Cost-effectiveness Analysis of Comprehensive Oral Health Care for Severe Early Childhood Caries in Urban Beijing, China

Yan Yi XIE[1], Meng Lin CHENG[1], Meng Ru XU[1], Yan SI[1], Tao XU[1]

Objective: *To evaluate the cost-effectiveness of comprehensive oral health care for severe early childhood caries (S-ECC) in urban Beijing, China.*
Methods: *A randomised cluster sampling method was used to select 187 children aged 3 to 5 years with S-ECC from two kindergartens in urban Beijing. Comprehensive oral health care and questionnaires for the parents/guardians were provided to the test group, while an oral health examination and questionnaires for the parents/guardians were provided to the control group. Data were collected and a Markov model was established for a cost-effectiveness analysis.*
Results: *One year later, 614 RMB yuan and 184 RMB yuan were needed for the control and test group, respectively, to reduce one average decayed tooth. The cost for the test group was continuously lower than for the control group during the 4-year simulation. The cumulative cost for the test group was lower than for the control group when the model was circulated for more than 1.5 years. At this time, the change of decayed teeth was stable in the test group.*
Conclusion: *Comprehensive oral health care had extraordinary cost-effectiveness for S-ECC. The optimal time to process S-ECC may be after 1.5 years.*
Key words: *comprehensive oral health care, severe early childhood caries (S-ECC), cost-effectiveness analysis, Markov model*
Chin J Dent Res 2019;22(1):45–50; doi: 10.3290/j.cjdr.a41774

S̲evere early childhood caries (S-ECC) is a disease that severely affects the growth of preschool children and the quality of life of families. It has become a public health problem. Children with S-ECC are at a high risk of suffering permanent tooth caries. On mainland China, the prevalence of ECC is 53.5% to 74.2% and that of S-ECC is 38.1% to 40.1%[1,2]. While there is a huge demand for dental treatment in this particular population, the general demand for dental services in China is relatively low and is not seen as critical[3]. Thus,

an effectiveness program to control and prevent S-ECC is urgently needed. Based on the principle of tertiary prevention, a comprehensive oral health care program aimed to increase demand and decrease caries is proposed.

The occurrence of childhood caries is related to a variety of factors, including oral flora, parents' oral health knowledge and attitude, children's oral hygiene and behaviour, previous caries experiences[4], topical fluoride applications, social demographics, socioeconomic characteristics and oral health service utilisation. Through comprehensive oral health care, interventions have been provided that may affect parents' oral health knowledge and attitude, children's oral hygiene and behaviour, topical fluoride applications and oral health service utilisation.

The Markov model is a cycle decision tree model. According to the degree that it will impact health, a disease is divided into several health statuses, with specific transition probabilities between the different statuses. After multiple circulations, both resource consumption and health outcome can be estimated.

1 Department of Preventive Dentistry, Peking University School and Hospital of Stomatology, National Engineering Laboratory for Digital and Material Technology of Stomatology, Beijing Key Laboratory of Digital Stomatology, Beijing, P.R. China.

Corresponding author: Dr Yan SI and Prof Tao XU, Department of Preventive Dentistry, Peking University School and Hospital of Stomoatolgy, 22# Zhongguancun South Avenue, HaiDian District, Beijing 100081, P.R. China. Tel: 86-10-82195561; Fax: 86-10-82195561. Email: siyanyy@163.com, taoxu@bjmu.edu.cn
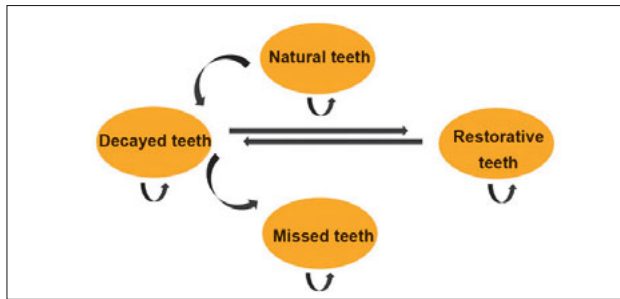
Fig 1 The relationship between health statuses due to caries.

The model is widely used in pharmacoeconomics and for decision making in the case of chronic disease. In recent years, the model has been used in the health economics analysis of the management of caries and may be widely used in preventive dentistry to perform long-term evaluations[5-7]. In this study, the authors sought to evaluate the cost-effectiveness in the short and long term by applying the Markov model so as to provide evidence for policy makers to design an optimal program to reduce the prevalence of caries.

Materials and methods

Clinical trial design

This study was a single-blinded clinical trial designed to test the effect of comprehensive oral health care on S-ECC. The enrolled children were selected from two kindergartens using a random cluster sampling method. They were then divided into a test and a control group. The eligibility criteria of the samples were children in two kindergartens in urban Beijing aged 3 to 5 years old and diagnosed with S-ECC. In this study, In this study, S-ECC was defined as the presence of ≥ 4 (age 3 years), ≥ 5 (age 4 years), ≥ 6 (age 5 years) decayed, missing and filled surfaces of teeth. The parents/guardians of all the enrolled children signed a consent form. For the test group, questionnaires for parents/guardians were provided and a comprehensive oral health care program was carried out on the children, including an oral health examination, oral health education, topical fluoride application and professional treatment. For the control group, questionnaires for parents/guardians were provided and an oral health examination was carried out on the children. All parents/guardians of children in both groups received the results of the oral health examination and professional advice for prevention and treatment. The parents/guardians of children in the test group could choose for them to receive the recommended interven-tion from the researchers or not. Parents/guardians of children in both groups had the right to search for other dental services beyond the study.

In the pilot survey, 10 S-ECC children were randomly chosen from two kindergartens. After 6 months, the average number of decayed teeth for the test and the control group was reduced by 1.62 (standard deviation [SD] = 2.87) and 0.27 (SD = 2.95), respectively. To detect a between-group difference with a 5% significance level and a power of 90%, a sample size of 91 children per group was necessary. Considering a 15% dropout rate, recruitment of at least 107 children per group was planned. Finally, a total of 109 and 134 S-ECC children were enrolled in the control and test group, respectively. One year later, only 91 children from the control group and 96 from the test group were still being monitored.

One year later, data on the average number of decayed teeth and cost for dental service over the previous year were collected to perform a short-term cost-effectiveness analysis. A Markov model of caries was established and used to simulate a 4-year circulation, with a circulation time of 6 months. In this way, a long-term analysis was performed and the optimal incremental cost-effectiveness ratio (ICER) was established. The Statistical Package for Social Sciences 20.0 (SPSS, Illinois, USA) was used to analyse the data.

Markov model

In this study, it was assumed that there were four health statuses for preschool children in the Markov model, being natural teeth, decayed teeth, teeth missing due to caries and teeth restored due to caries. The relationships between these four statuses are shown in Figure 1.

In addition, this model was based on the following assumptions:
1. During the simulation, there was no transition from primary to permanent teeth.
2. The cost of seeing a dentist during the last year was due to caries only.
3. The health status of every tooth was independent.
4. The transition probability of a different status did not change over time.

Considering the development of caries[8], the low treatment rate of Chinese children and the time of primary tooth loss, a cycle duration of 6 months and a simulation duration of 4 years were established for this study.

The data on the transition probabilities were obtained from the results at baseline and 1 year later; the data followed a beta distribution. The cost for treatment was calculated from the parents' questionnaire 1 year later

Table 1 The caries status of the two groups at baseline and 1 year later.

Time	Variables	Control group		Test group		Independent t test	P
		Mean	SD	Mean	SD		
Baseline	dt	4.31	3.03	4.56	3.33	-0.546	0.586
	mt	0.01	0.11	0.1	0.1	0.038	0.97
	ft	0.7	1.9	0.55	1.18	0.658	0.511
	dmft	5.02	3.47	5.13	3.34	-0.207	0.836
1 year later	dt	3.96	3.38	2.74	3.39	2.457	0.015
	mt	0.03	0.23	0.1	0.1	0.864	0.389
	ft	1.33	2.37	2.93	2.71	-4.301	< 0.001
	dmft	5.32	3.89	5.68	3.55	-0.659	0.511

and followed a gamma distribution. The effectiveness index was the reduction of the average decayed teeth. The discount rate was 3%. TreeAge Pro 2013 (TreeAge Software, Williamstown, MA, USA) was used to set up a Markov model and analyse the long-term cost-effectiveness.

Ethical statements

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee as well as with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the Peking University Institutional Review Board in Beijing (IRB00001052-10090). Informed consent was obtained from all individual participants included in the study.

Results

Oral health status at baseline and 1 year later

The average age of all 187 enrollees was 3.71 years (SD = 0.73) and 47.1% were boys. The chi-square test was used to test the correlation of sociodemographic and socioeconomic characteristics and dental service utilisation between the two groups. The results at baseline showed no statistical significance in age, gender, father or mother's highest education, family income in the last year, accuracy of correct oral health knowledge and attitude questions. Only for the question 'When was the last time you saw a dentist?' was there a significant difference between the two groups, as 30.6% of the control group and 72.2% of the test group had seen a dentist in the last year ($c2 = 32.403$; $P < 0.001$). Moreover, an independent t test was used to test the caries status at baseline of the two groups (Table 1) and no statistically significant difference was found in the average of primary teeth, decayed teeth (dt), missing teeth (mt), and filled teeth (ft).

One year later, the decayed, missing and filled primary teeth (dmft) of the test and control group were 5.68 (SD = 3.55) and 5.32 (SD = 3.89), respectively (Table 1). However, the reduction of the average number of decayed teeth in the test group was 1.82 (SD = 2.78), which was significantly higher than 0.35 (SD = 2.34) in the control group ($P < 0.001$). The intervention in the test group strongly changed the distribution of the caries status. More decayed teeth were treated and became filled teeth. The decrease of decayed teeth and the increase of restored teeth in the test group were statistically significant. The increase of restored teeth in the control group was also statistically significant. However, only the increase of the treatment could not improve the whole oral health status; the small decrease of the decayed teeth in the control group had no significance for the improvement of the whole oral health status. For the children with S-ECC, the

Table 2   The parameters of the Markov model.

Variables	Test		Control	
	Values	Distribution	Values	Distribution
Transition probability from natural teeth to decayed teeth	0.0188	beta	0.0179	beta
Transition probability from decayed teeth to restored teeth	0.3125	beta	0.0909	beta
Transition probability from decayed teeth to missed teeth	0.0023	beta	0.0026	beta
Transition probability from restored teeth to decayed teeth	0.0054	beta	0.0465	beta
Cost of decayed teeth/person/cycle time	335.06	gamma	214.95	gamma
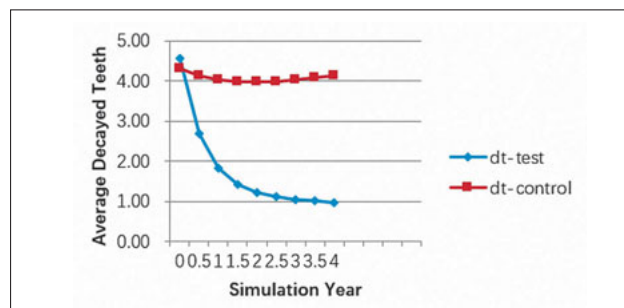
Fig 2   The trend of the average decayed teeth during the simulation.
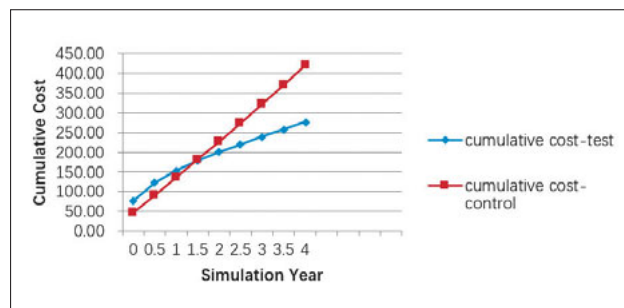
Fig 3   The trend of the cumulative cost during the simulation.
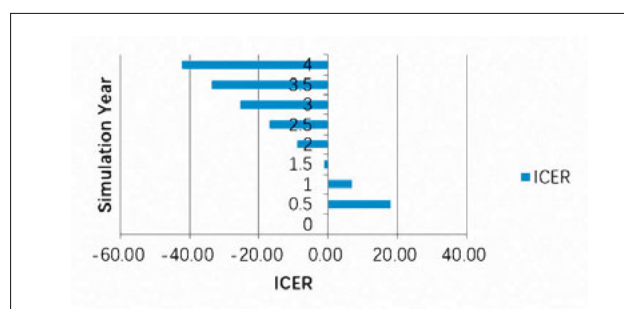
Fig 4   The ICER between the test group and the control group during the simulation.

intervention that combined prevention and treatment was more effective.

Short-term cost-effectiveness analysis

In the test group, treatment was only rendered where parents/guardians provided informed consent. Parents/guardians could refuse treatment for their children or choose other institutions. All of the children in the test group received an oral health examination and topical fluoride application. A total of 54 children in the test group and 29 in the control group had spent money on a dental service in the last year. In the questionnaire 1 year later, the average cost for dental services in the last year was 335 RMB yuan in the test group and 215 RMB yuan in the control group. Moreover, the average fee to reduce one average decayed tooth was 614 RMB yuan in the control group and 184 RMB yuan in the test group. The ICER between the two groups was 81, i.e. the children in the test group needed 81 RMB yuan more to reduce one average decayed tooth.

Long-term cost-effectiveness analysis

The transition probabilities and cost between the four health statuses are shown in Table 2. After a 4-year simulation, the cumulative cost to reduce one average decayed tooth was 2,320 RMB yuan in the control group and 77 RMB yuan in the test group, and the ICER was less than zero, i.e. the comprehensive intervention saved money and had greater effectiveness at this time. Figure 2 shows the trend of the average number of decayed teeth. When the model circulated for more than 1.5 years, the average number of decayed teeth in both groups was reduced to a stable level. The cumulative cost in the test group was lower than the cost in the

control group when the model was circulated for more than 1.5 years (Fig 3). When the results of the ICER were combined (Fig 4) it was found that the optimal time to process a comprehensive intervention may be more than 1.5 years.

Sensitivity analysis

A one-way sensitivity analysis showed that the cost and average decrease of decayed teeth in the two groups fluctuated by 20%. The results were consistent with the outcome of the short-term cost-effectiveness analysis. Furthermore, a tornado diagram was made to analyse the sensitivity of the model. All of the transition probabilities, the cost of the two groups and the discount rate were adjusted by 20%. The ICER was less than zero and the test group always had a cost-effectiveness advantage.

Discussion

Oral health status of children and the comprehensive oral health care model

According to the 3rd National Oral Health Survey in 2005 in China, the prevalence of dental caries in the 5-year-old age group was 66% and the average dmft was 3.5 per child. 79.3% of caries were concentrated in one third of the child population and their Significant Caries Index (SiC) was 8.33. However, only 9% of parents/guardians would help to brush their children's teeth, 96.7% of caries were not treated and only 15% of 5-year-old children had seen a dentist in the last year[9]. In other words, children's oral hygiene and the utilisation of dental services were insufficient.

A comprehensive intervention including oral health education, an oral health examination, topical fluoride application and treatment could realise tertiary prevention for children with S-ECC. Based on the results of this study, it seems feasible that the youngest children in kindergarten in urban China should receive a regular check-up, topical fluoride applications and necessary treatment until they graduate. Through a comprehensive oral health care program, children's decayed teeth can be controlled by restorative treatment and their oral health behaviour and oral hygiene could be improved through oral health education. Childhood may be a good time to prevent severe primary caries and save money on the population level. In an ideal state, a comprehensive way to promote tertiary prevention may be to reduce the risk factors for children and prevent the occurrence of permanent caries.

Markov model

The results of this study confirm that the comprehensive oral health care program had a cost-effectiveness advantage. At baseline, the caries status, social demographic characteristics, socioeconomic status and oral health knowledge and attitude had no statistical significance. The sensitivity analysis demonstrated the stability of the Markov model. Based on the high comparability of the two groups and the sensitivity analysis of the model, the results of the Markov model were reliable.

Schwendicke et al[10] used the Markov model to evaluate the cost-effectiveness of three different fluoride vanish applications for low-, moderate- and high-risk patients through a literature review. Schwendicke and Göstemeyer [11] evaluated the cost-effectiveness of preventive treatments of root caries though a randomised clinical trial that divided health statuses into sound teeth, carious teeth and filled teeth. Hill et al[12] used a Markov model to evaluate the treatment of caries in different National Health Service (NHS) settings in the UK and illustrated that the health statuses were made up of sound teeth, enamel caries, dentinal caries, deep dentinal caries and restored teeth. In the present study, the data collected allowed the authors to assume four health statuses for preschool children in the Markov model.

Furthermore, a change of average decayed teeth was shown with the Markov model, which provided a prediction of the intervention so that an optimal timeframe for the study could be identified as well as a timeframe for decisionmakers to consider when planning a program. This has not been seen in other oral health studies using Markov models.

Despite more and more economic analysis applications, model analysis still plays a significant role in clinical trials. Due to limited resources, not all clinical trials can be designed with an economic analysis component. As most clinical trials cannot follow up the final health outcomes, a model analysis is needed to estimate the long-term effect. The Markov model is fairly well suited to the investigation of diseases progressing over time and can estimate both resource consumption and health outcomes. Thus, this study attempted to evaluate the cost-effectiveness of comprehensive oral health care for S-ECC using a Markov model. More research studies need to be conducted in the future.

Limitations of the study

There were some limitations of the present study. Firstly, a confounding factor may have been the significant difference between the test and control groups when it

came to seeing a dentist in the last year (30.6% of the control group and 72.2% of the test group; c2 = 32.403; $P < 0.001$) at baseline. Secondly, the cost was obtained from questionnaires, which may have been subject to recall bias. Thirdly, the transition probabilities of different statuses were assumed to be fixed, which may have neglected the influence of time. Finally, the study of cost-effectiveness was conducted on a consumer level, but the preventive costs and the indirect costs from the supplier were unclear.

Conclusion

Comprehensive oral health care including oral health education, oral health examination, topical fluoride application and treatment for children with S-ECC had an extraordinary cost-effectiveness advantage. After 1 year of a random clinical trial, the cost to reduce one average decayed tooth was 184 RMB yuan in the test group and 614 RMB yuan in the control group. According to the Markov model simulation, the 4-year average cumulative cost to reduce one average decayed tooth was 77 RMB yuan in the test group and 2,320 RMB yuan in the control group. The results from the Markov model showed that the optimal time may occur after 1.5 years, at which time the comprehensive oral health care was more effective and cost less money.

Conflicts of interest

The authors report no conflicts of interest related to this study.

Author contribution

Drs Yan Yi XIE and Meng Lin CHENG established the Markov model and wrote the manuscript. These two authors contributed equally to the study; Dr Meng Ru XU collected and analysed data from samples; Dr Yan SI organized the work and collected samples; Drs Tao XU and Yan SI conceived and designed the study.

References

1. Jiang YY. Prevalence of Early Childhood Caries Among 2- to 5-year-old Preschoolers in Kindergartens of Weifang City, China: A Cross-sectional Study. Oral Health Prev Dent 2017;15:89–97.
2. Wulaerhan J, Abudureyimu A, Bao XL, Zhao J. Risk determinants associated with early childhood caries in Uygur children: a preschool-based cross-sectional study. BMC Oral Health 2014;14:136.
3. Liu J, Zhang SS, Zheng SG, Xu T, Si Y. Oral Health Status and Oral Health Care Model in China. Chin J Dent Res 2016;19:207–215.
4. Corrêa-Faria P, Paixão-Gonçalves S, Paiva SM, Pordeus IA. Incidence of dental caries in primary dentition and risk factors: a longitudinal study. Braz Oral Res 2016;30. pii: S1806-83242016000100254.
5. Zimmer S, Spyra A, Kreimendahl F, Blaich C, Rychlik R. Elevating the use of sugar-free chewing gum in Germany: cost saving and caries prevention. Acta Odontol Scand 2018;76:407–414.
6. Khouja T, Smith KJ. Cost-effectiveness analysis of two caries prevention methods in the first permanent molar in children. J Public Health Dent 2018;78:118–126.
7. Brazzelli M, McKenzie L, Fielding S, et al. Systematic review of the effectiveness and cost-effectiveness of HealOzone for the treatment of occlusal pit/fissure caries and root caries. Health Technol Assess 2006;10:iii–iv, ix–80.
8. Chi DL, van der Goes DN, Ney JP. Cost-effectiveness of pit-and-fissure sealants on primary molars in Medicaid-enrolled children. Am J Public Health 2014;104:555–561.
9. Qi XQ. Investigation report of the third national oral health survey in China, ed 1 [in Chinese]. Beijing: People's Medical Publishing House, 2008:11–15.
10. Schwendicke F, Splieth CH, Thomson WM, Reda S, Stolpe M, Foster Page L. Cost-effectiveness of caries-preventive fluoride varnish applications in clinic settings among patients of low, moderate and high risk. Community Dent Oral Epidemiol 2018;46:8–16.
11. Schwendicke F, Göstemeyer G. Cost-effectiveness of root caries preventive treatments. J Dent 2017;56:58–64.
12. Hill H, Macey R, Brocklehurst P. A Markov model assessing the impact on primary care practice revenues and patient's health when using mid-level providers, lesson learned from the United Kingdom. J Public Health Dent 2017;77:334–343.