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Cost-effectiveness simulation of a universal publicly funded sealants application program

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Abstract

Objectives: No cost-effectiveness evaluation of pit and fissure sealants has ever been carried out in Quebec. The objective of this study was to simulate a publicly funded program of pit and fissure administration, either in the public or private sectors, and compare these hypothetical situations with the current one, i.e., a publicly funded, school-based selective program.
Methods: A Markov model was developed using a virtual population of 8-year-old children that was monitored over a time span of 10 years. The incremental cost per child without decay was computed.
Results: The current situation and a publicly funded program in the public sector were more cost-effective than the other option: a universal, publicly funded, private practice. However, the most cost-effective option varied, depending on the incidence of decay and the proportion of children identified as being at high-risk for decay.
Conclusion: By implementing a school-based program of universal pit and fissure sealant application, access to preventive dental care could be improved at an equivalent cost-effectiveness to the current one.

Introduction

Caries is still a problem among Quebec children, especially socioeconomically disadvantaged children (1). Pit and fissure decays represent 78 percent of decayed, filled or extracted tooth surfaces among sixth grade Quebec children (1). Yet, most caries can be prevented by the application of pit and fissure sealants. When the sealant stays in place, protection efficiency is almost 100 percent (2).

The Quebec Provincial Dental Public Health action plan (3) proposes that the regional health authorities offer pit and fissure sealants in their programs, using portable clinics. The target population is 8- and 9-year-old pupils identified as being at high-risk based on their socioeconomic status and a dental examination by a dentist (Table 1). Children who are ineligible for this program must seek paid preventive care in private dental clinics, resulting in health inequalities related to family incomes (mixed situation). Discussions have taken place at the provincial level about the possibility of offering sealants to all children through a publicly funded private practice program (private situation) or a school-based program (school situation).

The cost-effectiveness (C/E) of pit and fissure sealants has been studied by several researchers. Many studies have shown that sealants are more cost-effective than restorations, especially when applied to children identified as being at high-risk for decay (5-7). Obviously, sealants applied by a dental hygienist are more cost-effective than those applied by a dentist (8). To date, however, no economic evaluation of the currently available option and the two proposed options has been performed. This study aims to provide this missing information using a Markov model.

Methods

Design

A Markov model was constructed to compare the three options of sealant delivery: the mixed, private, and school situations. Markov models consist of a representation of caries-related probabilistic events occurring over time. They allow costs and effectiveness to be estimated in terms of the number of children without decay on the surface of the first permanent molar for each of the three options.

Table 1 Caries Risk Evaluation of Pit and Fissure Surfaces (4)

Sociocultural risk factors
Recent immigrant status (less than 5 years)
Known family history of high caries risk
Risk factors related to dental condition
History of dental care under general anesthesia
Previous experience of decay: all types of restorations and extractions due to caries
Abundant plaque or lack of proper dental hygiene
Risk factors related to morphology of pit and fissure surfaces
Pit and fissure surfaces show enamel decay
Pits and fissures are narrow and/or deep
Pits and fissures present a discoloration that is resistant to prophylaxis and to dental explorer

Modeling

The model used was based on a study by R.B. Quiñonez *et al.* (9) and three options were compared. In the mixed situation, application of sealants in schools is offered by the public health care system to children identified as being at high-risk for pit and fissure decays. Children should match at least one of the criteria developed in Table 1 to be qualified as high-risk. Those who were excluded from the program might receive sealants at their own cost in private dental clinics. In the private situation, application of the sealant would be offered free of charge to all children and performed in private clinics, paid for by public health insurance for children under 10 years old. In the school situation, sealant application would be offered free of charge to all children, performed in schools, and funded by the Health Ministry.

A Markov model (Figure 1a,b,c) was built to analyze the occurrence of cavities and costs under the different probabilistic occurrences of events. A 10-year time span was chosen based on literature on the effectiveness of the procedure (10). The model was validated by dental health professionals: two public health dentists and two general dentists practicing in private clinics.

Virtual population

The virtual population consisted of 8-year-old children. This age category was chosen because the application of pit and fissure sealants would take place after the complete eruption of permanent molars. The 78,372 children of the cohort corresponded to the number of 8-year-old children living in the province of Quebec on July 1, 2008 (11).

Variables and data collection

Data from Quebec were privileged because the prevalence of cavities can differ greatly from one country to another, as does the prevalence of high-risk children. When Quebec data were missing, they were retrieved from published meta-analyses. When no data were available, two experts in dental public health from Quebec were consulted. Some probabilities were deduced from the available information, such as the percentage of "high risk, no sealant" that complemented the known percentages of "high risk, sealant at school" and "high risk, sealant in private clinic." The probabilities and their plausible intervals are presented in Table 2.

Data were validated by two public health dentists. A consensus among the experts was obtained for the final model.

Outcomes

The effectiveness measure was the number of children without decay (on first permanent molars), which is a recognized index to measure caries activity in a population. Children, rather than teeth showing evidence of decay, were chosen as an analysis unit to avoid the cluster effect (the increase in the probability of affecting other teeth when a cavity is already present).

Effectiveness parameters

Parameters, including baseline and extreme values are presented in Table 2. For each of the three options, the parameters include the proportion of children in different situations, the rates of sealant retention, resealing and re-restoration, as well as the decay incidence for high- and low-risk children.

Costs

The health care system and parents' perspectives were adopted. The items considered and their unit prices are presented in Table 3. The costs are related to screenings in schools, examinations in private clinics, sealant application, and restoration in private clinics. These include the costs of staff, materials, travel by patients and their parents, as well as the productivity loss for parents. The portable equipment (i.e., chairs, lamps, hand pieces) and fixed assets were not included in the calculation of costs. Moreover, it was assumed that in the private situation, there was no cost related to hiring additional staff or to increasing the capacity of private clinics. Both direct and indirect costs were taken into account. The fees recommended by the Fee Guide and Description of Dental Treatment Services (23) were used as a proxy of costs of examinations, sealant application, and restoration in private clinics. Note that all data integrated into the model are specific to each of the options (e.g., time needed to apply sealants in private clinics differs from that needed in the school environment).

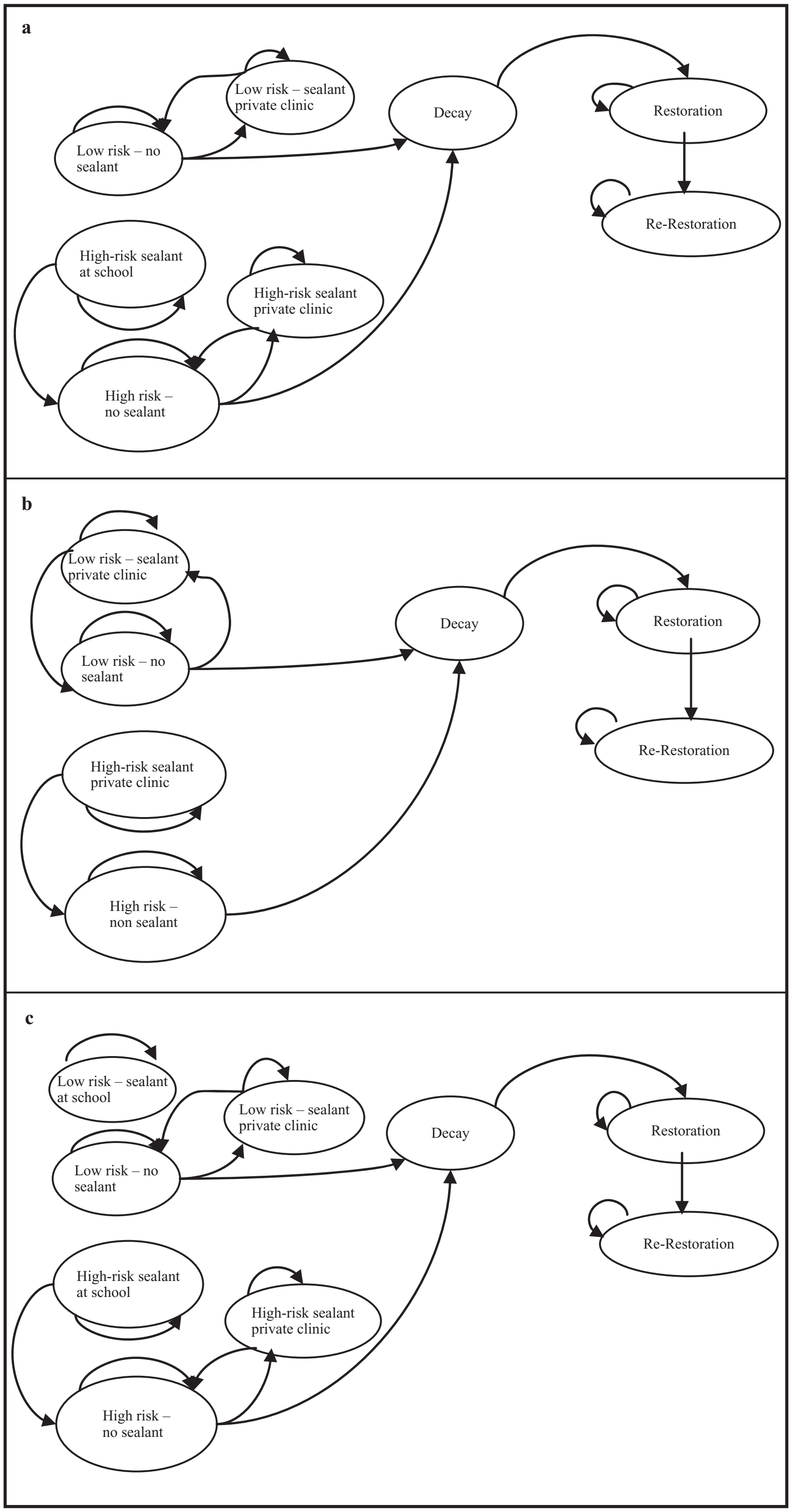

Figure 1 The models compared are presented graphically. Figure 1a represents the current situation (mixed situation) in which some high-risk children are offered sealants at school, while others might receive them in private clinics. Figure 1b represents a hypothetical situation (private situation) in which publicly funded sealants are offered universally in private clinics, while Figure 1c represents the situation (school situation) where the sealants are offered universally through the public system. Eight-year-old children are categorized according to their risk for decay and are monitored over a period of 10 years (see Table 1). In the various models, children who benefited from a sealant and lost it could receive another one in the future at the same rate for high-risk and low-risk children. Because of government policies, a lost sealant cannot be replaced at school, and when decay occurs, it leads to a restoration.

Table 2 Parameters: Baseline and Extreme Values* (%)

Item	Mixed situation	Private situation	School situation
Children at risk of pit and fissure decays	71.55 [55.93-87.8] (1)	71.55 [55.93-87.8] (1)	71.55 [55.93-87.8] (1)
High risk, sealant at school	22 (12) [15-30] (experts†)	-------------------------	59.55 (deduction‡)
High risk, sealant in private clinic	33.0 (experts, 13) [11.7-38.4] (1)	62.35 (deduction)	10 [5-15] (experts)
High risk, no sealant	16.55 (deduction)	9.2 (14) [7-11] (experts)	2 [0-4] (experts)
Low risk, sealant at school	-------------------------	-------------------------	16.45 (deduction)
Low risk, sealant in private clinic	4 (experts, 13) [2-10] (experts)	19.92 [0-28.45] (experts)	10 [5-15] (experts)
Low risk, no sealant	24.45 (deduction)	8.53 [0-28.45] (experts)	2 [0-4] (experts)
Sealant retention	1 Y : 86.7 [73.4-100] 2 Y : 73.3 [59.5-97] 3 Y : 79.6 [60.1-99] 4-5 Y : 62 [52-72] 7 Y : 60 [50-70] 9 Y : 41 [28-54] (15-17)	1 Y : 86.7 [73.4-100] 2 Y : 73.3 [59.5-97] 3 Y : 79.6 [60.1-99] 4-5 Y : 62 [52-72] 7 Y : 60 [50-70] 9 Y : 41 [28-54] (15-17)	1 Y : 86.7 [73.4-100] 2 Y : 73.3 [59.5-97] 3 Y : 79.6 [60.1-99] 4-5 Y : 62 [52-72] 7 Y : 60 [50-70] 9 Y : 41 [28-54] (15-17)
Resealing rate	3.91 / year [1-7.6] (9)	100 until 10 YO and 3.91 over 10 YO (9, experts)	3.91 / year [1-7.6] (9)
Re-restoration rate	6.86 / year [2.5–16.0] (9,18)		
Decay incidence for low-risk children	8 YO : 11.44 [13.73-9.15] 9 YO : 5.35 [4.28-6.42] 10 YO : 2.0 [1.6-2.4] 11 YO : 0.5 [0.4-0.6] 12 YO : 0.2 [0-0.5] 13 YO and more : 0.1 [0-0.5] (1,6,9,14,19,20)	8 YO : 11.44 [13.73-9.15] 9 YO : 5.35 [4.28-6.42] 10 YO : 2.0 [1.6-2.4] 11 YO : 0.5 [0.4-0.6] 12 YO : 0.2 [0-0.5] 13 YO and more : 0.1 [0-0.5] (1,6,9,14,19,20)	8 YO : 11.44 [13.73-9.15] 9 YO : 5.35 [4.28-6.42] 10 YO : 2.0 [1.6-2.4] 11 YO : 0.5 [0.4-0.6] 12 YO : 0.2 [0-0.5] 13 YO and more : 0.1 [0-0.5] (1,6,9,14,19,20)
Decay incidence for high-risk children	8 YO : 24.44 [19.44-29.44] 9 YO : 18.35 [14.68-22.02] 10 YO : 14.35 [11.5-17.24] 11 YO : 6.00 [4.8-7.2] 12 YO : 4.8 [3.84-5.76] 13 YO : 4.8 [3.6-5.4] 14 YO and more : 4.5 [3.6-5.4] (1,6,10,16,21,22)	8 YO : 24.44 [19.44-29.44] 9 YO : 18.35 [14.68-22.02] 10 YO : 14.35 [11.5-17.24] 11 YO : 6.00 [4.8-7.2] 12 YO : 4.8 [3.84-5.76] 13 YO : 4.8 [3.6-5.4] 14 YO and more : 4.5 [3.6-5.4] (1,6,10,16,21,22)	8 YO : 24.44 [19.44-29.44] 9 YO : 18.35 [14.68-22.02] 10 YO : 14.35 [11.5-17.24] 11 YO : 6.00 [4.8-7.2] 12 YO : 4.8 [3.84-5.76] 13 YO : 4.8 [3.6-5.4] 14 YO and more : 4.5 [3.6-5.4] (1,6,10,16,21,22)

* The baseline value is shown first with the extreme values presented in square brackets. The source of each value is shown in parentheses.

† When no data were available, two experts in dental public health from Quebec were consulted.

‡ Some probabilities were deducted from the available information, such as the percentage of "high risk, no sealant" that is the complement of the known percentages of "high risk, sealant at school" and "high risk, sealant in private clinic."

Y, years; YO, years old.

Programming

Programming was done using Microsoft Office Excel. Visual Basic for Applications language was used to develop the algorithms allowing the virtual population to evolve in the Markov model. Algorithms are available upon request.

Analyses

All costs were discounted at a baseline rate of 3 percent and, in sensitivity analyses, at 0 and 5 percent, as suggested by the Canadian guidelines for economic evaluation (26). Sensitivity analyses (two-way analyses) were also performed on uncertain data related to effects and costs, using the extreme values specified in Table 2, and by linking them to different discount rates. Discounting effects were performed in sensitivity analyses at the same rates as the costs: 0, 3, and 5 percent. An incremental analysis was conducted as no option was dominant.

Results

Baseline analyses (Table 4)

The estimated total care cost for the first permanent molars of 8-year-old children over a time period of 10 years was $10,890,966 for the mixed situation, $14,257,324 for the private situation, and $11,723,584 for the school situation. Of these costs, approximately 70 percent would be absorbed by

Table 3 Cost Items: Consumption Amount and Unit Prices

Option	Item	Consumption amount	Unit prices ($) *	Cost ($)†
School (screening)	Dentist	5 minutes (C-A ASSS‡)	79.10/hour (23)	6.59
	Hygienist	5 minutes (C-A ASSS)	27.63/hour (C-A ASSS)	2.30
	Meals	2/100 children (C-A ASSS)	14.30 (C-A ASSS)	0.28
	Travel hygienist	40 km/100 children (C-A ASSS)	0.43/km (C-A ASSS)	0.17
	Travel dentist	100 km/100 children (C-A ASSS)	0.43/km (C-A ASSS)	0.43
	Materials and equipment¶	(Estrie ASSS §)	(Sinclair dental•)	0.86
	Total screening/child			10.66
School (sealant)	Hygienist	93 min (C-A ASSS)	27.63/hour (C-A ASSS)	42.83
	Hygienist (assistant)	93 min (C-A ASSS)	27.63/hour (C-A ASSS)	42.83
	Meals hygienists	2/(4.5 children) (C-A ASSS)	14.30 (C-A ASSS)	6.35
	Travel	80 km/(4.5 children) (C-A ASSS)	0.43/km (C-A ASSS)	7.56
	Materials and equipment	(Estrie ASSS)	(Sinclair dental)	15.57
	Total sealant/child:			115.14
	Total (4 screenings and 3.14∞ sealants):			157.78
Private clinic (3.14 sealants, children <10 years old#)	Sealant	3.14 sealants	35.00 (23)	109.90
	Complete examination	1 examination	38.25 (21)	38.25
	Productivity loss	73.2 minutes (Survey)	8.50/hour (22)	10.37
	Travel	32.16 km (Survey)/ 9.04 L of fuel/100 km (24)	1.185/L (25)	3.45
	Total/child:			161.97
Private clinic (3.14 sealants, children ≥10 years old)	Sealant	3.14 sealants	35.00 (23)	109.90
	Complete exam	1 examination	64.00 (23)	64.00
	Productivity loss	73.2 min (Survey)	8.50/hour (22)	10.37
	Travel	32.16 km (Survey) / 9.04 L/100 km (24)	1.185/L (25)	3.45
	Total/child:			187.72
Private clinic (1.96** restoration, children <10 years old)	Complete exam	1 examination	38.25 (21)	38.25
	Restoration class I amalgam	1.96 restoration	60.00 (21)	117.60
	Productivity loss	85.3 minutes (survey)	8.50/hour (22)	12.08
	Travel	32.16 km (survey) / 9.04 L/100 km (24)	1.185/L (25)	3.45
	Total/child:			171.38
Private clinic (1.96 restoration, children ≥10 years old)	Complete exam	1 examination	64.00 (23)	64.00
	Restoration class I amalgam/composite	1.96 restoration	104.00 (23)	203.84
	Productivity loss	85.3 minutes (survey)	8.50/hour (22)	12.08
	Travel	32.16 km (survey) / 9.04 L/100 km (24)	1.185/L (25)	3.45
	Total/child:			283.37

* All costs are in Canadian dollars.

† The costs per child were obtained by multiplying the amount consumed by the unit price.

‡ C-A ASSS: Regional Health Agency of the Chaudière-Appalaches region.

¶ The costs for products are calculated for schools only because the cost of treatments for private clinics includes the cost of materials. The details of these costs are not presented here.

§ Estrie ASSS: Regional Health Agency of the Estrie region.

• Sinclair dental: Canadian dental supply company.

∞ 3.14: Average number of sealants made per child in C-A ASSS.

Curative treatments and examination of children under 10 years old are covered by public health insurance in Quebec but children over 10 years old might receive these services at their own cost. Costs are then different.

** 1.96: Average number of restorations per child (1).

the parents and 30 percent by the health care system in the mixed situation, while in the private situation about 30 percent would be absorbed by the parents and 70 percent by the public health care system. In the school situation, 47 percent of the total costs would be absorbed by the parents and 53 percent by the public health care system.

Estimated effectiveness would amount to 60,792 children without decay in the mixed situation, 64,672 children in the

Table 4 Results of C/E Baseline Analyses*†

Option	Total costs ($)	Costs for parents ($)	Costs for health care system	Effectiveness (children without decay)	Parents' perspective C/E	Health care system's perspective C/E	Global C/E	Incremental C/E ratio‡
Mixed situation	10,890,966	7,646,329	3,244,638	60,792	125	53	179	---------------
Private situation	14,257,324	4,402,523	9,854,801	64,672	68	152	220	868 (private versus mixed)
School situation	11,723,584	5,510,236	6,213,348	65,626	84	95	179	172 (school versus mixed)

* Costs are discounted at 3% and effects at 0%.
† All costs are in Canadian dollars.
‡ (Total costs 2 – Total costs 1)/(Effectiveness 2 – Effectiveness 1).
C/E, cost-effectiveness.

private situation, and 65,626 children in the school situation. The private situation, therefore, could be expected to produce 3,880 additional children without decay compared with the mixed situation. The school situation would produce an additional 954 children without decay compared with the private situation.

The estimated C/E ratio was calculated to be $179 per child without decay in the mixed situation, $220 per year in the private situation, and $179 per year in the school situation. The estimated C/E ratio for parents was $125 per child without decay in the mixed situation, $68 in the private situation, and $84 in the school situation. The estimated C/E ratio for the health care system was $53 per child without decay in the mixed situation, $152 in the private situation, and $95 in the school situation. The incremental C/E ratio was calculated to be $868 for an additional child without decay in the private situation compared with the mixed situation, and $172 in the school situation compared with the mixed situation.

Sensitivity analyses (Figure 2)

Sensitivity analyses showed that the results were not robust. The mixed situation was more cost-effective when the retention of sealants was minimal, when the rate of resealing was maximum, when the rate of restoration was minimal, when the incidence of decay was minimal, or when the number of children at high-risk was minimal. The school situation was more cost-effective when the retention of sealant was high, when the rate of resealing was minimal, when the rate of

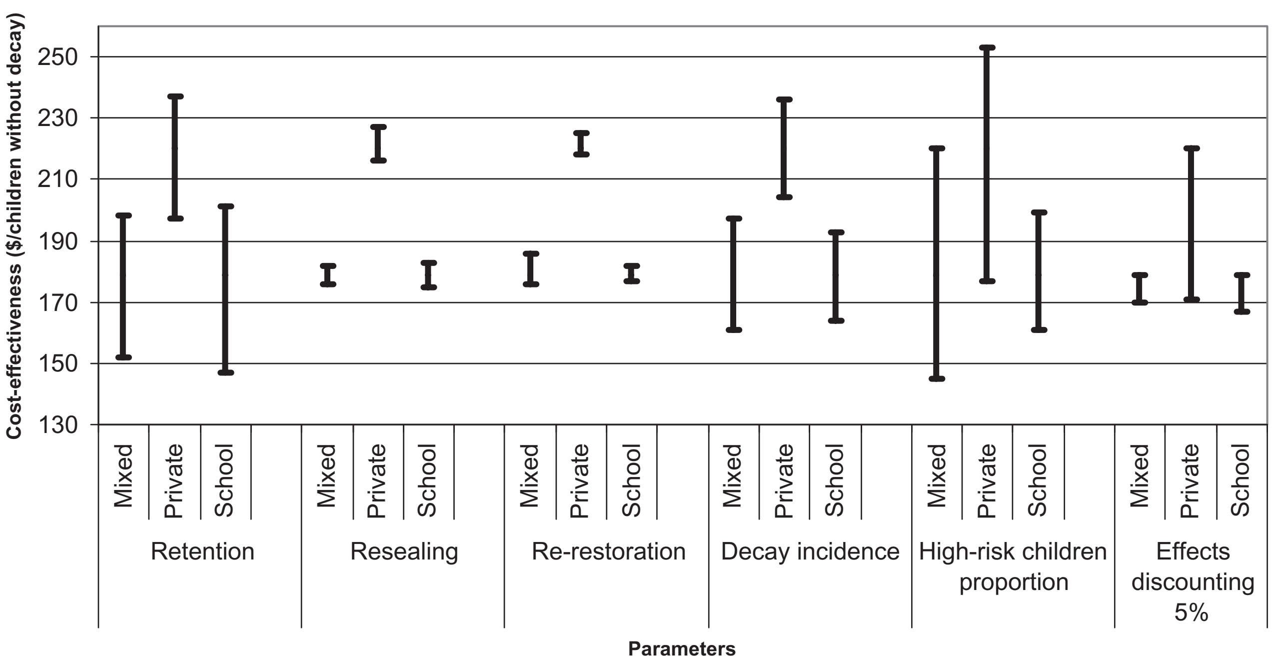

Figure 2 Sensitivity analyses results: effect on cost-effectiveness due to a change in key parameters. The black lines represent the interval between the minimum and maximum results of different parameters according to the sensitivity analyses. The probabilities varied according to the intervals present in Table 2.

restoration was high, when the incidence of decay was high, or when the number of high-risk children was greatest. Moreover, simultaneously discounting the effects and costs at 3 and 5 percent made the school situation the most cost-effective option. The private situation was calculated to be the least cost-effective option and this result is robust.

Discussion

The results of this study should be considered, while taking into account that it was a simulation. Although great care was taken to create a realistic model, as with all simulations, the model is a simplification of reality.

Also, the scope of this study was limited to the application of pit and fissure sealants. Other benefits, such as a check-up for other dental problems that might have changed the global results, were not considered. The simulation was designed only to analyze preventive measures and its results should not be extrapolated to other activities in dentistry.

Moreover, because of controversies regarding discounting effects (27-29), discounting at the same rate as costs (0, 3, and 5 percent) was only performed in sensitivity analyses. However, these sensitivity analyses did not affect the results. Also, the portable equipment and fixed assets were not included in the calculation of costs. However, they would probably not have changed the results because of their long lifespan, which would lead to a very small share when distributed among patients.

The limited information that can be retrieved from the indexed and non-indexed literature is another limitation of this study. Expert opinion was required to complete missing information, although sensitivity analyses were used to diminish the importance of this potential bias.

One should also note that, because of computing power, only limited two-way analyses were performed in sensitivity analyses. Possible interactions between factors could not be taken into account.

Finally, as with any economic evaluation, great care should be taken when extrapolating the results to another health care setting, as costs were computed based on Quebec medical practice and cost structure.

This study also has several strengths. Unlike other published studies, the cluster effect for an individual's teeth was controlled by using the child as the analysis unit. The real marginal cost per tooth was also considered because the sealant and restoration costs were determined per mouth, not per tooth. Similarly, unlike the studies of R.B. Quiñonez *et al.* (9) and S.O. Griffin *et al.* (5), the incidence of tooth decay was varied by age and risk status. Finally, the cost calculation was quite comprehensive and should offer a more complete viewpoint than comparable studies.

With these cautions in mind, our results suggest that in the province of Quebec, when the options for sealant application to 8-year-old children are compared, the private situation is dominated, while the mixed situation and the school situation are equivalent in terms of C/E.

These results are consistent with the studies of S.O. Griffin *et al.* (5), K. Leskinen *et al.* (6), R.B. Quiñonez *et al.* (9), and P. Bhuridej *et al.* (7) who showed that preventive programs of pit and fissure sealants application are more cost-effective when sealants are applied selectively in children with a higher risk of pit and fissure decays. Conversely, the results compare poorly to the study of C.W. Werner *et al.* (30) which found a more favorable C/E ratio in private clinics compared with schools. However, results cannot be compared in a straightforward manner because different studies have chosen different outcomes to measure effectiveness and because settings, hence practice and costs, are not the same.

This study aims to bring information to policymakers that should help them to compare the different options available for improving the accessibility to preventive measures in decay prevention. The school situation is appealing because it has a C/E ratio equivalent to the mixed situation, and it is more efficient. Implementing a universal, school-based program of pit and fissure sealant application, would improve access to preventive dental care and ameliorate the social equity of the Quebec's healthcare system. Obviously, it is important to determine if the required investment is socially acceptable. This is a political decision, which, hopefully, can be approached in a more evidence-based manner due to studies like this one.

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