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Economic evaluation of fluoride varnish application in Iranian schools

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Original Article

Abstract

BACKGROUND AND AIM: Dental caries is still one of the most common chronic diseases among children, although it can be prevented through early and regular professional services. This study aimed to analyze cost-effectiveness of fluoride varnish therapy intervention to develop and implement appropriate strategies in order to reduce incidence of tooth decay.

METHODS: This study modelled the cost-effectiveness of fluoride varnish therapy plan to prevent dental caries in elementary students with age range between 7-12 years, in Urmia, northwestern Iran. All costs and benefits were measured from a provider perspective in order to obtain the cost-effectiveness analysis (CEA). We estimated the direct medical costs of fluoride varnish in a school-based setting and compared this to the benefits of reducing the incidence of dental caries, as measured by the disability-adjusted life year (DALY) index. The Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist was used to report this economic evaluation. To calculate Incremental Cost Effectiveness Ratio and sensitivity analysis, TreeAge software was used.

RESULTS: Based on the DALY index, the incremental cost-effectiveness ratio (ICER) was obtained $200.02 per DALY averted. According to the threshold defined by World Health Organization (WHO), fluoride varnish therapy intervention in this study is cost-effective. The results of this research were not sensitive to the desired parameters based on the results of one-way sensitivity analysis.

CONCLUSION: This study recommends fluoride varnish therapy intervention because of reducing caries, improving quality of life (QOL), and financial saving for families in the long term. The results of this study can also help health policy makers and managers to make decisions about allocating resources to prevent dental diseases.

KEYWORDS: Dental Caries; Fluoride Varnish; Costs; Students; Incidence

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Oral health is a basic indicator of general health, well-being, and quality of life (QOL). Oral health is being free of oral infection, tooth decay, tooth loss, periodontal disease, and other diseases that limit one's ability to chew, speak, and live well (decrease in QOL).[1]

As countries develop, the prevalence of oral diseases and the share of oral disorders in the global disability-adjusted life year (DALY) burden will be notably increased.[2]

According to the World Health Organization (WHO), oral diseases are the most common non-communicable disease

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(NCD) in the world and approximately, 2.4 billion people and 486 million children suffer from permanent and primary dental caries, respectively.[3] Moreover, dental treatment accounts for an average of 5% of total health expenditure[4] and 20% of out-of-pocket health expenditure,[5] so that the costs spent on dental diseases were estimated to be approximately $544.41 billion with direct costs of $356.80 billion and indirect costs of $187.61 billion in 2015.[6]

Oral conditions in the treatment costs are in fourth rank. In the United States (US), paying costs for oral healthcare are $110 billion yearly, and in the European Union (EU), these annual spending was estimated to be €79 billion during 2008-2012.[7]

Since 1990, the number of people with untreated dental disease has been increased by about 40% and almost 3.5 billion people worldwide have not been treated.[8] In most low-income countries, the prevalence of this disease is very high and approximately, 90% of dental caries have remained untreated.[9]

Nowadays, oral health is one of the most important health interventions. Few people can be found who are not affected by oral diseases throughout their lives.[10] Due to the high prevalence of dental caries, its related diseases, and the high costs of treating this disease, health policy makers have increasingly focused on preventive interventions.[11,12]

In this regard, it is important to pay attention to the age group of 7-14 years, due to the complete number of permanent teeth as well as the formation of tooth enamel. There are several measures to prevent oral diseases, especially tooth caries, such as adding fluoride to drinking water, fissure sealant, povidone fluoride (PVP), and fluoride varnish.[13] Among the dental interventions to prevent tooth caries, fluoride varnish displays the strongest evidence for its effectiveness in preventing tooth caries.[14] Due to its ease of use, effectiveness, and safety, oral health professionals have paid the highest attention to the fluoride varnish and it is commonly used twice a year to increase its effectiveness.[15,16]

In recent decades, most countries have experienced significant increase in health care costs due to increasing technology changes, changes in lifestyle, greater attention to people's health, and transformation in people expectations from health systems.[17] Considering the limited resources, the numerous needs and goals, and the inability to achieve all of them, the importance of prioritizing interventions for policy makers seems to be crucial.

Cost-effectiveness analysis (CEA), as an economic evaluation technique, is considered as a way to examine both the costs and health consequences of one or more interventions. It compares an intervention to another intervention by estimating how much it costs to gain a unit of a health consequence or outcome, like a death prevented or a life year gained.[18]

Since 2014, after the implementation of the health system transformation plan in Iran, fluoride varnish therapy in the age group of 7 to 12 years in Iranian schools has been one of the measures taken in the field of health. It is performed by health workers and healthcare providers in six-month periods and approximately, 100% of elementary school students receive fluoride varnish therapy. Investigating the cost-effectiveness of this national plan clarifies understanding the investment and spending the resources as well as outcomes and success gained in this field. Limited research has been conducted on CEA of macro national plans and policy making in Iran, and various therapeutic approaches have been often investigated. A review of the studies revealed that no study has been conducted in Iran in this regard and economic evaluation of the national plan of fluoride varnish therapy was first implemented in Iran. Some of the external studies conducted in this regard include: the study conducted by Neidell et al.[19] under the title of "Cost-effectiveness analysis of sealants versus fluoride varnish in Colombian schools", the study conducted by Fyfe et al.[20] under the title of "Cost-effectiveness analysis

of adding fluoride to drinking water in New Zealand", the study conducted by Schwendicke et al.[21] under the title of "Cost-effectiveness of fluoride varnish applied in German dental clinics to prevent common and severe dental caries", and the study conducted by Chestnutt et al.[22] under the title of "Sealant or varnish?" The results of these studies suggest effectiveness of the fluoride varnish method over other methods of preventing dental caries. This study aimed to evaluate the cost-effectiveness of fluoride varnish application to prevent the occurrence and progression of dental caries in elementary schools of Urmia, Iran.

Methods

This study was a cost-effectiveness analysis and descriptive-analytical type of an economic evaluation, which has been conducted from the service provider perspective. In this study, implementation of fluoride varnish therapy was investigated in elementary schools of Urmia in terms of health economics.

Study population

Since Implementation of Health System Reform Plan in 2013, fluoride varnish therapy intervention was done in all primary schools. The research population included whole children aged between 7-12 years, who were studying at elementary schools of Urmia.

Model inputs

Costs and effectiveness: The data were collected through a pre-designed form with two sections. The first section covered the current costs of the fluoride varnish therapy plan, including the cost of compensating the contracted staffs for the plan and the materials and equipment used for this plan (varnish, 2 × 2 gauze, applicator, container to hold varnish, dental's disposable mouth mirrors, toothbrush, dental bib or lap barrier, and cold glass of water). They were collected from the financial and accounting unit of the Deputy of Health Affairs of Urmia University of Medical Sciences. Top-down or micro costing was the used valuation method of the direct costs in this study. Costs are expressed in 2016 US dollars.

In the second section, data on the effectiveness (incidence rate of caries for fluoride varnish therapy in 2016 and no use of fluoride varnish therapy in 2012) were obtained from the Deputy of Health Affairs. A model designed by WHO in Excel software and the sensitivity analysis in TreeAge software were used to calculate DALY.[23] As fluoride varnish therapy plan for children is implemented in the school environment; there is no need to calculate the indirect medical costs (resulting from overhead costs).

In this study, in order to calculate the effectiveness, DALY changes in the study population were considered in the year before the implementation of the fluoride varnish plan and one year after the implementation of this plan. DALY index represents the years of healthy life which have been lost due to disease and disability. It includes two components of years lost due to premature death and years lost due to a life with disability. In this study, DALY index was calculated using the model designed by WHO in Excel software. Effectiveness based on DALY index was calculated using the following formula:

$$DALY = YLL + YLD$$

Where YLL stands for "years of life lost" and YLD stands for "years lost due to disability".

$$YLL = KCe^{ra}/(\beta + r)^2 [e^{-(\beta + r)(L + a)} \{-(\beta + r)(L + a) - 1\} - e^{-(\beta + r)a} \{-(\beta + r)a - 1\}] + 1\text{-}K/r (1 - e^{-rL})$$

$$YLD = D [KCe^{ra}/(\beta + r)^2 [e^{-(\beta + r)(L + a)} \{-(\beta + r)(L + a) - 1\} - e^{-(\beta + r)a} \{-(\beta + r)a - 1\}] + 1\text{-}K/r (1 - e^{-rL})]$$

K stands for relative value of age, β stands for world bank parameter = 0.04, C stands for adaptive constant = 0.16243, e stands for natural logarithmic base, D represents disability weight, r represents discount rate = 0.05, L represents mean treatment period (based on year) in YLD and raw year lost in YLL, and a is the age of tooth caries, age group of YLD, and age at death in YLL. The disability weight for dental caries is 0.081 that

was obtained from the Global Burden of Disease (GBD).[24]

Dental services tariffs of year 2017 were also used to calculate the cost of controlling and treating dental caries. Costs and effectiveness were also entered in the software with a 5% discount rate. The incremental cost-effectiveness ratio (ICER) was calculated according to the incremental cost required to avert DALY and the average cost-effectiveness ratio (ACER) was calculated based on the following formula:[25]

$$ICER = \frac{Cost_{Intervention} - Cost_{NoIntervention}}{DALYaverted_{Intervention} - DALYaverted_{NoIntervention}}$$

$Cost_{No\ Intervention}$ and $Cost_{Intervention}$ are the expected costs of non-intervention and the expected costs of intervention of fluoride varnish therapy, respectively. DALY $averted_{Intervention}$ and DALY $averted_{No\ Intervention}$, respectively, were considered as the expected effectiveness of fluoride varnish intervention and the expected effect of fluoride varnish non-intervention.

Then, the cost-effectiveness of the fluoride varnish therapy plan was evaluated based on the ICER obtained from this study and comparing it with the threshold set by the WHO for developing countries[26] [three times more than gross domestic product (GDP) per capita]. After calculating the cost-effectiveness ratio, it is necessary to evaluate the power of this ratio. In other words, rate of change in the ICER needs to be evaluated, due to changes in each of the parameters. Thus, after plotting the Tornado diagram using TreeAge software, the parameters with the highest effect on the cost-effectiveness ratio were identified. Given these parameters, one-way sensitivity analysis was performed with 10% change in their upper and lower range to obtain the acceptable threshold of these parameters for effectiveness of fluoride varnish therapy plan.

The study was approved by the Ethics Committee of Urmia University of Medical Sciences (Approval ID: IR.UMSU.REC.1397.178).

Results

A total of 109755 people participated in this plan (a population of 7-12-year old students in Urmia). The total costs of the plan, including the cost of staff compensation, consumables, and other costs were also reported to be $406249.23. The average cost of fluoride varnish therapy per student was $3.7 in this plan. Table 1 indicates demographic characteristics of the students at risk of dental caries based on age and rate of dental caries incidence.

The rate of incidence and prevalence of dental caries in 2012-2016 and the base population as well as the disability weight of oral diseases were used to estimate the prevalence of dental caries. Table 2 shows the calculated value of DALY separately by age for the years 2012 (before the intervention) and 2016 (after the intervention).

The ICER was estimated based on DALY changes caused by dental caries in the studied population following the implementation of the fluoride varnish therapy plan and the costs of plan implementation and caries treatment. Based on what was mentioned, the ICER criterion was calculated to be $200.0242 per DALY, as shown in table 3.

Table 1. Demographic characteristics of the studied population based on age in Urmia, Iran, in 2012 and 2016

Year	2012		2016	
Student age (year)	Caries incidence rate	At-risk population	Caries incidence rate	At-risk population
7	0.38	19693	0.42	16101
8	0.38	19240	0.43	15346
9	0.37	19172	0.44	14966
10	0.36	18417	0.45	14995
11	0.35	16744	0.46	14963
12	0.33	16489	0.46	15019
Total	0.36	109755	0.44	91390

Table 2. The number of disability-adjusted life year (DALY) for the years before and after fluoride varnish intervention

Year	Estimated number of DALYs for dental caries in 2012	Estimated number of DALYs for dental caries in 2016
7	1922	1739
8	1923	1699
9	1960	1648
10	1926	1541
11	1790	1362
12	1763	1264
Total	11284	9253

DALY: Disability-adjusted life year

In the next stage, according to the Tornado diagram, one-way sensitivity analysis was performed for the parameters that had the highest effect on the cost-effectiveness ratio, which included the probability parameter of dental caries in the fluoride varnish therapy plan. In this study, the results showed no sensitivity to the desired parameter and the fluoride varnish therapy intervention was superior to its non-intervention due to reduction of caries in improving QOL in the studied population.

Figure 1 indicates that the threshold estimated for the probability of caries in the case of non-implementation of a fluoride varnish therapy plan with regard to the ICER index is 0.315. The fluoride varnish therapy plan was not cost-effective before implementing the plan, but it was cost-effective after its implementation.

Figure 2 shows that, given the effect of the plan, the threshold estimated for the probability of caries in the case of implementing fluoride varnish therapy plan is 0.440.

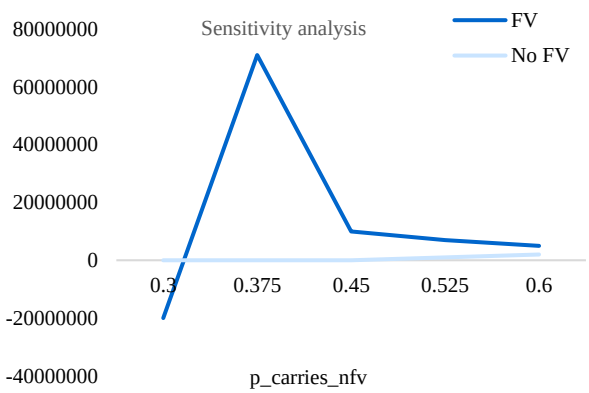

Figure 1. One-way sensitivity analysis for probability of caries with no fluoride varnish therapy intervention

In other words, the fluoride varnish therapy plan implementation was effective compared to lack of its implementation.

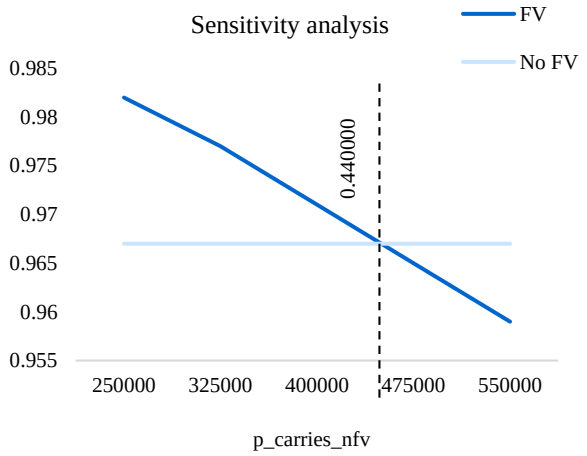

Figure 2. One-way sensitivity analysis for probability of caries with fluoride varnish therapy intervention

Table 3. The incremental cost-effectiveness ratio (ICER) separately based on age in Urmia, Iran

Year	Costs of fluoride varnish therapy	Number of DALY averted	ICER ($ per DALY)
7	72892.04	183	398.3172
8	71215.30	224	317.9254
9	70963.60	312	227.4474
10	68169.03	385	177.0624
11	61976.56	428	144.8050
12	61032.70	499	122.3100
Total	406249.23	2031	200.0242

ICER: Incremental cost-effectiveness ratio; DALY: Disability-adjusted life year

Discussion

This study aimed to examine the cost-effectiveness of a fluoride varnish therapy intervention, as a national dental caries prevention program, which was measured based on DALY index. In economic evaluation, CEA and ICER are calculated when one method is more or less effective and more expensive or cheaper than the other. Thus, in this study, the more effective and expensive method of fluoride varnish therapy was evaluated compared to its non-implementation option.

In this study, the effectiveness of fluoride varnish therapy at age group of 12 years was higher than other age groups, so that the value of DALY averted was 499 in this age group. This index was calculated to be 1763 for one year before implementing the plan and 1264 for one year after implementing the fluoride varnish therapy plan. The ICER for this age group was estimated to be $122.31 per DALY. In addition, the effectiveness of this plan was 183 DALY for the age group of 7 years, which was the least effective age group compared to other age groups under study. The ICER was calculated to be $398.3172 for this age group. Thus, based on the results, it can be concluded that the application of fluoride varnish therapy at the age of 12 years was more cost-effective than the other age groups under study.

In general, in the studied population, total DALY averted was estimated to be 2031 years and the total cost of fluoride varnish therapy plan was estimated to be $406249.23.

DALY index for the age group of 7-12 years included the study population, which was estimated to be 11284 in 2012 and 9253 in 2016. Accordingly, the ICER of the plan in the desired population was calculated to be $200.0242 per DALY. Based on the WHO criteria and report of International Monetary Fund (IMF) (GDP per capita of Iran:[27] US$4680 in 2016), the dental fluoride varnish therapy plan was cost-effective in this study.

In this study, the trend of DALY was decreasing, indicating an improvement in tooth caries in the years after implementing the fluoride varnish therapy plan in the study population.

Few studies have been conducted on developing countries to evaluate the cost-effectiveness of dental caries prevention plans, while dental caries is the second leading cause of disease in low- and middle-income countries;[10] therefore, its prevention is crucial. Neidell et al. compared the fluoride varnish method with fissure sealants in Colombian schools. The results of mentioned study revealed the cost-effectiveness of fluoride varnish versus fissure sealant, so that the ACER for tooth caries was $104.25 in the sealant method and $44.96 for fluoride varnish.[19] The results of above study are consistent with those of the present study in terms of fluoride varnish therapy intervention. In a study conducted by O'Neill et al., in Northern Ireland, on the cost-effectiveness of dental caries prevention, the researchers conducted a two-group controlled trial to evaluate the cost-effectiveness of dental caries prevention in 2-3-year children without dental caries. The participants in the intervention group received 22600 ppm fluoride varnish, toothbrush, and toothpaste containing 50 ml of 1450 ppm fluoride and counseling for prevention. The second group, which was under control, received counseling at 6-month intervals for 3 years. The cumulative outcomes and costs for each group were shown by the ICER, which were €2093 for the first group per decayed tooth and €251 for the control group.[28] Based on results of the mentioned study, the fluoride varnish used in the first intervention was not cost-effective unlike the present study.

Schwendicke et al. evaluated the cost-effectiveness of a fluoride varnish applied in German dental clinics, in which the cost-effectiveness data were extracted from a Cochran's review and costs were extracted from the cost payment guidelines. The results of mentioned study emphasized on the cost-effectiveness of fluoride varnish at older

ages. In this study, the ICER was calculated €343 per prevented Decayed, Missing, and Filled Teeth (DMFT).[21] Moreover, in a longitudinal study conducted by Skold et al., to analyze the cost of fluoride varnish and mouthwash in Sweden, the results revealed that the fluoride varnish plan had better effectiveness in reducing caries compared to fluoride washing and incurred lower costs.[29] The results of these studies partially confirm that varnish fluoride therapy is cost-effective in reducing early childhood caries.

Thus, fluoride varnish application can extend the life of teeth, control future medical costs, increase the utility of life, and confirm the results of this study.

Conclusion

Identifying new effective strategies to control oral diseases improves the QOL of people and reduces their healthcare costs. Therefore, implementation of plans to prevent these diseases should be considered as a public health priority of the country. One of the limitations of this study was lack of information on the direct and indirect costs associated with fluoride varnish therapy for children who might have received this service in dental clinics under the dentists. Hence, it is recommended to conduct a field study to estimate these costs in order to make decision on the cost-effectiveness of this intervention with more certainty.

Conflict of Interests

Authors have no conflict of interest.

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