germany (n=4); or Australia (n=4). Studies were also conducted in Brazil (n=3); Netherlands (n=2); India (n=2); and New Zealand (n=2); Chile (n=1); China (n=1); and Thailand (n=1). Background information has been summarized in Table 1.

The majority (n=26; 78.8%) of the economic evaluations reviewed were conducted on dental caries prevention programs including water fluoridation (n=3), preventive sealants and varnishes (n=13), other caries prevention programs (n=5), and mixed methods. This was despite a narrower time frame (2012 onwards) for this type of prevention programs. Other economic evaluations were done on periodontal disease prevention (n=2), oral cancer screening (n=4) and one other oral health related topics (i.e. management of third molar). The

majority of the studies had conducted a cost-effectiveness analysis (CEA) (n=24; 72.7%). Four studies conducted a cost-utility analysis (CUA) and only one was a cost-benefit analysis. The rest used a combination of cost analysis techniques, that is, CEA-CUA (n=4).

Technical aspects of quality appraisal of economic evaluations

Study design

Study design score ranged from 4 to 7 (highest score possible: 7), with 81.8% scoring either 6 or 7. These scores demonstrate nearly complete reporting of all details of study design in the majority of the publications. Study objectives is the most important piece of info required. All the included studies identified the research question and the importance of the research question. Six studies did not indicate the viewpoint or could not be identified.

Comparator information is also an important requirement. Thirty-two (93.9%) clearly described the comparator (alternative intervention) and the rationale behind choosing it. The majority (n= 29; 87.9%) reported the form of economic evaluation used. However; about a quarter (24.1%) of those that indicated it, did not justified the rationale for choosing a particular form of economic evaluation. The viewpoint of the study was reported by 27 (81.8%) studies. The York University's evaluative framework check list items and results are presented in Table 2.

Data collection method

Data collection method scores (highest score possible: 14) ranged from 7 to 13. The overall mean was 10.4 (s.d. 1.9), with about three-quarters (72.7%) of the studies scored 10 or above. All studies clearly defined the source of effectiveness data. Overall, 69.7% of studies provided

details of the design and results of the study used, but justification of the choice of model, among those studies that reported a model, was not always given in. All but one reported the methods the primary outcome measure (97.0%); and about the methods used to value health states and other benefits (97.0%).

Problem areas were identified with respect to reporting productivity costs and, when using modelling, the justification of model used. In the majority of the studies the economic evaluation was based on models (n=29; 87.9%). Of them, just above half of the studies (58.7%; n=17) provided a justification for the choice of model used and the key parameters on which it was based. Regarding productivity costs [i.e., the costs associated with paid and unpaid production loss and replacement due to illness, disability, or death of productive persons (46)], were factored in by 33.3% (n=11) of the studies. Productivity costs, when applicable, were not reported by 42.1% (n=8) of the studies, despite the perspective demanding it. Furthermore, discussion of the relevance of productivity costs was present in 57.9% of these cases (n=11).

Although the currency used was explicitly reported by the majority of the studies (78.8%, n=26). However, just above half of the studies (51.5%; n=17) failed to give details of currency conversion into a commonly used currency (e.g., US Dollars, Euros, etc.). Most of the studies (71.4%) that did report currency conversion into a commonly used currency (e.g., US Dollars, Euros, etc.). were relatively new (i.e., after 2014). Three of the seven studies which failed to do so were from the USA and another two from the UK.

Data analysis

Data analysis scores (highest score possible: 15) ranged from 6 to 15 with an overall mean of 12.0 (s.d. 2.2). About half the studies (48.5%) scored 13 or above. Two obtained the maximum score on this category. All studies appropriately provided an answer to the study question and reported conclusions, with 81.8% (n=27) reporting limitations of the study. More than half of the studies (48.5%; n=16) reported on the generalizability of the study with the 56.2% of them conducted in 2016 or later.

The majority of studies (97.0%; n=32) reported and clearly defined the timeframe considered. Discounting is an economic evaluation concept that allows for appropriate comparison between costs incurred or outcomes seen at two different points in time (a year or more apart). Out of the studies included, four did not require discounting. Another 23 (69.7%) mentioned the discount rate used, but six (18.2%) did not report on discounting even though the time frame was over a year. Of the studies that mentioned the discount rate used (n=23), just above half (n=13; 56.5%) provided justifications for the chosen rate.

Twenty-nine (87.9%) studies conducted a sensitivity analysis for the evaluation, but only 24 (82.8%) reported on the variables taken into consideration. Additionally, three studies (10.3%) failed to report the range over which the sensitivity analysis was done. Incremental cost-effectiveness ratio (ICER) was reported in 23 (69.7%) studies. The majority of them (90.9%) compared relevant alternatives in order to devise the ratio.

The overall assessment score was calculated as the sum of the scores in the three evaluated categories (See Table 2). They ranged from 20 to 35 with a mean of 28.7 (s.d. 3.8); 45.5% of the studies scored 30 or above. Only one study, Koh and collaborators (30), obtained a score of 35.

Compared to EE dental caries prevention studies and other areas of preventive dentistry, no statistical differences are present in any of the three domains. Overall, EEs on dental caries prevention showed better quality compared to other areas of prevention (28.9 vs 28.0, respectively). For the categories of data collection and data analysis, dental caries prevention studies scored higher than other areas of preventive dentistry (10.7 vs 9.4 and 12.0 vs 12.1 respectively). For example, a higher proportion of EE in other preventive dentistry failed to report discount rates, currency and price data or to provide details of statistical test used for stochastic data, or to discuss generalizability issues (Figure 2). However, when compared to the 2012 analysis (9), the quality assessment for all three components are significantly higher ($p<0.0001$).

Discussion

This systematic review identified thirty-two economic evaluation studies covering a range of oral health prevention programs, including dental caries prevention (e.g., water fluoridation, dental sealants), and to a less extent, oral cancer, periodontal disease and other oral diseases and conditions (e.g. prevention of complications with third molars retention). Consistent with quality of reporting appraisals done previously (9,10), the present review indicates that the most commonly used form of economic evaluation is cost-effectiveness analysis (CEA). Three studies also included a combination of cost-utility analyses alongside CEA implying the use of multiple outcome measures while conducting the analyses. Although, there were discrepancies in the use of economic evaluation terms (e.g. cost-utility and cost-effectiveness used interchangeably).

A simply comparison with reports of economic evaluations on dental caries prevention interventions that were published before 2012 (9) with current findings, shows remarkable improvements in the quality of its reporting (See Figure 2). Among the most noteworthy progress in reporting has been seen in stating the perspective and comparators, type of economic evaluation utilized and its justification, and aspects of sensitivity analyses (i.e., choice of variables and range while conducting sensitivity analysis). Areas in need of improvement, which might affect the robustness of the studies (3), were the lack of inclusion of productivity costs and unjustified choice of discount rate. This is important because, depending on the perspective of the study (e.g., societal), costs for productivity lost due to the time spent in dental care and costs of transportation to and from the health centre, are to be included. Additionally, when the time horizon exceeds 12 months, adjustments must be made due to the temporal distribution of costs (3); in these cases, the selection of different discount rates would have an effect on the results of the EE.

Other issues of concern in the present review were the generalizability and portability of the results. Although it is not always possible to account for generalizability factors as cost considerations vary with setting (18); it should nevertheless be addressed in the conclusion (47,48). This comparison also shows areas of slight improvement. For example, the reporting of an incremental analysis still allows for improvements.

Data quality is an important concern, although it was not assessed in the present review for any of the studies included. However, some studies reported unavailability of sound data to base models on as a major limitation in their evaluation. For example, it is challenging to estimate the prevalence of dental caries because of the absence of updated data (49).

Additionally, both Kroon and Van Wyk (50) and Mariño and collaborators (6) emphasized the difficulty of measuring indirect or intangible outcomes in oral health, such as less disability or pain. This can be particularly challenging for a cost-benefit analysis where monetary values have to be assigned to outcomes (3).

The number of economic evaluations on dental caries prevention significantly outnumbered those done on prevention of periodontal disease or oral cancer. Exposure to fluoridation programs (e.g. community water fluoridation) and other dental caries prevention approaches lead to more natural teeth being retained potentially increasing dental and periodontal care needs. Additionally, the combined effect of increasing life expectancy, advances in medicine, and other social and economic factors brings about new challenges and other potential threats to oral health that should be considered for health promotion and disease prevention. Campain and her collaborators (51) modelled the impact of changing dental needs on the cost savings from community water-fluoridation. Their conclusion was that water-fluoridation might stop being cost-effective, not because of its effectiveness in preventing dental caries, but because of the increase in cost of treatment of periodontal disease, retreatment of old restorations, etc. This is important and relevant as it highlights the need for oral health preventive interventions focussed on periodontal disease as an area of increasing relevance.

Additionally, as the population ages, the risk of oral and pharyngeal cancers increases, screening and early diagnosis play important roles in creating awareness of oral cancer, and promoting healthy lifestyles, attitudes and habits. Nonetheless, this review found that the amount of economic evaluations done on preventive interventions of oral diseases, other than dental caries, continued to be limited. The number of oral cancer screening interventions (n=4)

is significantly lower than interventions for dental caries (n=26). To put this finding into perspective, a single PubMed search of economic evaluations revealed 62 done on skin cancer and 501 on lung cancer based on the cost-effectiveness of education and behavioural change or screening campaigns. Given the financial burden, morbidity and mortality associated with oral cancer, a greater number of programs need to be evaluated in order to gather economic evidence before implementation.

The study highlights gaps in reporting economic evaluation in the literature on oral health primary prevention interventions, in order to encourage qualitative improvement for research on EE, which would provide more attractive and robust input to decision makers. However, there are a few limitations of this review on which future quality appraisals should be conducted. For example, no attempt was made to search grey literature or contact authors of unpublished studies. Searching the grey literature might have expanded the evidence (52). In addition, although the majority of the economic evaluations found were in English, Spanish or Portuguese, a language bias was present, as some economic evaluations were found either in Dutch or in German and therefore not included. Further evaluation of the quality of effectiveness data must also be scrutinised. This review could be extended by reporting the quality findings by type of intervention, so users of this information understand the quality of the economic studies for the particular intervention they are considering.

Although our search does not exclude the possibility of missing other relevant publications, we do not consider that that would have our conclusions importantly affected. However, we believe that this was minimized due to the sensitive search strategy used, the additional search of references by hand and the double independent review process used.

Additionally, although there is no gold standard evaluation tool for economic evaluations, there are by now several standards of EE reporting. For example, the Critical Appraisal Skills Programme (CASP) (53); the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) (54); Drummond et al, (3) to name a few. In the present review, the University of York checklist was used to keep it in line with that used in a previous review (9) to facilitate a comparison. Should one of those being used instead of the University of York checklist may have affected the results of this review.

Good quality economic evaluations have enormous potential to assist policy makers to objectively make decisions regarding program implementation. This systematic review was an attempt to exhibit shortcomings in the quality of economic evaluations reporting done solely on preventive oral health interventions. Previous quality appraisals either used a very broad category to assess the cost analyses with respect to both prevention and treatment or employed narrow selection criteria (i.e., dental caries prevention only) (9,10). The present study also hopes to provide the foundation and encouragement for more evaluations as well as quality appraisals in order to maintain the standard of economic evaluations published in the future. Having said that, despite the limited quantity of economic evaluations, the quality has been steadily improving compared to economic evaluations published in the past.

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Table 1. Systematic Review of Economic Evaluations in Oral Health Preventive Programs. Study characteristics and quality assessment.

Reference	Country	Intervention category	Type of EE	Source of effectiveness data	Outcome measure	Perspective	Design assessment (Range 0-7)	Data collection assessment (Range 0-14)	Analysis assessment (Range 0-15)
Wesley et al. 1992 (14)	India	Oral cancer (Screening)	CEA	Trial	Cost per early cancers and pre-cancers detected	Societal	7	11	12
Edwards et al. 1999 (15)	UK	Third molar retention	CEA	Model	Cost per management of asymptomatic, third molars	Health care provider/ patient	7	11	12
Higashi et al. 2002 (16)	USA	Periodontal disease Genetic testing to identify high risk patients)	CUA	Model	QALY gained	Health payer	6	10	13
Van der Meij et al. 2002 (17)	Netherlands	Oral cancer (Screening)	CUA	Model	QALY gained	Not stated	6	7	13
Subramanian et al. 2009 (18)	India	Oral cancer (Screening)	CEA	Trial	Cost per life saved	Societal	7	9	13
Dedhia et al. 2011 (19)	USA	Oral cancer (Screening)	CUA	Model	QALY gained	Societal	6	10	11
Cobiac & Vos, 2012 (20)	Australia	Caries prevention (Water fluoridation)	CUA	Model	DALY averted	Public payer	6	12	11
Frazão 2012 (21)	Brazil	Caries prevention (Supervised tooth brushing)	CEA	Trial	dmft	Not stated	5	8	7

Mariño et al. 2012 (22)	Chile	Caries prevention (water-fluoridation, dental sealants, milk-fluoridation, fluoridated mouthrinses, APF-Gel, supervised tooth brushing)	CEA	Model	DMFT averted	Societal	6	12	14
Pukallus et al. 2013 (23)	Australia	Caries Prevention (Telephone prevention programme)	CEA	Model	Carious teeth prevented	Public Payer	7	13	12
Tagliaferro et al. 2013 (24)	Brazil	Caries prevention (Glass-ionomers sealants, fluoride varnish)	CEA	Trial	DMFT	Health care system	6	8	11
Ney et al. 2014 (25)	USA	Caries prevention (Dental sealants)	CEA	Model	Restorations, extractions averted	Public Payer	7	11	11
Mariño et al. 2014 (6)	Australia	Periodontal disease	CEA/CM A	Trial	Gingival bleeding	Societal	7	8	10
Chi et al. 2014 (26)	USA	Caries prevention (Dental sealants)	CBA	Model, clinical database	Cost per treatment averted	Public Payer	7	11	13
Vermaire et al. 2014 (27)	Netherlands	Caries prevention (Professional fluoride applications)	CEA	Trial	DMFS	Health care system, societal	7	11	14
Fyfe et al. 2015 (28)	New Zealand	Caries prevention (Water fluoridation)	CEA	Model	dmft/DMFT	Societal	7	9	14
Edelstein et al. 2015 (29)	USA	Caries prevention (Community water fluoridation, dental sealants, fluoride	CEA	Model	dmft/DMFT	Not stated	4	10	6

		varnish applications, home tooth brushing with fluoride toothpaste, and counseling)							
Koh et al. 2015 (30)	Australia	Caries prevention (Telephone prevention programme, hoe visits)	CEA/CU A	Model	Cost per treatment averted, QALY	Societal	7	13	15
Atkins et al. 2016 (31)	USA	Caries prevention (Community water fluoridation, dental sealants, fluoride varnish applications, home tooth brushing with fluoride toothpaste, and counseling)	CEA	Model	Dental caries prevented, general anesthesia prevented	Health care payer	7	13	9
Goldman et al. 2016 (32)	Brazil	Caries prevention (Dental sealant; supervised toothbrushing)	CEA	Trial	New cavitated dentine carious lesion prevented	Government programme	7	11	14
Goldman, et al. 2016b (33)	China	Caries prevention (Glass-ionomers sealants of different viscosity)	CEA	Trial	New cavitated dentine carious lesion prevented	Government programme	6	11	15
Griffin et al. 2016 (34)	USA	Caries prevention (Dental sealants)	CEA/CU A	Model	DMFS/DALY averted	Societal	7	11	11
Neidell et al. 2016 (35)	USA	Caries prevention (Dental sealant, fluoride varnish)	CEA	Trial	DMFT averted	Public Health	7	7	10

Schwendicke, & Gostemeyer 2016 (36)	Germany	Caries prevention (Fluoride rinses, chlorhexidine varnish, silver diamine fluoride varnish)	CEA	Model	Root caries averted	Public-Private Payer	7	10	14
Tickle et al. 2016 (37)	UK	Caries prevention (Fluoride varnish, tooth brushing with fluoride toothpaste, and preventive advice)	CEA	Trial	dmsf averted	Societal	4	10	14
Chestnutt et al. 2017 (38)	UK	Caries prevention (Dental sealant, fluoride varnish)	CEA/CUA	Trial, model	Caries avoided, QALY, QATY	National Health Service	7	13	14
Khouja & Smith 2017 (39)	USA	Caries prevention (Fluoride varnish, dental sealants,)	CEA	Model	Caries lesion in first permanent molars	Private Payer	6	8	9
Moore et al. 2017 (40)	New Zealand	Caries prevention (Water fluoridation)	CUA	Model	QALY gained	Not stated	6	11	10
O'Neill et al. 2017 (41)	UK	Caries prevention (Varnish fluoride)	CEA	Trial	Caries free, DMFS averted	Public Payer	5	7	12
Schwendicke et al. 2017 (42)	Germany	Caries prevention (Fluoride Varnish)	CEA	Model	DMFT averted	Public-Private Payer	7	13	14
Schwendicke and Stolpe. 2017b (43)	Germany	Caries prevention (Fluoride Varnish, Fluoride -Gel)	CEA	Model	DMFT averted	Public-Private Payer	5	12	13
Mariño et al. 2018 (44)	Thailand	Caries prevention (Fluoridated milk)	CEA	Model	DMFS averted	Societal	7	16	9
Schwendicke et al. 2016 (44)	Germany	Caries prevention (Sugar tax)	CEA	Model	DMFT averted	Public-Payer	5	11	12

CEA: Cost-effectiveness analysis; CUA: Cost-utility analysis; CBA: Cost-benefit analysis; DALY: Disability adjusted life years; QALY: Quality adjusted life years; QATY: Quality adjusted tooth years; DMFT/S: Decayed, Missing, Filled Teeth/Surfaces; dmft/s: Decayed, Missing, Filled teeth/surface in temporary dentition.

STUDY DESIGN:	Yes	No	Not clear/ not applicable
1. Was the research question stated?	100		
2. Was the economic importance of the research question stated?	100		
3. Was/ were the viewpoint(s) of the analysis clearly stated and justified ?	81.8	12.1	Not clear 6.1
4. Was the rationale reported for the choice of the alternative programmes or interventions compared?	97.0		Not clear 3.0
5. Were the alternatives being compared clearly described?	93.9	6.1	
6. Was the form of economic evaluation stated?	87.9	12.1	
7. Was the choice of form of economic evaluation justified in relation to the questions addressed?	69.7	21.2	Not clear 9.1
DATA COLLECTION:			
8. Was/ were the source(s) of effectiveness estimates used stated?	100		
9. Were details of the design and results of the effectiveness study given (if based on a single study)?	71.9		Not app 30.3
10. Were details of the methods of synthesis or meta-analysis of estimates given (if based on an overviews of several effectiveness studies)?	39.4	6.1	Not app 54.5
11. Were the primary outcome measure(s) for the economic evaluation clearly stated?	97.0	3.0	
12. Were the methods used to value health states and other benefits stated?	97.0	3.0	
13. Were the details of the subjects from whom valuations were obtained given?	87.9	3.0	Not clear 3.0 Not app 6.1
14. Were productivity changes (if included) reported separately?	33.4	24.2	Not app 42.4
15. Was the relevance of productivity changes to the study question discussed?	39.4	24.2	Not app 36.4
16. Were quantities of resources reported separately from their unit cost?	78.8	21.2	
17. Were the methods for the estimation of quantities and unit costs described?	75.8	24.2	
18. Were currency and price data recorded?	78.8	21.2	
19. Were details of price adjustments for inflation or currency conversation given?	45.5	42.4	Not clear 12.1
20. Were details of any model used given?	66.7	21.2	Not app 12.1
21. Was there a justification for the choice of model used and the key parameters on which it was based?	51.1	18.2	Not clear 3.0 Not app 27.3
ANALYSIS AND INTERPRETATION OF RESULTS			
22. Was time horizon of cost and benefits stated?	97.0	3.0	
23. Was the discount rate stated?	69.7	18.2	Not app 12.1
24. Was the choice of rate justified?	39.4	39.4	Not app 21.2
25. Was an explanation given if cost or benefits were not discounted?	12.1	15.2	Not app 72.7
26. Were the details of statistical test(s) and confidence intervals given for stochastic data?	54.5	45.5	
27. Was the approach to sensitivity analysis described?	87.9	12.1	
28. Was the choice of variables for sensitivity analysis justified?	72.7	21.2	Not app 6.1
29. Were the ranges over which the parameters were varied stated?	78.8	15.2	Not app 6.1
30. Were relevant alternatives compared? (i.e. were appropriate comparisons made when conducting the incremental analysis?)	90.9	9.14	
31. Was an incremental analysis reported?	69.7	24.2	Not clear 6.1
32. Were major outcomes presented in a disaggregated as well as aggregated form?	93.9	6.1	
33. Was the answer to the study question given?	100.0		
34. Did conclusions follow from the data reported?	100.0		

35. Were conclusions accompanied by the appropriate caveats?	81.8	18.2	
36. Were generalisability issues addressed?	45.5	51.5

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STUDY DESIGN:	Yes	No	Not clear/ not applicable
1. Was the research question stated?	100		
2. Was the economic importance of the research question stated?	100		
3. Was/ were the viewpoint(s) of the analysis clearly stated and justified ?	81.8	12.1	Not clear 6.1
4. Was the rationale reported for the choice of the alternative programmes or interventions compared?	97.0		Not clear 3.0
5. Were the alternatives being compared clearly described?	93.9	6.1	
6. Was the form of economic evaluation stated?	87.9	12.1	
7. Was the choice of form of economic evaluation justified in relation to the questions addressed?	69.7	21.2	Not clear 9.1
DATA COLLECTION:			
8. Was/ were the source(s) of effectiveness estimates used stated?	100		
9. Were details of the design and results of the effectiveness study given (if based on a single study)?	71.9		Not app 30.3
10. Were details of the methods of synthesis or meta-analysis of estimates given (if based on an overviews of several effectiveness studies)?	39.4	6.1	Not app 54.5
11. Were the primary outcome measure(s) for the economic evaluation clearly stated?	97.0	3.0	
12. Were the methods used to value health states and other benefits stated?	97.0	3.0	
13. Were the details of the subjects from whom valuations were obtained given?	87.9	3.0	Not clear 3.0 Not app 6.1
14. Were productivity changes (if included) reported separately?	33.4	24.2	Not app 42.4
15. Was the relevance of productivity changes to the study question discussed?	39.4	24.2	Not app 36.4
16. Were quantities of resources reported separately from their unit cost?	78.8	21.2	
17. Were the methods for the estimation of quantities and unit costs described?	75.8	24.2	
18. Were currency and price data recorded?	78.8	21.2	
19. Were details of price adjustments for inflation or currency conversation given?	45.5	42.4	Not clear 12.1
20. Were details of any model used given?	66.7	21.2	Not app 12.1
21. Was there a justification for the choice of model used and the key parameters on which it was based?	51.1	18.2	Not clear 3.0 Not app 27.3
ANALYSIS AND INTERPRETATION OF RESULTS			
22. Was time horizon of cost and benefits stated?	97.0	3.0	
23. Was the discount rate stated?	69.7	18.2	Not app 12.1
24. Was the choice of rate justified?	39.4	39.4	Not app 21.2
25. Was an explanation given if cost or benefits were not discounted?	12.1	15.2	Not app 72.7
26. Were the details of statistical test(s) and confidence intervals given for stochastic data?	54.5	45.5	
27. Was the approach to sensitivity analysis described?	87.9	12.1	
28. Was the choice of variables for sensitivity analysis justified?	72.7	21.2	Not app 6.1
29. Were the ranges over which the parameters were varied stated?	78.8	15.2	Not app 6.1
30. Were relevant alternatives compared? (i.e. were appropriate comparisons made when conducting the incremental analysis?)	90.9	9.14	
31. Was an incremental analysis reported?	69.7	24.2	Not clear 6.1
32. Were major outcomes presented in a disaggregated as well as aggregated form?	93.9	6.1	
33. Was the answer to the study question given?	100.0		
34. Did conclusions follow from the data reported?	100.0		
35. Were conclusions accompanied by the appropriate caveats?	81.8	18.2	
36. Were generalisability issues addressed?	45.5	51.5	

Table 1: Search strategy used in each database for caries

Source	Strategy
Medline	(((((((((tooth) OR teeth) OR dental)) AND (((caries) OR carious) OR cavit*) OR decay*))) OR "DMF Index"[Mesh]) OR "Dental Caries"[Mesh])) AND (((((((("Costs and Cost Analysis"[Mesh]) OR "Cost-Benefit Analysis"[Mesh]) OR cost-effectiveness[tiab]) OR cost-benefit[tiab]) OR cost-utility[tiab]) OR economic evaluation[tiab]) OR economic analysis[tiab]) Filters: Publication date from 2012/01/01 to 2018/12/31
Embase	#22. #6 AND #20 AND [embase]/lim AND [1-1-2012]/sd NOT [2-5-2018]/sd #21. #6 AND #20 #20. #7 OR #18 OR #19 #19. #11 AND #17 #18. 'dmf index'/exp #17. #12 OR #13 OR #14 OR #15 OR #16 #16. decay* #15. cavit* #14. lesion* #13. carious #12. caries #11. #8 OR #9 OR #10 #10. dental #9. tooth #8. teeth #7. 'dental caries'/exp #6. #1 OR #2 OR #3 OR #4 OR #5 #5. 'cost benefit':ti,ab #4. 'cost utility':ti,ab #3. 'cost effectiveness':ti,ab #2. 'cost benefit analysis'/exp #1. 'cost'/exp
ScieLo	(MH:"Costs and Cost Analysis" OR MH:"Cost-Benefit Analysis" OR cost-effectiveness OR cost-utility OR cost-benefit) AND (caries OR MH:"Dental Caries" OR MH:"DMFIndex")
LILACS	(MH:"Costs and Cost Analysis" OR MH:"Cost-Benefit Analysis" OR cost-effectiveness OR cost-utility OR cost-benefit) AND (caries OR MH:"Dental Caries" OR MH:"DMFIndex")
NHS EED	1 MeSH DESCRIPTOR Costs and Cost Analysis EXPLODE ALL TREES IN NHSEED 2 (cost-effectiveness) 3 (cost-utility) 4 (cost-benefit) 5 #1 OR #2 OR #3 OR #4 6 MeSH DESCRIPTOR Dental Caries EXPLODE ALL TREES IN NHSEED 7 MeSH DESCRIPTOR DMF Index EXPLODE ALL TREES 8 (caries) 9 #6 OR #7 OR #8 10 #5 AND #9 11 (#5 AND #9) WHERE LPD FROM 01/01/2012 TO 01/05/2018
Web of Science	TI=(cost-effectiveness OR cost-utility OR cost-benefit OR economic evaluation) AND TI=(caries)

Table 2: Search strategy used in each database for other conditions

Source	Strategy
Medline	((((((((((("Costs and Cost Analysis"[Mesh])) OR "Cost-Benefit Analysis"[Mesh]) OR cost-benefit[tiab]) OR cost-utility[tiab]) OR cost-effectiveness[tiab]) OR economic analysis[tiab]) OR economic evaluation[tiab])) AND (((((((((((("Maxillofacial Injuries"[Mesh]) OR "Dentofacial Deformities"[Mesh]) OR periodontitis[tiab]) OR "Periodontitis"[Mesh]) OR gingivitis[tiab]) OR "Gingivitis"[Mesh]) OR traumatic dental injur*) OR "Pathology, Oral"[Mesh]) OR oral cancer[tiab]) OR "Mouth Neoplasms"[Mesh]) OR "Periodontal Diseases"[Mesh]) OR malocclusion[tiab]) OR "Malocclusion"[Mesh])) AND ("1975/01/01"[PDat] : "2018/12/31"[PDat]))) AND ("1975/01/01"[PDat] : "2018/12/31"[PDat]))
Embase	#25. #26 AND #28 AND [embase]/lim AND [1975-2018]/ #24. #26 AND #28 #23. #2 OR #3 OR #4 OR #5 #22. #15 OR #16 OR #17 OR #18 OR #19 #21. 'periodontitis'/exp #20. 'malocclusion'/exp #19. malocclusion:ti,ab #18. oral AND cancer:ti,ab #17. traumatic AND dental AND injur:ti,ab #16. gingivitis:ti,ab #15. periodontitis:ti,ab #14. 'periodontal disease'/exp #13. 'mouth tumor'/exp #12. 'oral mucosal disease'/exp #11. 'gingivitis'/exp #10. 'dentofacial deformity'/exp #9. 'maxillofacial injury'/exp #8. #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 #7. economic AND evaluation:ti,ab #6. economic AND analysis:ti,ab #5. 'cost effectiveness':ti,ab #4. 'cost utility':ti,ab #3. 'cost benefit':ti,ab #2. 'cost benefit analysis'/exp #1. 'cost'/exp
ScieLo	(MH:"Costs and Cost Analysis" OR MH:"Cost-Benefit Analysis" OR cost-effectiveness OR cost-utility OR cost-benefit) AND (MH:"Malocclusion" OR MH:"Periodontal Diseases" OR MH:"Mouth Neoplasms" OR MH:"Pathology, Oral" OR MH:"Gingivitis" OR MH:"Periodontitis" OR MH:"Dentofacial Deformities" OR MH:"Maxillofacial Injuries")
LILACS	(MH:"Costs and Cost Analysis" OR MH:"Cost-Benefit Analysis" OR cost-effectiveness OR cost-utility OR cost-benefit) AND (MH:"Malocclusion" OR MH:"Periodontal Diseases" OR MH:"Mouth Neoplasms" OR MH:"Pathology, Oral" OR MH:"Gingivitis" OR MH:"Periodontitis" OR MH:"Dentofacial Deformities" OR MH:"Maxillofacial Injuries")
NHS EED	1 MeSH DESCRIPTOR Costs and Cost Analysis EXPLODE ALL TREES 2 MeSH DESCRIPTOR Cost-Benefit Analysis EXPLODE ALL TREES 3 (cost-effectiveness) 4 (cost-benefit) 5 (cost-utility) 6 #1 OR #2 OR #3 OR #4 OR #5 7 MeSH DESCRIPTOR Malocclusion EXPLODE ALL TREES

	8 MeSH DESCRIPTOR Periodontal Diseases EXPLODE ALL TREES 9 MeSH DESCRIPTOR Mouth Neoplasms EXPLODE ALL TREES 10 MeSH DESCRIPTOR Pathology, Oral EXPLODE ALL TREES 11 MeSH DESCRIPTOR Gingivitis EXPLODE ALL TREES 12 MeSH DESCRIPTOR Periodontitis EXPLODE ALL TREES 13 MeSH DESCRIPTOR Dentofacial Deformities EXPLODE ALL TREES 14 MeSH DESCRIPTOR Maxillofacial Injuries EXPLODE ALL TREES 15 #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 16 #6 AND #15 17 (#6 AND #15) IN NHSEED, HTA 18 (#6 AND #15) IN NHSEED
Web of Science	TI=(cost-effectiveness OR cost-utility OR cost-benefit OR economic evaluation) AND TI=(maxillofacial Injuries OR periodontitis OR gingivitis OR traumatic dental injur* OR oral pathology OR oral cancer OR mouth neoplasms OR periodontal diseases OR malocclusion)

Table 1. Systematic Review of Economic Evaluations in Oral Health Preventive Programs. Study characteristics and quality assessment.

Reference	Country	Intervention category	Type of EE	Source of effectiveness data	Outcome measure	Perspective	Design assessment (Range 0-7)	Data collection assessment (Range 0-14)	Analysis assessment (Range 0-15)
Wesley et al. 1992 (14)	India	Oral cancer (Screening)	CEA	Trial	Cost per early cancers and pre-cancers detected	Societal	7	11	12
Edwards et al. 1999 (15)	UK	Third molar retention	CEA	Model	Cost per management of asymptomatic, third molars	Health care provider/patient	7	11	12
Higashi et al. 2002 (16)	USA	Periodontal disease (Genetic testing to identify high risk patients)	CUA	Model	QALY gained	Health payer	6	10	13
Van der Meij et al. 2002 (17)	Netherlands	Oral cancer (Screening)	CUA	Model	QALY gained	Not stated	6	7	13
Subramanian et al. 2009 (18)	India	Oral cancer (Screening)	CEA	Trial	Cost per life saved	Societal	7	9	13
Dedhia et al. 2011 (19)	USA	Oral cancer (Screening)	CUA	Model	QALY gained	Societal	6	10	11
Cobiac & Vos, 2012 (20)	Australia	Caries prevention (Water fluoridation)	CUA	Model	DALY averted	Public payer	6	12	11
Frazão 2012 (21)	Brazil	Caries prevention (Supervised tooth brushing)	CEA	Trial	dmft	Not stated	5	8	7
Mariño et al. 2012 (22)	Chile	Caries prevention (water-fluoridation, dental sealants, milk-fluoridation, fluoridated	CEA	Model	DMFT averted	Societal	6	12	14

		mouthrinses, APF-Gel, supervised tooth brushing)							
Pukallus et al. 2013 (23)	Australia	Caries Prevention (Telephone prevention programme)	CEA	Model	Cariou teeth prevented	Public Payer	7	13	12
Tagliaferro et al. 2013 (24)	Brazil	Caries prevention (Glass-ionomers sealants, fluoride varnish)	CEA	Trial	DMFT	Health care system	6	8	11
Ney et al. 2014 (25)	USA	Caries prevention (Dental sealants)	CEA	Model	Restorations, extractions averted	Public Payer	7	11	11
Mariño et al. 2014 (6)	Australia	Periodontal disease	CEA/CMA	Trial	Gingival bleeding	Societal	7	8	10
Chi et al. 2014 (26)	USA	Caries prevention (Dental sealants)	CBA	Model, clinical database	Cost per treatment averted	Public Payer	7	11	13
Vermaire et al. 2014 (27)	Netherlands	Caries prevention (Professional fluoride applications)	CEA	Trial	DMFS	Health care system, societal	7	11	14
Fyfe et al. 2015 (28)	New Zealand	Caries prevention (Water fluoridation)	CEA	Model	dmft/DMFT	Societal	7	9	14
Edelstein et al. 2015 (29)	USA	Caries prevention (Community water fluoridation, dental sealants, fluoride varnish applications, home tooth brushing with fluoride toothpaste, and counseling)	CEA	Model	dmft/DMFT	Not stated	4	10	6

Koh et al. 2015 (30)	Australia	Caries prevention (Telephone prevention programme, hoe visits)	CEA/CU A	Model	Cost per treatment averted, QALY	Societal	7	13	15
Atkins et al. 2016 (31)	USA	Caries prevention (Community water fluoridation, dental sealants, fluoride varnish applications, home tooth brushing with fluoride toothpaste, and counseling)	CEA	Model	Dental caries prevented, general anesthesia prevented	Health care payer	7	13	9
Goldman et al. 2016 (32)	Brazil	Caries prevention (Dental sealant; supervised toothbrushing)	CEA	Trial	New cavitated dentine carious lesion prevented	Government programme	7	11	14
Goldman, et al. 2016b (33)	China	Caries prevention (Glass-ionomers sealants of different viscosity)	CEA	Trial	New cavitated dentine carious lesion prevented	Government programme	6	11	15
Griffin et al. 2016 (34)	USA	Caries prevention (Dental sealants)	CEA/CU A	Model	DMFS/DALY averted	Societal	7	11	11
Neidell et al. 2016 (35)	USA	Caries prevention (Dental sealant, fluoride varnish)	CEA	Trial	DMFT averted	Public Health	7	7	10
Schwendicke, & Gostemeyer 2016 (36)	Germany	Caries prevention (Fluoride rinses, chlorhexidine varnish, silver diamine fluoride varnish)	CEA	Model	Root caries averted	Public-Private Payer	7	10	14
Tickle et al. 2016 (37)	UK	Caries prevention	CEA	Trial	dmsf averted	Societal	4	10	14

		(Fluoride varnish, tooth brushing with fluoride toothpaste, and preventive advice)							
Chestnutt et al. 2017 (38)	UK	Caries prevention (Dental sealant, fluoride varnish)	CEA/CUA	Trial, model	Caries avoided, QALY, QATY	National Health Service	7	13	14
Khouja &.Smith 2017 (39)	USA	Caries prevention (Fluoride varnish, dental sealants,)	CEA	Model	Caries lesion in first permanent molars	Private Payer	6	8	9
Moore et al. 2017 (40)	New Zealand	Caries prevention (Water fluoridation)	CUA	Model	QALY gained	Not stated	6	11	10
O'Neill et al. 2017 (41)	UK	Caries prevention (Varnish fluoride)	CEA	Trial	Caries free, DMFS averted	Public Payer	5	7	12
Schwendicke et al. 2017 (42)	Germany	Caries prevention (Fluoride Varnish)	CEA	Model	DMFT averted	Public-Private Payer	7	13	14
Schwendicke and Stolpe. 2017b (43)	Germany	Caries prevention (Fluoride Varnish, Fluoride -Gel)	CEA	Model	DMFT averted	Public-Private Payer	5	12	13
Mariño et al. 2018 (44)	Thailand	Caries prevention (Fluoridated milk)	CEA	Model	DMFS averted	Societal	7	16	9
Schwendicke et al. 2016 (44)	Germany	Caries prevention (Sugar tax)	CEA	Model	DMFT averted	Public-Payer	5	11	12

CEA: Cost-effectiveness analysis; CUA: Cost-utility analysis; CBA: Cost-benefit analysis; DALY: Disability adjusted life years; QALY: Quality adjusted life years; QATY: Quality adjusted tooth years; DMFT/S: Decayed, Missing, Filled Teeth/Surfaces; dmft/s: Decayed, Missing, Filled teeth/surface in temporary dentition.

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Title:

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