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ORIGINAL ARTICLE

# Cost-effectiveness analysis of fissure sealants for caries prevention in children

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**Abstract**

**Objective:** To evaluate the cost-effectiveness of resin-based and glass ionomer-based fissure sealants compared with no intervention for children.

**Methods:** We developed a Markov-based decision analytic model that simulated Turkish children from aged 6 to 15 years. Two types of costs were explored from the payers' perspective and the health care system perspectives. A cost-effectiveness analysis of resin-based and glass ionomer-based fissure sealants was conducted to quantify their effectiveness using the number of caries prevented and the quality-adjusted tooth years (QATYs). Costs and effectiveness measures were discounted at 3% per year.

**Results:** The most cost-effective intervention was resin-based fissure sealant, with an additional $5.34 per caries prevented and $1.86 per QATY gained compared with no treatment.

**Conclusion:** Fissure sealants particularly resin-based sealants are cost-effective for children in Turkey due to their low cost and highly preventive characteristics.

KEYWORDS
cost-effectiveness analysis, decision analytic models, Markov models, pit and fissure sealants, preventive dentistry, public health dentistry

## INTRODUCTION

The World Health Organization (WHO) has reported that the prevention of dental caries is strategically important for the prevention of global disease [1]. Permanent molars are the most susceptible teeth to dental caries due to their occlusal morphology, their position in the arch, and the immaturity of the teeth during eruption. The complex anatomy of the pits and fissures causes food remnant accumulation, and the position of the molar teeth in the arc also causes inadequate oral hygiene [2]. The application of pit and fissure sealants is an efficient way to protect permanent molars against dental caries. Fissure sealants provide a smooth surface, thus preventing bacterial accumulation and food retention on the occlusal surfaces and decreasing the risk of developing dental caries [3].

Many commercially available fissure sealants with different properties are available. Fissure sealants help inhibit the development of dental caries, but all types of fissure sealants have advantages and disadvantages due to their material characteristics. Of these materials, the two most frequently used are resin-based and glass ionomer-based fissure sealants. Resin-based fissure sealants have been used for decades [4]. Their advantage is the micro retention of enamel tags, which are formed after acid etching; however, resin-based fissure sealants are sensitive to moisture due to their hydrophobic nature. In moist environments, glass ionomer cement s may be preferred as an alternative because of their hydrophilic properties. Glass ionomer cements provide adhesion due to calcium bonds and protect the tooth against dental caries by releasing fluoride [5, 6]. Numerous clinical studies have investigated the clinical effectiveness of resin-based and glass ionomer-based fissure sealants in preventing caries. While some of them have reported that both fissure sealants are efficient for caries prevention [7], while others report that resin based fissure sealants are more effective than glass ionomer-based fissure sealants in long term [8].

The majority of the previous related studies have compared the dental caries prevention effectiveness of fissure sealants and other caries prevention options, such as fluoride varnish, water fluoridation, and fluoride gels [9, 10]. Few studies have investigated the cost-effectiveness of resin-based and glass ionomer-based fissure sealants using economic analysis [11, 12].

  

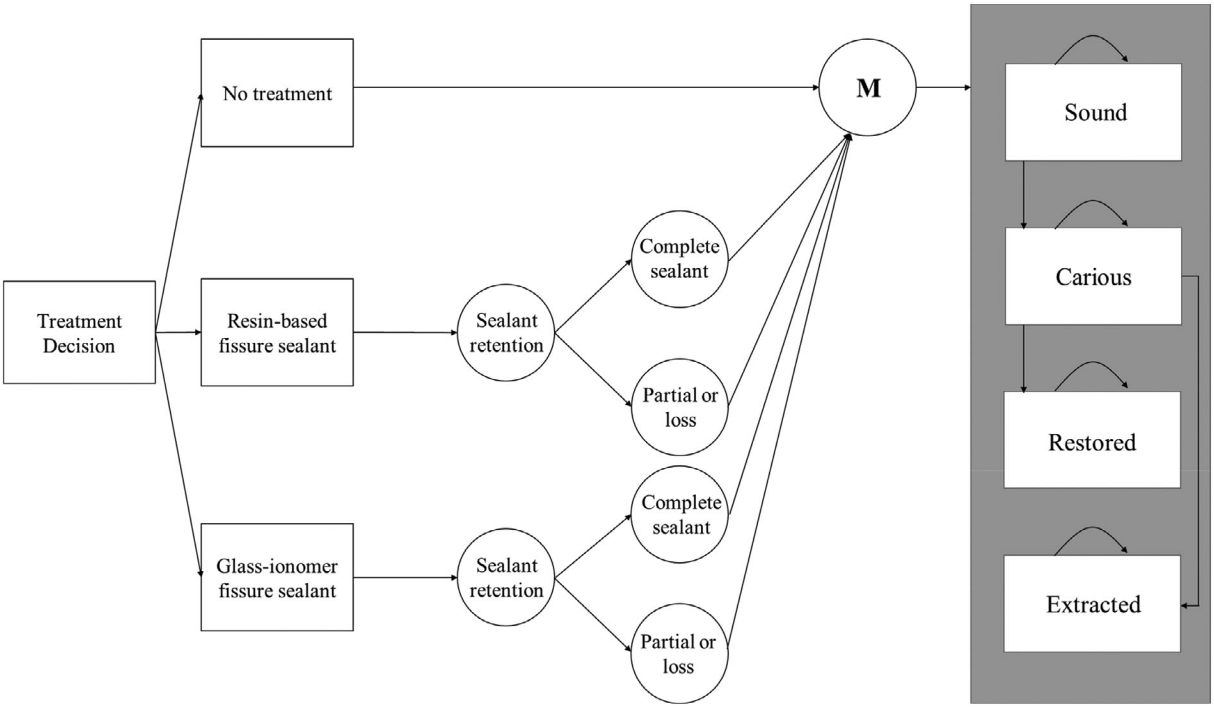


**FIGURE 1** Decision analytic model where decision tree denotes the decision and chance nodes and M denotes Markov nodes. Markov states are presented in the gray area where transition between states are defined with predefined transition probabilities.

Cost-effectiveness studies for treatment options and prevention methods gained importance in recent decades because scarce public health resources have to be distributed across many competing programs. Finding cost-effective ways maximizes the delivery of efficient and effective oral health prevention in the government-sponsored programs. Based on the Turkish Dental Association's (TDA) oral health reports, 4.6 million Turkish Lira (TL) were spent by the state-insured health providers on dental treatments in 2013 [13]. This amount constituted about 5% of the costs of general health expenditures (84 billion TL) [13]. Studies have investigated the cost-effectiveness of pits and fissure sealants in Chile, China, and Brazil [11, 12, 14, 15], but no cost-related studies on fissure sealants have been conducted in Turkey.

This study aimed to compare the cost-effectiveness of resin-based and glass ionomer-based fissure sealants for prevention of dental caries on the occlusal surfaces of the first permanent molars in children from the health care system and the payer's perspectives using a decision analytical model. Microcosting was adapted for the cost estimation for the health care system perspective, and TDA fees represented the payer's perspective. We compared the application of fissure sealants with a baseline of no treatment and we used sensitivity analysis to determine whether and how the incremental cost-effectiveness ratios (ICERs) might change when the cost, efficacy, and retention of fissure sealants varied.

# METHODS

## Model summary

We developed a Markov-based decision tree model (Figure 1) to determine the progress of dental caries in children from age 6 up to 15. The first permanent molars, to which a fissure sealant can be applied to prevent caries, often erupt around age six. In pediatric dentistry clinics in Turkey, children up to age 18 may be treated; however, we selected age 15 as the end point of our simulation. The natural history of caries was simulated annually via a Markov model, and fissure sealant applications were included as interventions in the decision model. The cost and efficacy of interventions were assessed by the model, while health outcomes are considered based on quality-adjusted tooth years (QATYs) as well as the number of caries prevented.

The health states of Markov models included sound, carious, restored, and extracted teeth. The last two states were absorbing states in the model. If a child progresses to the caries state, two treatment options are possible: carious tooth is restored or extracted. The annual transition probabilities for these treatment options were based on a national caries survey of around 7800 samples conducted in 2004 [16].

The decision analytic model of the natural history of caries incorporated the Markov model and a decision tree explored possible fissure sealant applications and their effects on caries prevention. Two fissure sealant

**TABLE 1** Annual transition probabilities of decision analytic model for the base case analysis where lower and upper limits are applied in the sensitivity analysis

| Variable | Value | Lower limit | Upper limit |
|---|---|---|---|
| No treatment | | | |
| Annual probability of caries when no fissure sealant applied | 0.220 | 0.127 | 0.294 |
| Resin-based fissure sealant | | | |
| Retention probability | | | |
| Annual probability of complete resin sealant | 0.83 | 0.53 | 0.97 |
| Annual probability of partial or loss resin sealant | 0.17 | 0.47 | 0.03 |
| Caries probability | | | |
| Annual probability of caries when resin sealant applied and it is complete | 0 | 0 | 0.001 |
| Annual probability of caries when resin sealant applied and it is partially retained or loss | 0.452 | 0 | 1 |
| Glass ionomer-based fissure sealant (GIS) | | | |
| Retention probability | | | |
| Annual probability of complete GIS | 0.2 | 0.14 | 0.72 |
| Annual probability of partially retained or loss GIS | 0.8 | 0.86 | 0.28 |
| Caries probability | | | |
| Annual probability of caries when GIS applied and it is complete | 0.034 | 0 | 0.0626 |
| Annual probability of caries when GIS applied and it is partial or loss | 0.220 | 0.127 | 0.294 |
| Restoration and extraction when caries | | | |
| Annual probability of restoration when caries | 0.057 | 0.034 | 0.079 |
| Annual probability of extraction when caries | 0.043 | 0.021 | 0.065 |

types (resin-based and glass ionomer-based) were compared with a no fissure sealant strategy. We also considered the retention of fissure sealants, consequently, the efficacy of the two fissure sealants varied according to whether the fissure sealant was complete or partially or completely lost. The costs of intervention options were included in the decision analytic model together with health outcomes as the number of caries and QATYs.

To illuminate how the decision model performed, it was assumed that a resin-based fissure sealant was applied to a 6-year-old child. In the following years, the fissure sealant could be complete, partially complete, or totally lost. Depending on the retention of the sealant, the tooth could remain sound or develop caries. Caries probability was significantly lower for a complete sealant than a partial or totally lost sealant as well as no sealant. If the child developed caries, it could remain in the same state or be restored or extracted.

The model was developed using Microsoft Excel. We obtained transition probabilities of sealant retention and caries with and without fissure sealants are obtained from a Cochrane Review (Table 1) [8]. We selected studies that applied resin-based and glass ionomer-based sealants and collected information on their retention and effectiveness in preventing caries. All outcomes were converted to annual probabilities assuming exponential distribution. Restoration and extraction probabilities were estimated from a cross-sectional survey of around 7800 Turkish people [16].

## Model assumptions

The following assumptions were made:

- Fissure sealant is applied once when the child is 6 years old, and if the fissure sealant is partially or totally lost, resealing is not required.
- The risk of caries is constant over time, and only depending on whether the fissure sealant is retained.
- The probability of losing a sealant is constant over time; in other words, a new fissure sealant has the same risk of failure as a fissure sealant that is only a few years old.
- The model starts with a sound tooth, and if a fissure sealant is applied, it is on a sound tooth.

TABLE 2 Costs and fees associated with resin-based fissure sealant, glass-ionomer fissure sealant, restoration, and dental extraction

| Intervention | Item | Cost per molar treated (USD) | Cost range (USD)(min-max) |
|---|---|---|---|
| Resin-based sealants (30 min required) | Dentist | 5.93 | 3.291–7.12 |
| | Assistant | 1.09 | 1.09–1.31 |
| | Supplies | 3.34 | 1.09–7.41 |
| | Equipment and instruments | 2.77 | 0.90–6.05 |
| | Total | 13.14 | 6.38–21.90 |
| | Fee | 14.29 | 1.05–17.15 |
| Glass ionomer-based Sealants (30 min required) | Dentist | 5.93 | 3.29–7.12 |
| | Assistant | 1.09 | 1.09–1.31 |
| | Supplies | 3.12 | 1.95–4.31 |
| | Equipment and instruments | 2.77 | 0.90–6.05 |
| | Total | 12.92 | 7.24–18.79 |
| | Fee | 14.29 | 1.05–17.15 |
| Restoration (composite) | Dentist | 7.91 | 4.38–9.49 |
| | Assistant | 1.45 | 1.45–1.74 |
| | Supplies | 14.84 | 7.63–21.85 |
| | Equipment and instruments | 2.77 | 0.90–6.06 |
| | Total | 26.99 | 8.33–46.61 |
| | Fee | 45.88 | 4.52–55.06 |
| Extraction | Dentist | 5.93 | 3.29–7.12 |
| | Assistant | 1.09 | 1.09–1.31 |
| | Supplies | 0.52 | 0.49–0.56 |
| | Equipment and instruments | 2.76 | 0.90–6.02 |
| | Total | 10.31 | 5.78–15.06 |
| | Fee | 26.32 | 2.55–31.59 |

## Costs

We used microcosting to determine the direct costs of resin-based and glass ionomer-based fissure sealants as well as restored and extracted. Using this method, we considered the costs of supplies, equipment, the instruments used for the procedures, and the average salaries of a dentist and dental assistant. Whenever possible, we considered at least three brands and used average of their prices. The details of these calculations are presented in Supplemental Tables A1–A6. We calculated the cost of the dentist and dental assistant as the proportion of the salaries for the time required for each intervention. We excluded transportation costs, overhead costs, and other indirect costs such as productivity loss costs. Costs per molar treated are presented in 2020 US dollars, using the same ranges that were used for the sensitivity analysis (Table 2). In addition, to estimate costs from the health care system perspective, we obtained TDA fees and Turkish governmental social health insurance system fees for each intervention. We conducted all the analyses using costs from both the health care system perspective and the payers' perspectives.

TABLE 3 Quality-adjusted tooth years (QATY) estimates for sound and carious tooth, restoration, and dental extraction

| QATY | Value | Lower limit | Upper limit | Source |
|---|---|---|---|---|
| Sound | 1 | | | |
| Caries | 0.81 | 0.51 | 0.9 | [17] |
| Restoration | 0.9 | 0.72 | 0.95 | [17] |
| Extraction | 0 | | | |

## Health outcomes

In this study, we assessed the effectiveness of interventions using two health outcomes: the number of caries prevented and QATYs, which provide a measure of disease burden that is similar to quality-adjusted life years (QALYs). QATYs were estimated based on published literature (Table 3). We evaluated the utility following dental diseases of a perfect (healthy) tooth with a QATY of 1 and an extracted (dead) tooth with a QATY of 0. The benefits of QATYs are twofold: First, QATYs help in comparing interventions and treatments across different oral diseases. Second, they quantify different tooth states, such as sound, decayed, restored, and extracted teeth, with a less than perfect tooth having a utility below 1. However, we also provide the number of caries prevented for each scenario to provide decision makers another measure to compare the benefits and costs of fissure sealants. In addition, we demonstrated the effectiveness with respect to the number of restorations and extractions prevented in the Supplemental Appendix which would be a portion of the number of caries as we assume there is a percentage of caries that would stay be restored or extracted.

## Cost-effectiveness analysis

To evaluate the effectiveness of fissure sealants for the prevention of caries in children, we conducted a cost-effectiveness analysis and estimated the cost per QATY gained for resin-based and glass ionomer-based fissure sealants compared with no sealant. For a 10-year time horizon, we adjusted all costs and effects to 2020 US dollars and discounted any future costs and effects at the 3% discount rate suggested by the Panel on Cost-Effectiveness in Health and Medicine [18]. We calculated the ICER, which divides differences in costs into differences in effects relative to the next best strategy. Due to the lack of a threshold of willingness-to-pay (WTP) threshold for a one-QATY gained or for one caries prevented in Turkey, we compared our results with the cost of dental restorations ($45), which was suggested in a similar study, and the gross domestic product of Turkey in 2020 ($8608) as recommended by the WHO for low and middle-income countries [19].

## Sensitivity analysis

We conducted a one-way sensitivity analysis for the ranges presented in Tables 1–3. Cost ranges were calculated for the lowest cost and the highest cost brands, and annual probability and QATY ranges were determined from the medical literature. The results of the one-way analysis were summarized with a tornado graph.

# RESULTS

We estimated the average cost per molar treated for resin-based and glass ionomer-based sealants to be $13.14 and $12.92, respectively, with ranges of $6.38–$21.90 and $7.24–$18.79, respectively. The estimated costs of both sealants were close to the fees that are recommended by the TDA; however, the average costs of restoration and extraction; which were estimated to be $26.99 and $10.3, respectively, were almost half of the recommended fees for these procedures.

Applying resin-based and glass ionomer-based fissure sealants to 6-year-old children compared with a no sealant strategy gained 2.16 and 0.2 QATYs and prevented 0.75 and 0.13 caries, respectively. The estimated costs of glass ionomer-based and resin-based sealants were very similar to each other, whereas the retention of resin-based sealants was significantly better than that of glass ionomer-based sealants (0.83 vs. 0.2). Therefore, the cost-effectiveness of glass ionomer-based sealants compared with resin-based sealants were dominated in the analysis. Resin-based sealants were estimated to cost an additional $4 with an ICER of $5.34 per caries prevented and $1.86 per QATY gained (Table 4). Figure A1 in the Supplemental Appendix shows an incremental cost-effectiveness diagram of sealant strategies compared with no sealant.

From the payer's perspective, the costs of resin-based and glass ionomer-based sealants increased to $14.29, as reported by the TDA. Since the costs of both sealants were the same and the effectiveness and retention of resin-based sealants were better than the glass ionomer sealants, glass ionomer sealants were dominated in the cost-effectiveness analysis. The total cost of all strategies increased due to the higher cost compared with micro-costing; therefore, the ICER for applying resin-based sealants in children increased to $16 per caries prevented and $5.43 per 1 QATY gained (Table A7 and Figure A2 in the Supplemental Appendix).

Our results were robust, and resin-based sealants remained cost-effective in all cases. The variables that had the greatest impact on the ICER were the annual probability of a complete resin sealant, the annual probability of caries when no fissure sealant was applied, QATYs for carious teeth, the annual probability of caries when resin sealant was applied and partially or completely lost, the annual probability of restoration for caries, and the annual probability of extraction for caries (Figure 2 and Figure A3 in the Supplemental Appendix). The ICER has increased to $6.04 per caries prevented and $2.11 per QATY gained as the highest value when the annual probability of complete resin sealant decreased to its lowest

**TABLE 4** Cost-effectiveness of resin-based and glass-ionomer fissure sealants for children

| Treatment choice | Cost ($) | Incremental cost ($) | Effectiveness (number of caries/QATY) | Incremental effectiveness (number of caries prevented/QATY) | ICER ($ per caries prevented/$ per QATY gained) |
|---|---|---|---|---|---|
| No treatment | 14 | | 0.92/7.47 | | |
| Resin-based fissure sealant | 18 | 4 | 0.17/9.63 | 0.75/2.16 | 5.34/1.86 |
| Glass ionomer-based fissure sealant | 26 | 8 | 0.79/7.68 | −0.62/−1.96 | (Dominated) |

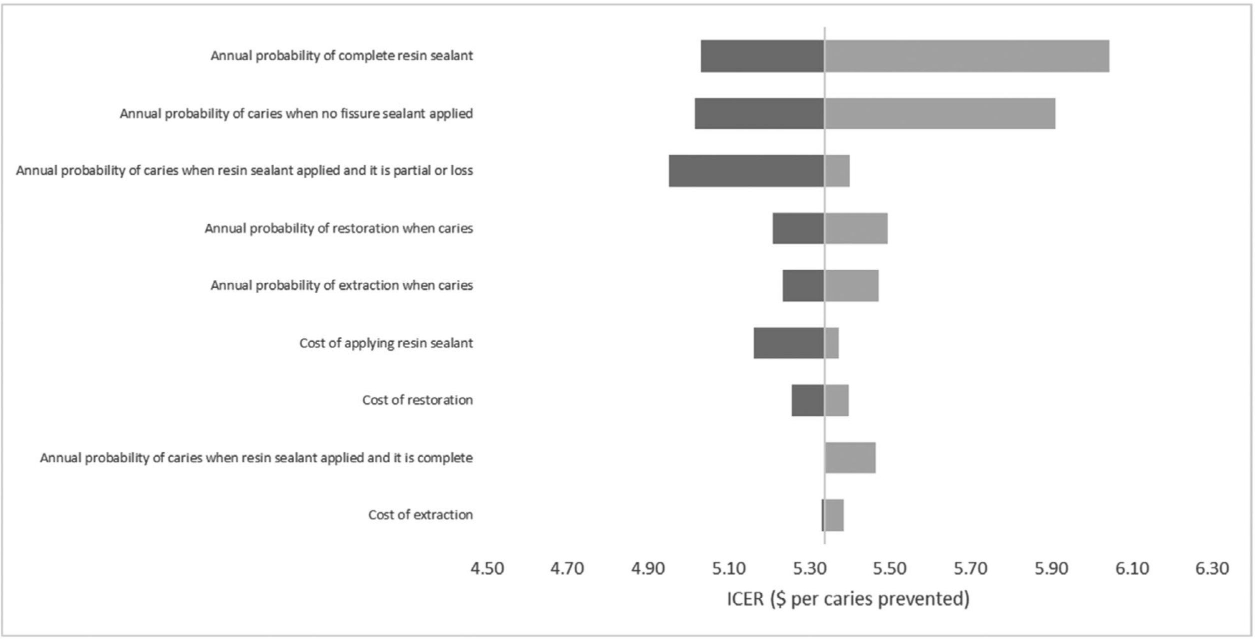


**FIGURE 2** Tornado diagrams of one-way sensitivity analyses of the cost-effectiveness of resin-based and glass ionomer-based fissure sealants for children. The horizontal bar shows the range in cost-effectiveness ($ per caries prevented), given the variation in model parameters and the parameter values explored in sensitivity analyses. The vertical line shows the base case cost-effectiveness.

value (0.51). The lowest estimated ICER in the sensitivity analysis was $1.65 per QATY gained when QATYs for carious teeth varied and $5.02 per caries prevented when annual probability of caries when resin sealant applied and it is partial or loss varied. Overall, all parameters varied the ICER between 0% and 14%. While glass ionomer-related parameters had an impact on the cost and effectiveness of glass ionomer-based sealants, resin-based sealants performed better in all cases, and the ICER remained the same; hence, we excluded these parameters from the tornado graph. Similarly, QATYs for restored teeth which had a very limited effect on the ICER, are not included in Figure A3.

## DISCUSSION

This study aimed to analyze the cost-effectiveness of resin-based and glass ionomer-based fissure sealants for preventing occlusal caries development in the first permanent molars of children in Turkey. The model's 10-year time horizon showed that resin-based fissure sealants are more cost-effective than glass ionomer-based fissure sealants and no treatment.

There is no consensus on QATY WTP in the literature; however, the cost of dental restoration was used as a WTP threshold in one study [14]. Using that measure ($46 in Turkey according to 2020 fees), both types of fissure sealant could be considered as significantly cost-effective because the cost of sealants per caries prevented and per QATY gained was below this limit. The costs of resin-based and glass ionomer-based fissure sealants were comparable to each other, but the retention of resin-based fissure sealants was significantly better than that of glass ionomer-based sealants. Consequently, the cost of resin-based fissure sealants per 1 QATY gained is nearly two times lower than the cost of glass ionomer-based fissure sealants per 1 QATY gained.

Only limited studies have included both resin-based and glass ionomer-based sealants and compared the results [12]. To the best of our knowledge, our study is the first CEA study to evaluate sealant materials in Turkey. While it is difficult to compare our study to other similar studies due to differences in effectiveness measures and the materials evaluated, the most relevant studies to ours compared the cost-effectiveness of fissure sealants with different treatment options. Espinoza-Espinoza et al. [14] compared a first permanent molar sealants program with nonintervention. QATY WTP was $6.48 for school-based molar sealing; however, this program was evaluated at the community level, and we evaluated the intervention at the patient level; which may explain the difference in costs. Khouja et al. analyzed the cost-effectiveness of fluoride varnish and fissure sealant-based prevention methods for first permanent molar teeth. They reported that the cost-effectiveness of preventing occlusal caries was almost $157 [9]. This cost was significantly higher than in our study, in which we reported the ICER for each fissure sealant type. This difference could be related to cost estimates for fissure sealants in the two studies. Khouja et al. [9] reported the cost of pit and fissure sealant around $47, while our estimates were one-third of this amount.

Although we did not include this in our study, glass ionomer-based sealants have an advantage over resin-based fissure sealants due to their hydrophilic nature, making it easier to apply them to erupting teeth. We included the cost, effectiveness, and retention of materials in our study, and resin-based fissure sealants have been claimed to be better than glass ionomer-based sealants; however, ease of use and new glass ionomer technologies may provide advantages over resin. A few studies on glass carbomer materials have suggested that both glass carbomer fissure sealants and resin-based fissure sealants are similarly effective for caries prevention, but glass carbomer fissure sealants are not cost-effective [6, 11, 12].

According to the sensitivity analysis, the retention and effectiveness of fissure sealants had more impact on the ICER than the cost of the materials, but this phenomenon could be due to low-cost estimates for fissure sealants and restoration in Turkey. The estimates for the retention of resin-based and glass ionomer-based sealants used in this study were determined from pre-2014 studies. With new technologies or updated clinical information about the effectiveness and retention of these materials, as well as the local cost of the materials in the application countries, the cost-effectiveness of fissure sealants could potentially change. Nevertheless, in many countries, the cost of restoration and/or extraction is similar to or greater than the cost of applying preventive methods, such as fissure sealants, and the health benefits of noncarious teeth are greater than those of restored or extracted teeth. Therefore, fissure sealants would probably be cost-effective in other countries compared with the no sealant option, while the choice of the most cost-effective fissure sealant remains an open question, with new studies reporting different values for retention and effectiveness.

While QATYs, as a tooth utility measure, capture the transition of tooth health from sound to extracted, they include only four intermediate stages: decayed and non-painful, decayed and painful, restored but restoration needs replacing, and restored. Although there are more sensitive outcome measures that capture more detailed stages of a tooth decay, our model included two states between healthy and extracted. As a result, QATYs were adequate for our study purpose. Another widely used effectiveness measure in CEA studies is QALYs. QALYs allow to comparison across different diseases and health conditions, including dental problems.

This study has limitations. The effectiveness of fissure sealants was calculated based on published studies. In addition, cost-effectiveness analysis based on one tooth which could have caused a bias in the analysis, since sealing more than one tooth could change the results due to differing costs. We also assumed that if a sealant was partially or completely lost, the sealant would not be replaced. We did not include indirect costs of fissure sealants such as productivity loss due to parents accompanying children, and children missing school for dental visits, as well as transportation cost. Moreover, we did not include root treatment, but previous studies have shown that it does not change the direction of cost-effective analysis [20]. Finally, we did not consider follow-up appointments or resealing costs, which may have affected the global results.

Future studies could analyze of risk populations for the development of dental caries, including new materials for fissure sealants and indirect costs, such as productivity loss and transportation costs. In addition, we included restoration and extraction as the treatments for caries, but, more comprehensive treatment methods could be considered in subsequent models, such as personalized treatment decisions and other treatment options, such as root treatment.

## CONCLUSIONS

This study provides evidence for the cost-effectiveness of fissure sealants for children in Turkey. Turkey is a country with a high prevalence of dental caries; therefore, the effectiveness of preventive measures such as fissure sealants has great potential to decrease the incidence of caries, and as our study suggested, all preventive measures are less costly than treating caries. These findings should be taken into consideration when planning caries prevention programs and developing recommendations for clinical practice and public health dental programs.

### CONFLICT OF INTEREST

The authors declare no potential conflicts of interest concerning the authorship as well as publication of this article.

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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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