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SYSTEMATIC REVIEW

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An economic evaluation of pit and fissure sealants and fluoride varnishes in preventing dental caries: a systematic review

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Abstract

The aim was to systematically evaluate the cost-effectiveness of pit and fissure sealants (PFSs) compared with that of fluoride varnishes (FVs) in dental caries prevention. We searched four electronic databases including the Cochrane Oral Health Group's Trials Register (till 03 June 2022), Web of Science (from 1945 to 03 June 2022), PubMed (from 1996 to 03 June 2022), and EMBASE *via* Ovid (from 1980 to 03 June 2022) to identify the cost and effectiveness of PFSs and FVs in decreasing dental caries incidence. Two researchers independently screened search results, extracted data from the included studies, and conducted the risk of bias assessments. The main characteristics of the included studies were extracted and analyzed. The initial search produced 874 articles. After removing duplicates and full-text review, 19 studies were included. In this study: nine studies were on PFSs comparison with control; five on PFSs comparison with FVs; and five on FVs comparison with control. Regarding the type of economic evaluation (EE), 13 studies conducted cost-effectiveness analysis, five conducted cost-utility analyses, and one conducted both cost-effectiveness analysis and cost-utility analyses. The cost-effectiveness evaluation of PFSs and FVs in the available studies was limited. The prevalence of dental caries, payers' willingness to pay, length of follow-ups, delivery settings, retention rate of PFS, and application intervals of FV can affect the economic evaluation of these two methods for dental caries prevention. Therefore, more studies in the future are need to draw clear conclusions about which method is more cost-effective for the two preventive interventions in future.

Keywords

Economic evaluation; Pit and fissure sealants; Fluoride varnishes; Dental caries; Systematic analysis

1. Introduction

Dental caries is a prominent health problem worldwide [1, 2]. It affects 60%–90% of adults and children [3]. Only in 2010, the cost of dental treatment amounted to US$442 billion, accounting for 4.6% of the global health expenditure [4, 5]. Dentists have long recognized the importance of dental caries prevention as the treatment of dental caries is time- and resource-consuming and also does not prevent further development of secondary dental decay [6]. The heavy economic burden indicats that a great necessity exists for effective caries control strategies. Pit and fissure sealants (PFSs) and fluoride varnishes (FVs) are common professional interventions for dental caries prevention [7]. PFSs can form a physical barrier for preventing the growth of cariogenic bacteria [2, 3, 8]. Dental caries usually occur in the pits and fissures of molars [9]. The occlusal surfaces account for only 12.5% of the total surfaces of the teeth [10]. FVs have been proven to be an effective strategy for preventing smooth surface caries if applied two or four times annually [11–13]. The topical FVs can arrest or reverse the development of dental caries by inhibiting demineralization and enhancing the remineralization of early caries lesions [14].

The use of PFSs and FVs both has shown good efficacy in arresting or reversing caries lesion development compared with no intervention [15]. The present results of the Cochrane Review revealed that twice-yearly applications of FVs reduced decayed, missing and filled tooth surfaces (DMFS) increments by 11%–43% for children and adolescents [16]. Furthermore, PFSs effectively decreased the caries incidence by up to 70% in the primary and permanent molars [17, 18]. However, there exists gap concerning regarding the cost-effective assessment of PFSs versus FVs in dental caries prevention. The application of PFSs is more time-consuming and technique sensitive compared with that of FVs [19]. FVs have the advantages of being easy to apply and well-tolerated, and the

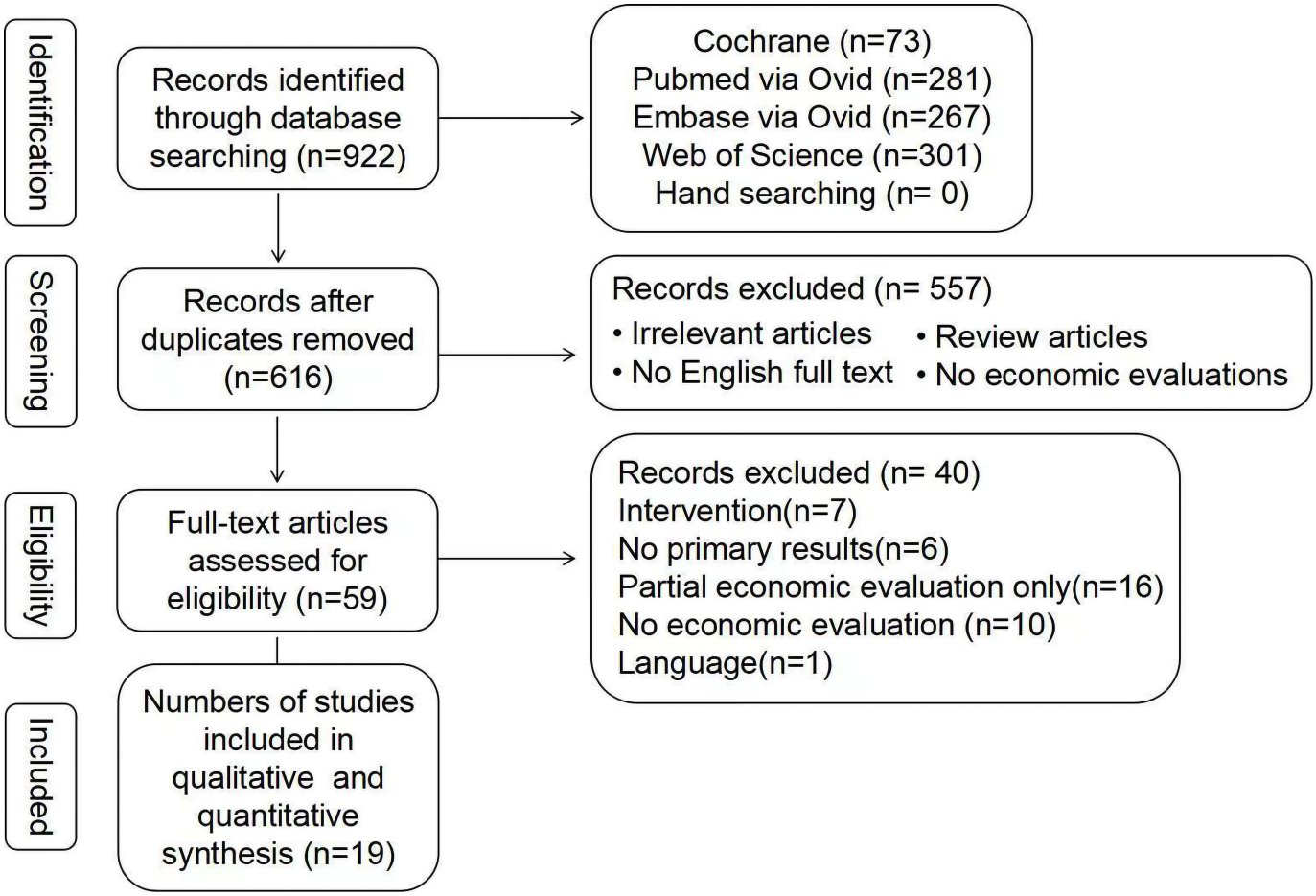

FIGURE 1. Study flow diagram for the selection of the articles.

time for FV application requires only 1–4 min per patient [20]. However, FVs also have the limitations of not forming a physical barrier against bacteria and the need for reapplication every 3–6 months to maintain the caries inhibition effect [20]. Given the limited availability of oral health service resources, dentists and health service planners must be familiar with the costs and effectiveness of PFSs and FVs in preventing dental caries.

Economic evaluation is a comparative analysis of both the costs and consequences of alternative programs [21]. From a public health perspective, it is important to make the most effective use of limited resources to get the largest healthcare gain. Economic evaluation is becoming essential for decision-making, public health policy, and clinical practice [22]. It includes cost-effectiveness analysis (CEA), cost-utility analysis (CUA), and cost-benefit analysis (CBA). CEA focuses equally on the costs and outcomes [22]. The utility in CUA refers to the change in the quality of life of patients such as the quality-adjusted life-year (QALY) of the intervention. In the cost-benefit analysis, the results of all measures are expressed in monetary terms [21]. Economic evaluations have been more and more used for the comparison of preventive measures [23, 24], with some of them revealing that FVs are less cost-effective than PFSs [19, 25]. However, other studies have shown that FVs demonstrated to be more cost-effective than PFSs in a primary care setting [7, 26]. Thus, the cost and effectiveness of PFSs and FVs are controversial.

Therefore, in this systematic review, we aimed to assess the cost and effectiveness of PFSs and FVs in reducing the incidence of dental caries in preschool children and adolescents. The findings may help policymakers to allocate limited resources to get the greatest health care gain.

2. Materials and methods

2.1 Inclusion criteria

This systematic review was conducted following the guidelines proposed by the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) [27]. The PICO framework including population, intervention, comparator, and outcome was used to guide the search strategy:

• Types of Participants (P).

Children and adolescents aged 3–18 years with primary and/or permanent teeth.

• Types of Intervention (I).

PFSs and/or FVs that can be applied in clinical, school or community settings.

• Types of Control/Comparison (C).

The control groups were those not receiving sealants or professional topical fluoride application. The FVs group was used as the control when making a comparison with the PFSs group.

• Types of Outcome Measures (O).

The primary outcome was to assess the effectiveness, utility,

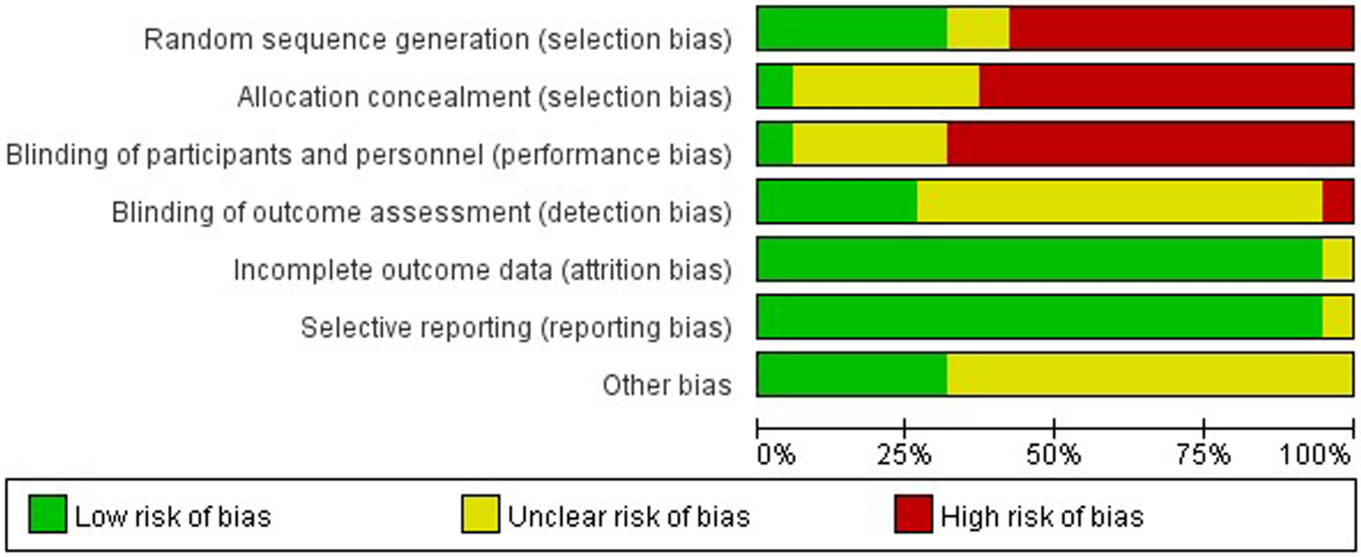

FIGURE 2. Risk of bias graph: review authors' judgments about each risk of bias domain presented as percentages across all included studies.

or benefits of PFSs and FVs, such as DMFT(S) reduction percentage, full mouth dental reconstructions (FMDRs) avoidance, quality adjusted life-year (QALY) and disability-adjusted life years (DALY) averting, the decrease in increment of dental caries reduction. The secondary outcome was the cost-saving and benefit associated with applying PFSs and FVs, such as the incremental cost-effectiveness ratio (ICER).

2.2 Exclusion criteria

Publications comparing PFSs or FVs with other preventive interventions without control were excluded. The language was restricted to English.

2.3 Search strategy and study selection

We searched the electronic databases Cochrane Oral Health Group's Trials Register (till to 03 June 2022), Web of Science (from 1945 to 03 June 2022), PubMed (from 1996 to 03 June 2022), and EMBASE *via* Ovid (from 1980 to 03 June 2022). A predefined search strategy was used in the search procedures: (((((Pit and fissure sealants) OR (Fissure sealants) OR (Dental sealants) OR (Tooth sealants))) OR Fluoride varnish)) AND ((Economic evaluation) OR (Cost evaluation) OR (Cost-effectiveness analysis) OR (Cost-benefit analysis) OR (Costs and benefits) OR (Cost-utility analysis) OR (money saving)). Two review authors independently performed a preliminary screening of the articles by reading the titles and abstracts. Next, they screened the selected articles by full text. The agreement about study inclusion, data extraction, and risk of bias assessment was achieved by discussion. We attempted to contact the study authors to obtain missing or unclear information.

2.4 Data extraction

We used a predesigned data extraction form to extract the following study characteristics: first author, year of publication, country, length of follow-up, age of the target population, number of participants, type of teeth, type of preventive program, type of economic evaluation, currency, discount rate, perspective (societal, public health, payer, or Medicaid payer), and outcomes (number of restorations avoided, dental caries reduction, calculation of cavity-free months/year, quality/disability-adjusted life years).

3. Results

The initial search yielded 922 articles, from which 306 duplicates were removed. After screening by the title and abstract, 59 articles were identified as potentially relevant ones and retrieved for eligibility assessment. In total, 19 articles were included in the final review. A detailed sequence of filtering search results to include relevant articles is shown in Fig. 1.

3.1 Study characteristics

A total of 19 selected studies were summarized. Nine studies were conducted in the USA [7, 9, 19, 24, 25, 28–31], three in Chile [16, 26, 32], one in the UK [33], one in Spain [3], one in Germany [34], and one in Australia [35], and three studies did not mention the country [36–38]. For intervention comparison, nine studies compared PFSs with control [9, 24, 28–32, 36, 38], five compared FVs with control [16, 26, 34, 35, 37], and five studies compared PFSs with FVs [3, 7, 19, 25, 33] (the general and methodological characteristics of the included studies was listed in **Supplementary Table 1**).

3.2 Summary assessments of "risk of bias"

To conclude the overall risk of bias for economic evaluation analysis of the intervention, the studies were classified as low, unclear, or high risk of bias. Our classification was mainly based on the following domains: random sequence generation, allocation concealment, blinding of outcome assessment, incomplete outcome data, and selective outcome reporting. Most of the included studies were retrospective cohort studies, except for a few studies that were randomized controlled trials

[7, 16, 33]. As information to judge most domains was often incomplete or missing, the quality of the studies was generally low, which was shown in Figs. 2,3.

3.3 Synthesis of the results

The most appropriate relevant results were summarized in a narrative synthesis, focusing on currency, economic evaluation type, and methodological characteristics that estimated the cost and effectiveness and cost. The characteristics of cost and effectiveness in the economic evaluations were presented in **Supplementary Table 2**. Given the heterogeneity of the studies, no meta-analysis or statistical grouping of the summary measurement was performed. 13 studies conducted CEA [3, 7, 16, 19, 24–26, 28, 30, 31, 34, 36, 37], five conducted CUA [9, 29, 32, 33, 38], and one conducted both CEA and CUA [35]. The discount rate in most studies was 3%.

4. Discussion

4.1 Overview

The high prevalence of dental caries renders an urgent requirement for effective caries control strategies. PFSs and FVs are two common professional approaches for caries prevention globally [7, 24]. In China, the National Oral Health Comprehensive Intervention Program for Children has funded a free dental sealing service for school children aged 6–9 years old since the late 2000s [39]. The American Dental Association recommends that sealants should be applied on both primary and permanent molars in children who are at high risk of dental caries [40]. Preschool and school-based FV programs have also been conducted in many countries, including the United States, Canada, Australia, Sweden, and Scotland [41–43]. Many studies have already evaluated the effectiveness of PFSs and FVs in caries prevention [44–46]; however, there is no agreement on how these prevention approaches affect downstream dental care expenditures and outcomes [3, 7, 19, 25, 33]. Economic evaluation has been defined as the comparative analysis of alternative programs in terms of their costs and consequences to assist policymakers to make effective use of scarce resources to obtain the largest benefit [22, 47]. However, the application of economic evaluation is still limited in preventive dentistry [21, 45]. Given the fact that the incidence of dental caries in developing countries remains unchanged and has shown no decreasing trend in the past two decades [48], approaches for reducing caries increment and following treatment costs are worth considering. In this study, 19 economic evaluations on PFSs and/or FVs published between 2002 and 2021 were reviewed. Most studies were conducted in America and Europe, and only a few were conducted in developing countries [16, 26, 32]. The length of follow-up was at least 3 years.

4.2 Assessing the costs and effectiveness of PFSs and FVs

The incidence of caries is one of the most important variables associated with economic evaluations of PFSs and FVs [16]. The application of PFSs and FVs became less costly as the annual caries increment increased [16, 36]. Griffin *et al*. [28] reported that if caries increments exceeded 0.019, seal all (SA) children would dominate seal none (SN) and if caries increment exceeded 0.034, seal all children would dominate seal high-risk children. This result was similar to that of Rocio's [36] conclusion, if the annual risk of developing a cavity was above 0.04, seal all will save more money than the cost. There is evidence suggesting that approximately 80% of caries is concentrated in 25% of high-risk people [28, 29]. Thus, it was proposed that PFSs and FVs are more effective and less expensive for children in the high-risk groups because the costs for the preventive methods would be compensated by avoiding consequent dental treatment [30, 34, 49]. The reduction in expenditures for high-risk children was greater than that for low- risk ones [9, 28, 36].

Pit and fissure caries remain the prominent in children and adolescents [36]. The clinical effectiveness of occlusal caries prevention of PFS has been established; however, the reduction of occlusal caries is mainly dependent on the maintenance of the sealants. The rate of sealant loss had the greatest effect on the increment cost-effectiveness ratio [32]. Sealants retention in molar teeth was projected to be 90% during the first 2 years, with a decrease of approximately 60% by 5 years [49]. The sensitivity analysis demonstrated that if the constant annual rate of sealant loss was less than 7%, the strategy of the seal all became more cost-effective, and that seal none would save money only if the annual rate of sealant loss exceeded 35% [36].

The costs of delivering PFSs and FVs may also differ based on different delivery settings. The application of PFSs and FVs in clinical settings by dentists or dental nurses is more expensive than that in non-clinical settings such as schools and communities. PFSs applied by a dental hygienist are more cost-effective than those applied by a dentist [50]. Usually, school sealant programs use portable dental equipment to apply sealants in schools at little to no cost to students [29]. Thus, it provides opportunities to reduce disparities in children with a low socioeconomic state and It offered opportunities to reduce disparities for children with low socioeconomic state and at high-risk of caries [30, 32]. Furthermore, school-based programs remove obstacles to accessing healthcare and reduce the high rate of broken appointments and time off work for parents [33]. However, the application of sealants costs more than the varnishes per student. This higher cost may largely stem from the differences in labor. The time spent in applying FVs in the school-based setting is 3–5 min per child [51, 52], whereas it takes approximately 30 min for dentists to apply PFS to four occlusal surfaces in a school setting [3]. The application of PFSs requires enamel etching, aspiration, and maintenance of a dry field, thus requiring more time than FVs [53]. When considering delivery costs, FVs do not require professional dental infrastructure, such as a dental chair with illumination, fluid evacuation, and so on, which is more cost-effective than PFSs when considering delivery costs [7]. Furthermore, the cost-effectiveness of FVs increases if some equipment such as an oral hygiene kit is not used and it is applied by qualified staff rather than dentists [26].

Since dental caries often takes long period to progress to a degree that restorative care is required, the studies used a

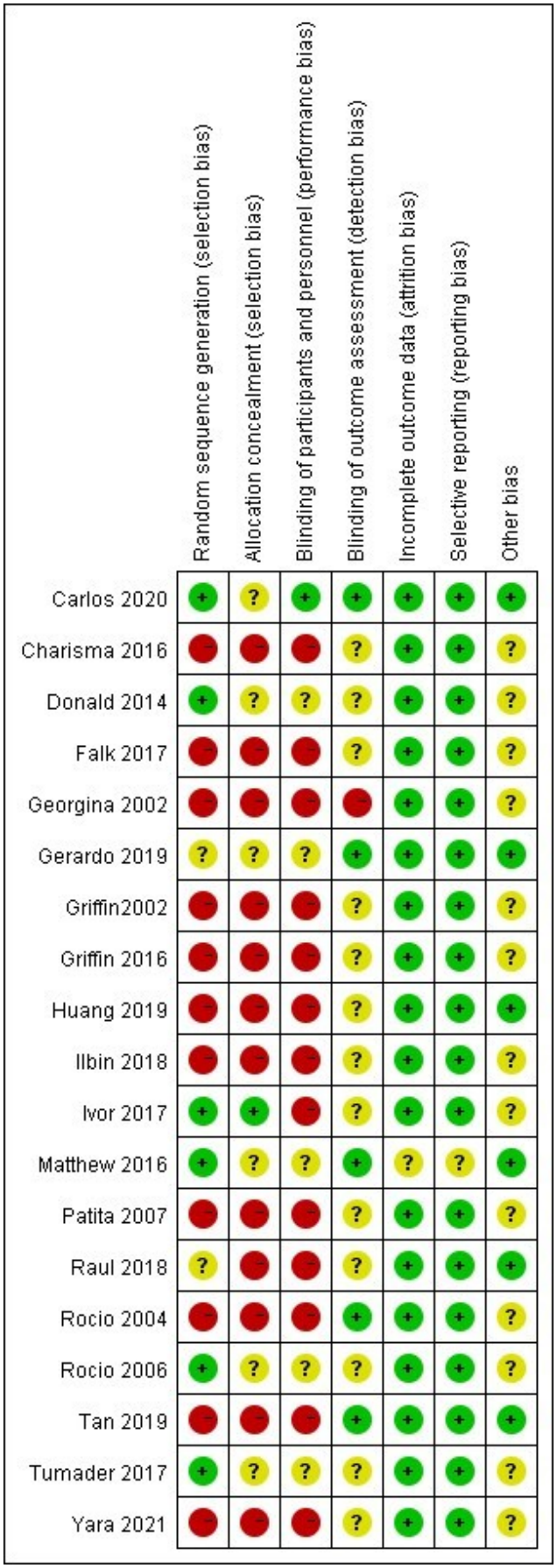

FIGURE 3. Risk of bias summary: review authors' judgments about each risk of bias domain for each included study. Green, low risk of bias; Yellow, unclear risk of bias; Red, high risk of bias.

shorter length of follow-ups which might have influenced the economic evaluation because the benefits did not have enough time to accumulate [26, 36]. Falk [34] reported that the health gains of FVs were greatest only if they were applied for a lifetime. Rocio [34] also discovered that FVs were not cost-saving when used in the medical setting in the first 42 months. Moreover, the cost-effectiveness of sealing the first permanent molar is less favorable when used for shorter periods [36]. In the sensitivity analyses, the application intervals of FV would affect the cost-effectiveness. If the application is only once per year, it would significantly lower the incremental cost-effectiveness ratio than when applied four times per year. Moreover, the US Preventive Services Task Force recommended that FVs should be applied at the beginning of eruption of the first primary tooth, suggesting that the age of FV application professionally is earlier than that of PFS [7].

The payer's willingness to pay for avoiding carious lesions is also an influencing factor [54]. Tumader [3] reported that when the willingness to pay threshold was between $0–$60 per caries lesion averted, seal none was more favorable; however, for willingness to pay thresholds above $300, PFS was the preferred strategy. Furthermore, regular application of FVs to Medicaid-enrolled children was found to be cost-saving although at a lower reimbursement rate [55, 56]. However, most studies were cohort studies rather than randomized controlled trials; thus, their effectiveness needs to be further verified.

4.3 Economic evaluation model

Economic evaluation is commonly adopted by decision policymakers in the health sector for investigating the cost and effectiveness of public health programs to help plan future initiatives [22]. Unlike clinical studies that report the consequences of the intervention only, economic evaluations require more reporting items, such as resources used,, costs, and effectiveness results [23]. Although economic evaluations are commonly used in decision-making processes for health programs, only a few of examples exist in the oral health literature. The present systematic review compared PFSs and FVs in preventing dental decay in children and adolescents. At present, PFSs were most commonly evaluated by CEA. CEA measures consequences in natural units, such as cavity-free months, carious teeth reduction, or DMFT detection. It is useful to help public health policymakers and aid primary dental care providers in choosing a more preferable intervention for reducing the prevalence of dental caries. However, a recognized drawback of CEA is the lack of intangible benefits such as relief from pain or quality of life, assigned a monetary value [23]. The use of CUA has been observed in other areas of dental service research. Patita [9] weighted the outcomes of quality-adjusted tooth years (QATYs) as the measure to assess the effectiveness of PFSs. Such methods of assessing cost quality-adjusted tooth year ratios can be used in the future comparison of preventive regimens such as FVs and oral hygiene instruction in preventing caries.

The findings of the present systematic review found that the quality of economic evaluation of PFSs and FVs needs to be improved. Therefore, future studies should include long-term costs and expenses assessment, the risk sub-groups analysis, and the patients' point of view [32], which would provide a greater understanding of the social effects of PFSs and FVs. There is a strong requirement for health economists and oral health researchers to work together on projects that will improve the quality and validity of future economic evaluations of dental caries prevention programs.

4.4 Limitations

There are some limitations to this systematic review. First, there was a lack of randomized controlled trials in the review as most of them did not meet our inclusion criteria. Next, while considering the results of this review, it should be recognized that most articles conducted theoretical models, wherein both cost and effectiveness were estimated according to the literature and general market conditions.

5. Conclusions

The presently available clinical data for the comparison of PFSs and FVs applications are scarce. Therefore, it is impossible to draw clear conclusions concerning cost-effectiveness n dental caries prevention between PFSs and FVs. Targeting high-risk children and non-clinical delivery settings may be an effective approaches to reducing the cost of PFSs and FVs. The list of cost and effectiveness analyses for each intervention may help policymakers to prioritize funding decisions in dental prevention. However, there is still a need for well-designed economic evaluation studies of PFSs versus FVs are still needed.

ABBREVIATIONS

PFS, Pit and fissure sealant; FV, fluoride varnishes; DMFT(S), decayed, missing and filled tooth (surfaces); EE, Economic evaluation; CEA, cost-effectiveness analysis; CUA, cost-utility analysis; CBA, cost-benefit analysis; QALY, quality-adjusted life-year; DALYs, disability-adjusted life years; FMDRs, full mouth dental reconstructions; ICER, incremental cost-effectiveness ratio; ICUR, incremental cost-utility ratio; ACER, average cost-effectiveness ratio; PMPY, per member per year; SSPs, school-based sealant programs; SA, seal all; SN, seal none.

AVAILABILITY OF DATA AND MATERIALS

All data generated or analyzed during this study are included in this published article and supplementary material.

AUTHOR CONTRIBUTIONS

BZ—drafted the protocol, searched for trials, obtained full texts, evaluated trials to include, extracted data from trials, entered data into Review Manager, carried out the analysis, and drafted the final review. MZ and SYD—drafted the protocol, searched for trials, obtained full texts, evaluated trials to include, extracted data from trials, carried out the analysis. JGT—evaluated trials to include, extracted data from trials, entered data into Review Manager, carried out the analysis. LL

and RZH—contributed to revise the manuscript. All authors contributed to writing and reviewing the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1697496217169084416/attachment/Supplementary%20material.docx.

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