

REVIEW ARTICLE



Cost-effectiveness of partial versus stepwise caries removal of deep caries lesions - a decision-analytic approach

Nikki Savolainen , Thomas Kvist  and Johanna Mannila 

Department of Endodontics, Institute of Odontology, The Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

ABSTRACT

Objective: The aim was to compare the cost-effectiveness of partial caries removal (PCR) and stepwise caries removal (SW) in mature permanent teeth diagnosed with deep caries lesions, in a Swedish Public Dental Care organization.

Materials and methods: A decision tree model was used to calculate the cost-effectiveness for PCR and SW. Probability values were obtained through a literature search in PubMed and Scopus. Treatment times were estimated by a group of dentists practicing at public dental care clinics in Västra Götaland county, Sweden.

Results: The expected costs for PCR and SW were 187,63 and 414,35 €, respectively, indicating that PCR was more cost-effective. Four articles were identified through the literature search. The *p*-values for PCR outcomes were 94% (success), 0% (pulp exposure) and 6% (pulpitis/apical periodontitis etc.). For SW, the *p*-values were 76% (success), 2% (pulp exposure during the first visit), 13% (pulp exposure during the second visit) and 9% (pulpitis/apical periodontitis etc.).

Conclusions: Given the presumptions in this decision analysis, the PCR method used on mature permanent teeth is more cost-effective ($p < .05$) compared to the SW method in protecting the pulp from exposure and avoiding the need for root canal treatment.

ARTICLE HISTORY

Received 6 May 2022

Revised 18 September 2022

Accepted 29 October 2022

KEYWORDS

Cost-effectiveness; decision analysis; partial caries removal; stepwise caries removal; deep caries lesion

Introduction

The issue of how to best manage a deep caries lesion jeopardizing the integrity of the dental pulp is of core interest in conservative dentistry [1]. Until recently, the Swedish National Board of Health and Welfare recommended stepwise caries removal (SW) in favour of complete caries removal (CCR). Partial caries removal (PCR), that is, leaving caries without a re-entry, was not listed among available options [2]. However, in the updated recommendations published in September 2021, both SW and PCR are equally suitable options and are preferred to CCR [3]. The SW method compared with the CCR method has an established position being a method of preserving pulp vitality in teeth with a deep caries lesion and has caused less frequent pulp exposures than the CCR technique [4]. It has been shown that PCR can be a suitable treatment option when treating deep caries lesions in primary teeth [5,6], but there has not been that much research done on the effect and success on mature permanent teeth that have been treated with PCR. However, the number of articles has increased in recent years [7–10].

A reserved attitude towards PCR has been seen in surveys conducted in the early 2010s targeting dentists' opinion on the matter [11,12]. Meanwhile, surveys carried out in Norway [13] and Finland [14] show that SW is currently relatively

popular in Nordic countries. Nevertheless, PCR and SW have been seen to perform similarly in success [7] as well as in restoration survival [15].

Decision analysis

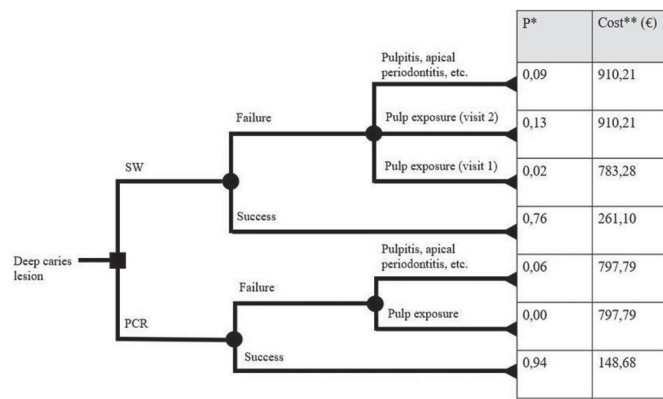
Health economic analyses can be used when giving general recommendations and distributing available resources in health care [16,17]. The theoretical basis of clinical decision analysis derives from 'expected utility theory' [18]. The model was suggested to medicine by Ledley & Lusted in 1959 [19] and it can be used for cost-effectiveness analyses [20].

The decision analysis starts by structuring the decision problem into a 'decision-tree', which logically displays available actions and their possible outcomes. Then, the listed outcomes are assessed regarding probabilities and costs. After this the weighted sum (expected cost) of each strategy is computed, and the action with the lowest sum is regarded as the most cost-effective.

The probabilities (*P*) for the different outcomes are derived from published literature of highest available quality, such as randomised controlled trials [21], but other types of studies can also weigh in when the area of research is under-explored. The costs can be estimated in different ways and may vary between different care providers.

CONTACT Nikki Savolainen  nikki.savolainen@gmail.com

© 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group on behalf of Acta Odontologica Scandinavica Society. This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.



*Weighted average of the probabilities (from literature search)

**Cost(€) = hourly cost (€/h) x estimated time (h)

For general practitioner

$$\begin{aligned}
 \text{PCR:} & \quad 217,58 \text{ €/h} \times \frac{41}{60} \text{ h} = 148,679666... \text{ €} \approx 148,68 \text{ €} \\
 \text{SW(1st visit):} & \quad 217,58 \text{ €/h} \times \frac{37}{60} \text{ h} = 134,174333... \text{ €} \approx 134,17 \text{ €} \\
 \text{SW(2 visits):} & \quad 217,58 \text{ €/h} \times \frac{72}{60} \text{ h} = 261,096 \text{ €} \approx 261,10 \text{ €} \\
 \text{RCT:} & \quad 217,58 \text{ €/h} \times \frac{179}{60} \text{ h} = 649,113666... \text{ €} \approx 649,11 \text{ €}
 \end{aligned}$$

$$\begin{aligned}
 \text{PCR(success)} & = 148,68 \text{ €} \\
 \text{PCR(failure)} & = \text{PCR} + \text{RCT} = 148,68 \text{ €} + 649,11 \text{ €} = 797,79 \text{ €} \\
 \text{SW(success)} & = 261,10 \text{ €} \\
 \text{SW(failure)} & = \text{SW(2 visits)} + \text{RCT} = 261,10 \text{ €} + 649,11 \text{ €} = 910,21 \text{ €} \\
 \text{SW(failure 1st visit)} & = \text{SW(1st visit)} + \text{RCT} = 134,17 \text{ €} + 649,11 \text{ €} = 783,28 \text{ €}
 \end{aligned}$$

Expected cost (€) = P x Cost(€)

$$\begin{aligned}
 E(\text{costPCR}) & = [P(\text{PCRsuccess}) \times \text{cost}(\text{PCRsuccess})] + [P(\text{PCRpulp exposure}) \times \\
 & \quad \text{cost}(\text{PCRfailure})] + [P(\text{PCRpulpitis, apical periodontitis etc.}) \times \\
 & \quad \text{cost}(\text{PCRfailure})] \\
 & = [0,94 \times 148,68 \text{ €}] + [0 \times 797,79 \text{ €}] + [0,06 \times 797,79 \text{ €}] \\
 & = 187,6266 \text{ €} \\
 & \approx 187,63 \text{ €} \\
 E(\text{costSW}) & = [P(\text{SWsuccess}) \times \text{cost}(\text{SWsuccess})] + [P(\text{SWpulp exposure 1st} \\
 & \quad \text{visit}) \times \text{cost}(\text{SWfailure 1st visit})] + [P(\text{SWpulp exposure 2nd visit}) \\
 & \quad \times \text{cost}(\text{SWfailure})] + [P(\text{SWpulpitis, apical periodontitis etc.}) \times \\
 & \quad \text{cost}(\text{SWfailure})] \\
 & = [0,76 \times 261,10 \text{ €}] + [0,02 \times 783,28 \text{ €}] + [0,13 \times 910,21 \text{ €}] + [0,09 \\
 & \quad \times 910,21 \text{ €}] \\
 & = 414,3478 \text{ €} \\
 & \approx 414,35 \text{ €}
 \end{aligned}$$

Figure 1. Decision tree with cost calculations and results.

Sensitivity analysis

Sensitivity analysis is used in a decision analysis to study how the outcomes of interest would change if the variables

were given different values. Since a decision analysis tries to answer which option is superior, a sensitivity analysis can show how much the variables can be altered before the decision should be changed to an alternative option.

Aim

The aim of this study was to compare the cost-effectiveness of PCR and SW in mature permanent teeth diagnosed with deep caries lesions, in a Swedish Public Dental Care organisation.

Materials and methods

This decision analysis study was originally a part of a master's thesis at the Institute of Odontology, Sahlgrenska Academy, University of Gothenburg. The study protocol was approved by the head of the institute, who stated that no external ethical approval was needed. Additionally, an approval was received from the clinic management prior to the interviews. No patients or patient data was involved in the study. The participants were sent an email containing information about the study and the participation, and this information was repeated verbally in the beginning of the interviews. The voluntariness and anonymity were emphasised. They were also informed that they at any time could stop their participation. Almost every participant gave a written consent, as well as a verbal one at the start of the interviews. The one participant who did not give a written consent only wanted to give their consent verbally.

Decision tree model

A decision tree was constructed starting at a deep caries lesion, and thereafter split into two branches: PCR and SW (Figure 1). PCR had three possible outcomes: 'success' (i.e. no further treatment needed), 'pulp exposure', 'pulpitis/apical periodontitis etc.'. SW had four possible outcomes: 'success', 'pulp exposure during the first visit', 'pulp exposure during the second visit', 'pulpitis/apical periodontitis etc.'. The outcomes 'pulp exposure (the first/second visit)' and 'pulpitis/apical periodontitis etc.' were set to result in root canal treatment (RCT).

Probabilities of outcomes

To elicit probability values for the different outcomes in the decision tree, a literature search model was set up (Figure 2), in accordance with the Swedish Agency for Health Technology Assessment and Assessment of Social Service's (SBU) [16]. The search was conducted on the 1st of November 2020 and again on the 24th of January 2022 in PubMed and Scopus. The search blocks were built on intervention and outcome (Figure 3). All articles found with these search blocks were exported to EndNote (Endnote X9.3.3 PDFNet SDK © PDF Tron™ Systems Inc., 2001–2018), where the duplicates were removed both automatically by EndNote and manually by the authors NS and JM. The remaining

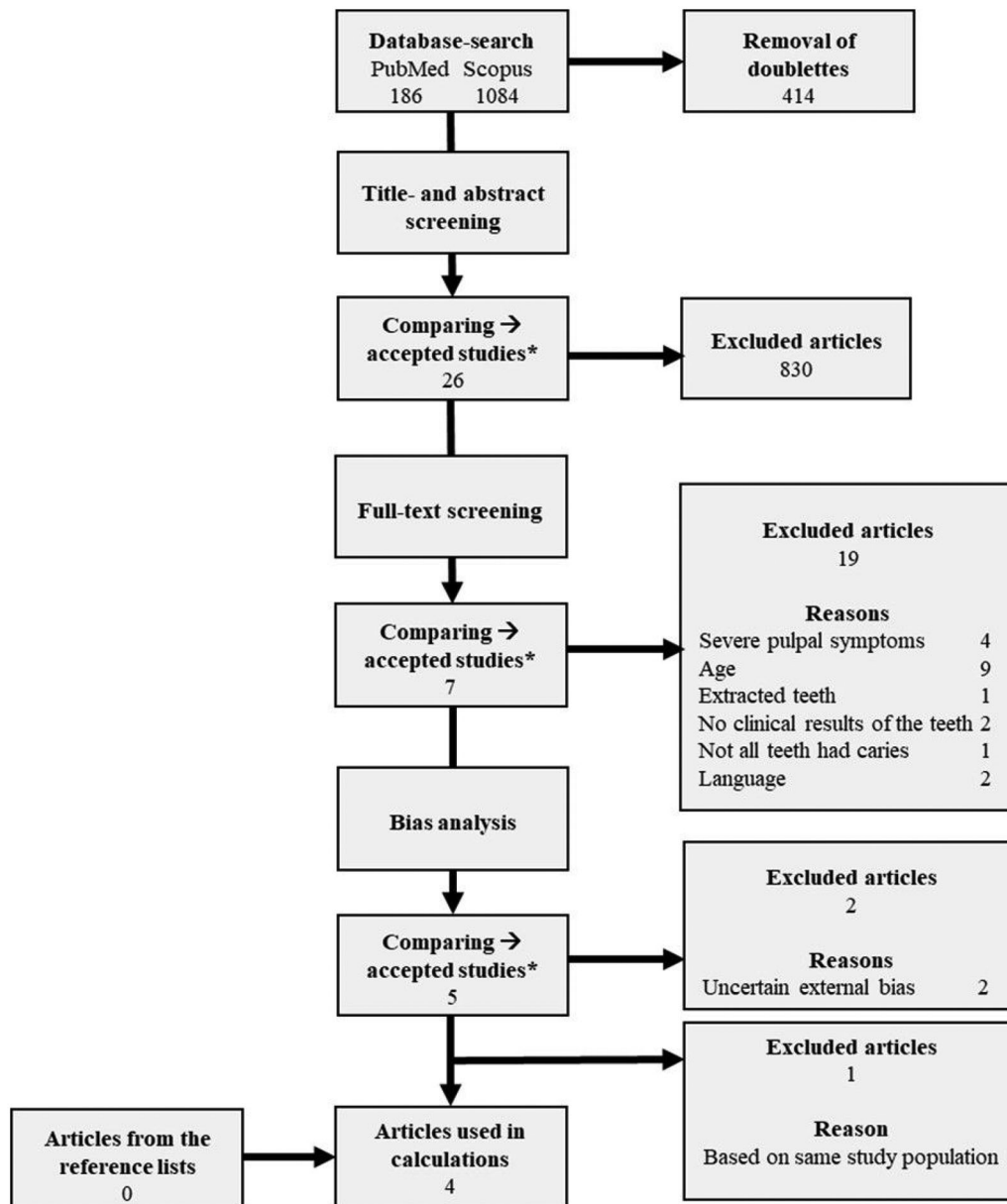


Figure 2. Flow chart with the number of studies excluded and included in the different stages of literature research. For more detailed information on the 19 excluded articles, see [Appendix Table A2](#). *If one or both assessors accepted the study, it was included in the next step. If both assessors chose to exclude the article, it was excluded.

articles were then screened by the two assessors (NS and JM) separately, reading the titles and abstracts, considering the following inclusion criteria:

- Study design: randomised controlled trial or prospective cohort study
- Teeth: Mature permanent human teeth with a vital pulp without symptoms that did not disappear after provocation
- Caries lesion: Penetrates more than 50% of the dentin thickness, and/or a CCR would create a risk for pulp exposure (established by radiographic examination)
- Follow-up: At least 1 year including a clinical and radiographic examination
- Methods: PCR, SW, or both
- Language: English, Swedish, Finnish, or German

The assessors compared their screening results, and if at least one had approved an article, it passed onto the next step which was reviewing the article in full text. The number of excluded articles in the full-text phase and the main reason for exclusion are listed in [Figure 2](#). The remaining articles were then evaluated by their quality, in accordance with the reviewing protocol for bias assessment by SBU [16]. The reference lists of the articles that passed the quality evaluation were examined for possible further publications.

The probabilities of the different outcomes of PCR and SW were elicited from the articles, and the differences in follow-up periods were noted. The average probability for each of the outcomes was estimated using a weighted average ([Figure 4](#)) that took into account the number of teeth in each study, since the studies had different sample sizes [22].

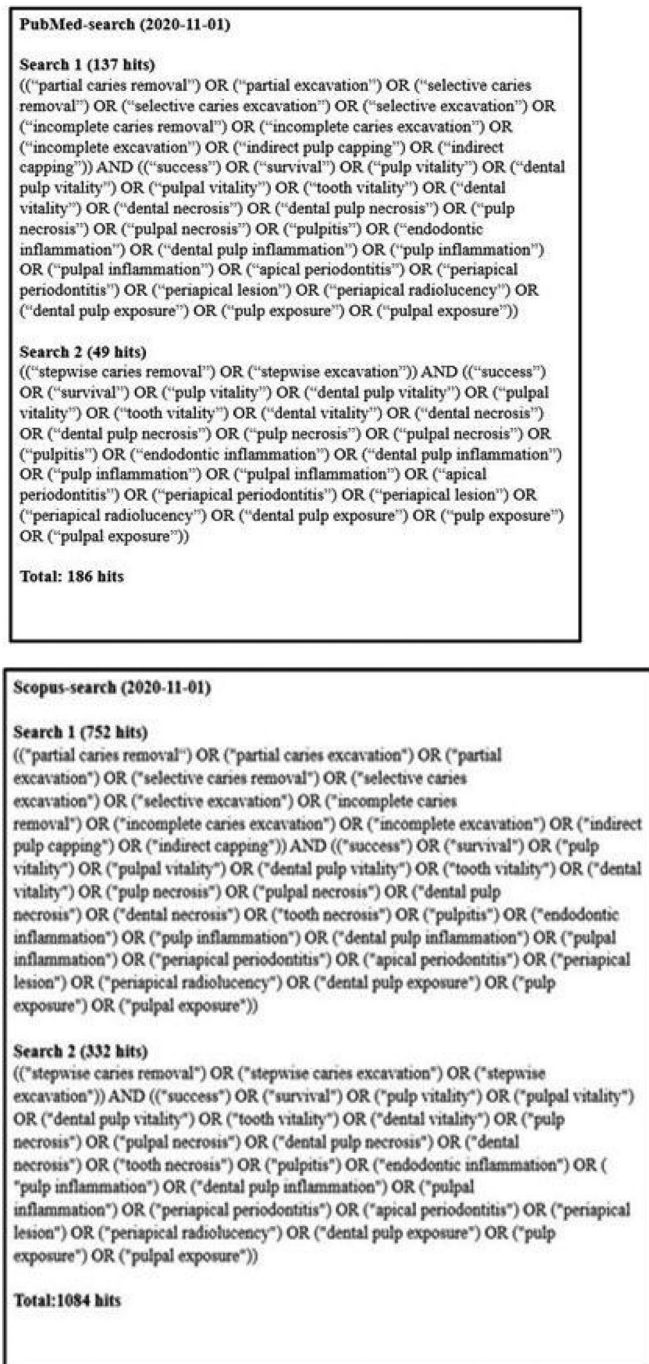


Figure 3. The search blocks used in the literature search. The searches for PCR and SW were done separately.

Cost estimation

A convenience sample of 37 general practitioners, employed by and practicing at the public dental care service in Västra Götaland county, in Sweden were invited for an interview. The general practitioners worked either at one of the authors' workplace at a public dental care clinic, or as clinical teachers involved in the undergraduate education at the Institute of Odontology, University of Gothenburg.

The interviews were conducted in a setting of two interviewers (the authors NS and JM) and one interviewee at a time, between January and April 2021. The interviewees were asked to estimate how much time they would need to

Partial caries removal

$$\text{Success} = \left(\frac{62+47+169}{67+54+176} \right) \times 100\% = 94\%$$

$$\text{Pulp exposure} = \left(\frac{0+0+0}{67+54+176} \right) \times 100\% = 0\%$$

$$\text{Pulpitis, apical periodontitis, etc.} = \left(\frac{5+7+7}{67+54+176} \right) \times 100\% = 6\%$$

Stepwise caries excavation

$$\text{Success} = \left(\frac{106+42}{143+52} \right) \times 100\% = 76\%$$

$$\text{Pulp exposure (visit 1)} = \left(\frac{4+0}{143+52} \right) \times 100\% = 2\%$$

$$\text{Pulp exposure (visit 2)} = \left(\frac{21+5}{143+52} \right) \times 100\% = 13\%$$

$$\text{Pulpitis, apical periodontitis, etc.} = \left(\frac{12+5}{143+52} \right) \times 100\% = 9\%$$

Figure 4. In the weighted average formula, the numerators in the formula are the number of that certain outcome in the studies. The number of teeth in total in those studies are placed as denominators.

treat a molar with a deep caries lesion with each of the following treatment methods: PCR, SW, and RCT, respectively. The answers were given in minutes. These three questions were a part of a semi-structured, more comprehensive interview on the topic of treating deep caries lesions, which was conducted for a master's thesis.

The costs of the three treatments were calculated by multiplying the estimated times required for each of the treatments with an hourly cost (€/h) for providing dental care at the public dental care service in Västra Götaland county, Sweden [23]. The expected costs for PCR ($E(\text{costPCR})$) and SW ($E(\text{costSW})$) were given by multiplying costs with probabilities (P) for each branch of the decision tree, which were then summarised (Figure 1):

$$\begin{aligned} E(\text{costPCR}) &= [P(\text{PCRsuccess}) \times \text{cost}(\text{PCRsuccess})] + \\ &\quad [P(\text{PCRpulp exposure}) \times \text{cost}(\text{PCRfailure})] + \\ &\quad [P(\text{PCRpulpitis, apical periodontitis etc.}) \times \text{cost}(\text{PCRfailure})] \\ E(\text{costSW}) &= [P(\text{SWsuccess}) \times \text{cost}(\text{SWsuccess})] + \\ &\quad [P(\text{SWpulp exposure 1st visit}) \times \text{cost}(\text{SWfailure 1st visit})] + \\ &\quad [P(\text{SWpulp exposure 2nd visit}) \times \text{cost}(\text{SWfailure})] + \\ &\quad [P(\text{SWpulpitis, apical periodontitis etc.}) \\ &\quad \times \text{cost}(\text{SWfailure})] \end{aligned}$$

Sensitivity analysis

A one-way sensitivity analysis was performed altering the probability values of success for PCR from 0 to 100% with 1% intervals, using Microsoft Excel (Microsoft® Excel® for Microsoft 365MSO (16.0.14326.20384) 64-bit edition), and IBM SPSS Statistics program (IBM® SPSS® Statistics version 27, release 27.0.1.0, 64-bit edition).

Statistical analyses

Histograms of estimated time consumption for PCR, SW and RCT were created in IBM SPSS Statistics to test for normal

distribution. Kruskal Wallis H-test was then used to test for significant values between the three treatment methods, and between only PCR and SW. The statistically significant value was set to $p < .05$. The same protocol was used with the expected costs for PCR and SW.

Results

The outcomes of PCR and SW

The results of the literature search are summarised in Table 1. A total of 856 articles were reviewed; five of them met the inclusion criteria and had either a 'low' or a 'low/moderate' risk of bias. Since Bjørndal et al. 2010 [4] and 2017 [24] were based on the same study sample, only one of them was used for the SW outcome probabilities in the calculations. Bjørndal et al. 2010 [4] was used for the outcomes of SW, since the results in Bjørndal et al. 2017 [24] did not specify at which stage failure occurred in the SW intervention group (first or second visit). Labib et al. 2019 [25] was used for both SW and PCR outcomes. The other studies used in the calculation of PCR probability were by Khokhar et al. [8] and Singh et al. [26]. No additional articles matching the inclusion criteria were found during the repeated search in 2022.

The weighted average p -values for PCR 'success', 'pulp exposure' and 'pulpitis/apical periodontitis' were 94%, 0%, and 6%, respectively. For SW the p -values for 'success', 'pulp exposure during the first visit', 'pulp exposure during the second visit' and 'pulpitis/apical periodontitis' were 76%, 2%, 13%, and 9%, respectively.

Costs

Nine general practitioners (women, age 47 ± 15 years, Swedish education, years practicing 20 ± 13 years) agreed to participate in the interviews. The mean estimated times per treatment method were 41, 72 and 179 min for PCR, SW and RCT, respectively (Table 2). The mean estimated time for the first SW visit was 37 min. The hourly cost of a general practitioner working at the public dental care service in Västra Götaland county was 2200 SEK/h in the year of 2021 [23], i.e. 217,58 €/h (according to the exchange rate 2021-04-28). There was a statistically significant difference in estimated time ($p < .05$) between all three treatment methods. Looking at only PCR and SW, the difference was also significant ($p < .05$) (Table 2). The expected costs for PCR and SW were 187,63 € and 414,35 €, respectively (Figure 1). There was a statistically significant difference in the expected costs ($p < .05$).

Sensitivity analysis

The one-way sensitivity analysis is presented in Figure 5. The expected cost of a 100% successful outcome of SW is 261,10 €. Under such circumstances PCR would still be more cost-effective as long as the probability for successful outcome exceeds 83%, at which point it is equally cost-effective as SW. When the expected cost of SW was based on a 76% successful outcome (the result of our literature search) PCR was found to be more cost-effective as long as the probability of successful outcome exceeds 59%, at which point it is equally cost-effective as PCR.

Table 1. Results of the literature search.

Articles	Method	Study design	Presented results	Bias assessment	Follow-up time (years)	Number of teeth, n	Success, n (%)	Pulp exposure, 1st visit, n (%)	Pulp exposure, 2nd visit, n (%)	Pulpitis, apical periodontitis etc., n (%)
Bjørndal et al. 2010 [4]	Stepwise	RCT	Clinical and radiographic	low/moderate	1	143	106 (74,1 %)	4 (2,8 %)	21 (14,7 %)	12 (8,4 %)
Labib et al. 2019 [25]	Stepwise	RCT (interim analysis)	Clinical and radiographic	low/moderate	1	52	42 (80,8 %)	0 (0 %)	5 (9,6 %)	5 (9,6 %)
Labib et al. 2019 [25]	Partial	RCT (interim analysis)	Clinical and radiographic	low	1	54	47 (87,0 %)	0 (0 %)	–	7 (13,0 %)
Khokhar et al. 2018 [8]	Partial	RCT	Clinical and radiographic	low/moderate	1,5	67	62 (92,5 %)	0 (0 %)	–	5 (7,5 %)
Singh et al. 2019 [26]	Partial	RCT	Clinical and radiographic	low	1	176	169 (96,0 %)	0 (0 %)	–	7 (4,0 %)

For additional information, see Appendix Table A1.

Table 2. Estimated times for the treatment methods.

	T ^a (PCR)	T ^a (SW)	T ^a (RCT)	p Value ^b (PCR, SW, RCT)	p Value ^b (PCR, SW)
Participants ($n = 9$)	M: 41 SD: ± 13 Median: 40 Min: 30 Max: 60	M: 72 SD: ± 11 Median: 70 Min: 60 Max: 90	M: 179 SD: ± 75 Median: 180 Min: 90 Max: 350	$< .001^*$	$< .001^*$

PCR: partial caries removal; SW: stepwise caries removal; RCT: root canal treatment.

*Statistically significant value, $p < .05$.

^aEstimated time of the treatment methods (minutes).

^bKruskal–Wallis H-test.

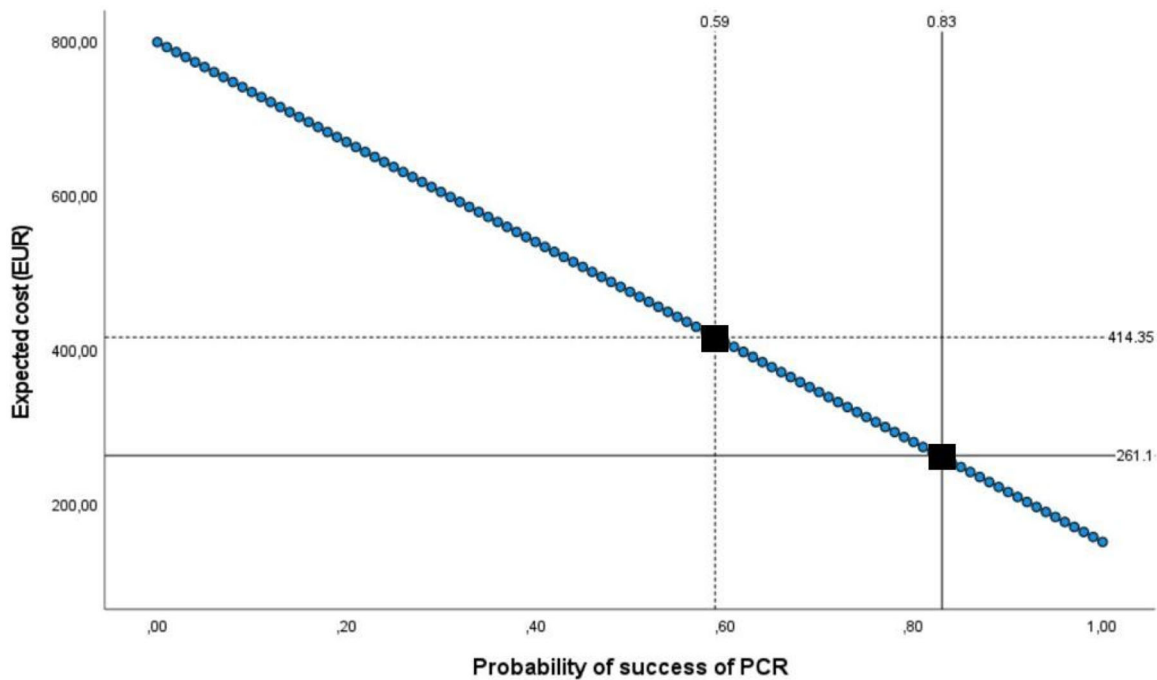


Figure 5. The diagonal line shows the expected cost of PCR, and it decreases as the probability for success rises. The horizontal threshold 261,10 € represents 100% success for SW and it crosses the diagonal line at 83%. The horizontal threshold 414,35 € represents 76% success for SW and it crosses the diagonal line at 59%.

Discussion

Given the evidence, presumptions, and estimations in this study, PCR is more cost-effective than the SW method in management of deep caries lesions in permanent teeth, at least in a short-time perspective. Consequently, our investigation indicates that PCR should prevail over SW as the first treatment of choice in this situation, which is supported by the sensitivity analysis. Even if the weighted average for PCR success probability (94%) had been too optimistic, there would still have been room for a wide margin-of-error. Even when the success rate for SW had been set at 100%, it would have been enough with a success rate of 83% for PCR to be the more cost-effective option. However, there are several reasons why the conclusion of our investigation could be questioned.

Many published decision analyses have used already-published systematic literature reviews to obtain the probability values of PCR and SW [9,10,27]. However, there were no systematic reviews that were based on only fully developed permanent teeth when studying the PCR and SW method. To match the aim of the study, a new literature search was needed to meet the specific inclusion criteria. Studies focusing on the adult population may offer more representative information, since deep caries lesions that risk resulting in root canal treatment are more frequently found in the adult populations in the Nordic countries [28].

Previous studies on PCR have been focussing on primary or mixed dentition, or permanent teeth with not fully developed apices. Orhan et al. [29] have constituted that in a sample of mixed dentition, there were no statistically significant differences in pulp exposure between PCR and SW. Leksell et al. [30] described on the contrary, that SW leads more often to pulp exposures than PCR in young permanent molars.

The short post-operative follow-up period is also a source of uncertainty. None of the included studies had longer follow-up periods than one year. Follow-up over longer periods could possibly reveal a higher frequency of pulpitis, pulp necrosis and apical periodontitis.

This decision analysis was somewhat simplified: It was based on a few dentists' estimations of needed time for the different procedures. The study sample was small and fairly homogenic, which might have caused a risk of bias. Due to the small number of participants as well as dental care clinics, the sample of this study might not be representative for the whole Swedish Public Dental Care Organisation. However, the estimated times given by the participants were relatively similar, hence the answers appear to be plausible.

The estimated times and results of this study should be seen as approximations. In order to decrease the risk of bias a larger study sample would have been desirable, or instead of interviews, directly measure how much time the different procedures required in practice.

In this decision analysis, it was also assumed that all teeth, where PCR or SW were not successful, were then treated with RCT. Moreover, the hourly cost was a rough estimation based on the estimated average costs of providing dental care in this dental organisation.

The study did not take into consideration societal costs such as loss of income and travel expenses. It also left out the intangible costs such as pain and suffering of the patient. These aspects would probably affect the patient's decision making, but the patient perspective was not included in this analysis.

Other uncertainties in comparing the two excavation protocols are, for example, whether the patient turns up for the appointments [7], how deep the caries lesions used in the

studies were, what the caries risk of the patients participating in the study was [31], or how much caries there is left after the excavation [29]. The role of the subjective component of the dentist needs to be considered due to the lack of distinct excavation-guidelines.

It is uncertain whether applying different liners under permanent fillings after PCR affects the survival of the tooth. Gurcan et al. [32] have studied these differences but stated no statistically significant differences between the different materials when it came to tooth survival and restoration success. From a cost-effectiveness perspective, using extra material under the fillings can also be thought to affect the costs for the clinic.

Further research on the PCR and SW treatment outcomes is still needed, especially randomised controlled trials with longer follow-up periods since retreatments are resource demanding. It would also be of interest to investigate whether the type of dental restorative material used during the intervention has an effect on the clinical success rate.

Since countries do not have similar dental organisations or systems for financing the dental care, the results of a study conducted in one country cannot be directly generalised universally. However, our decision analytic approach may be used universally by changing and replacing both estimated costs and probabilities for different outcomes when they are available in different countries and organisations.

Conclusions

Given the presumptions in this decision analysis, the PCR method used on mature permanent teeth is more cost-effective ($p < .05$) compared to the SW method in protecting the pulp from exposure and avoiding the need for root canal treatment.

Disclosure statement

No conflict of interest is reported by the authors of this study.

ORCID

Nikki Savolainen  <http://orcid.org/0000-0002-0359-2094>

Thomas Kvist  <http://orcid.org/0000-0002-2685-3656>

Johanna Mannila  <http://orcid.org/0000-0002-7137-9463>

References

- [1] Schwendicke F, Frencken JE, Bjørndal L, et al. Managing carious lesions: consensus recommendations on carious tissue removal. *Adv Dent Res*. 2016;28(2):58–67.
- [2] Socialstyrelsen. Nationella riktlinjer för vuxentandvård 2011 - Stöd för styrning och ledning [national guidelines for dental care 2011]. Stockholm: socialstyrelsen; 2011. SoS Nationella riktlinjer; 2011-5-1. Swedish.
- [3] Socialstyrelsen. Nationella riktlinjer för tandvård - Stöd för styrning och ledning [national guidelines for dental care]. Stockholm: socialstyrelsen; 2021. SoS Nationella riktlinjer; 2021-9-7549. Swedish.
- [4] Bjørndal L, Reit C, Bruun G, et al. Treatment of deep caries lesions in adults: randomized clinical trials comparing stepwise vs. direct complete excavation, and direct pulp capping vs. partial pulpotomy. *Eur J Oral Sci*. 2010;118(3):290–297. Jun
- [5] Franzone R, Guimarães LF, Magalhães CE, et al. Outcomes of one-step incomplete and complete excavation in primary teeth: a 24-month randomized controlled trial. *Caries Res*. 2014;48(5):376–383.
- [6] Elhennawy K, Finke C, Paris S, et al. Selective vs stepwise removal of deep carious lesions in primary molars: 12-Months results of a randomized controlled pilot trial. *J Dent*. 2018;77:72–77.
- [7] Maltz M, Koppe B, Jardim JJ, et al. Partial caries removal in deep caries lesions: a 5-year multicenter randomized controlled trial. *Clin Oral Investig*. 2018;22(3):1337–1343.
- [8] Khokhar M, Tewari S. Outcomes of partial and complete caries excavation in permanent teeth: a 18 month clinical study. *Contemp Clin Dent*. 2018; 9(3):468–473.
- [9] Ricketts D, Lamont T, Innes NP, et al. Operative caries management in adults and children. *Cochrane Database Syst Rev*. 2013; 28(3):CD003808.
- [10] Li T, Zhai X, Song F, et al. Selective versus non-selective removal for dental caries: a systematic review and meta-analysis. *Acta Odontol Scand*. 2018;76(2):135–140.
- [11] Schwendicke F, Meyer-Lueckel H, Dörfer C, et al. Attitudes and behaviour regarding deep dentin caries removal: a survey among german dentists. *Caries Res*. 2013;47(6):566–573.
- [12] Weber CM, Alves LS, Maltz M. Treatment decisions for deep carious lesions in the public health service in Southern Brazil. *J Public Health Dent*. 2011;71(4):265–270.
- [13] Stangvaltaite L, Kundzina R, Eriksen HM, et al. Treatment preferences of deep carious lesions in mature teeth: questionnaire study among dentists in Northern Norway. *Acta Odontol Scand*. 2013;71(6):1532–1537. Nov
- [14] Croft K, Kervanto-Seppälä S, Stangvaltaite L, et al. Management of deep carious lesions and pulps exposed during carious tissue removal in adults: a questionnaire study among dentists in Finland. *Clin Oral Investig*. 2019;23(3):1271–1280. Mar
- [15] Jardim JJ, Mestrinho HD, Koppe B, et al. Restorations after selective caries removal: 5-Year randomized trial. *J Dent*. 2020;99:103416.
- [16] SBU. Utvärdering av metoder i hälso- och sjukvården och insatser i socialtjänsten: en metodbok [evaluation of methods in health care and efforts in social services: a method book] [internet]. Stockholm: statens beredning för medicinsk och social utvärdering (SBU); 2020. <https://www.sbu.se/metodbok?pub=48286Swedish>
- [17] Chisholm D, Evans DB. Economic evaluation in health: saving money or improving care? *J Med Econ*. 2007;10(3):325–337.
- [18] Neumann JV, Morgenstern O. Theory of games and economic behavior. 3rd ed. Princeton (NJ): Princeton University Press; 1953.
- [19] Ledley RS, Lusted LB. Reasoning foundations of medical diagnosis; symbolic logic, probability, and value theory aid our understanding of how physicians reason. *Science*. 1959;130(3366):9–21.
- [20] Maryniuk GA, Haywood VB. Placement of cast restorations over direct pulp capping procedures: a decision analytic approach. *J Am Dent Assoc*. 1990;120(2):183–187.
- [21] Goel V. Decision analysis: applications and limitations. The health services research group. *CMAJ*. 1992;147(4):413–417.
- [22] Hepworth MJ, Friedman S. Treatment outcome of surgical and non-surgical management of endodontic failures. *J Can Dent Assoc*. 1997; 63(5):364–371.
- [23] Folk tandvården Västra Götaland. Prislista allmäntandvård [Price list of general dental care] [brochure on the internet]. Gothenburg: folk tandvården Västra Götaland; 2021. [cited 2021-09-26]. Available from: [https://mellanarkiv-offentlig.vgregion.se/alfresco/s/archive/stream/public/v1/source/available/sofia/ftv2863-1038498358-98/surrogate/Broschyr-A4-Extern-Prislista-ATV-210115-\(v1.1\)-MF.pdf](https://mellanarkiv-offentlig.vgregion.se/alfresco/s/archive/stream/public/v1/source/available/sofia/ftv2863-1038498358-98/surrogate/Broschyr-A4-Extern-Prislista-ATV-210115-(v1.1)-MF.pdf). Swedish.
- [24] Bjørndal L, Fransson H, Bruun G, et al. Randomized clinical trials on deep carious lesions: 5-Year follow-up. *J Dent Res*. 2017;96(7):747–753.

- [25] Labib ME, Hassanein OE, Moussa M, et al. Selective versus stepwise removal of deep carious lesions in permanent teeth: a randomised controlled trial from Egypt-an interim analysis. *BMJ Open*. 2019;9(9):e030957.
- [26] Singh S, Mittal S, Tewari S. Effect of different liners on pulpal outcome after partial caries removal: a preliminary 12 months randomised controlled trial. *Caries Res*. 2019;53(5):547–554.
- [27] Barros M, De Queiroz Rodrigues MI, Muniz F, et al. Selective, stepwise, or nonselective removal of carious tissue: which technique offers lower risk for the treatment of dental caries in permanent teeth? A systematic review and meta-analysis. *Clin Oral Investig*. 2020;24(2):521–532.
- [28] Wigsten E, Jonasson P, Kvist T, EndoReCo, et al. Indications for root canal treatment in a swedish county dental service: patient- and tooth-specific characteristics. *Int Endod J*. 2019;52(2):158–168.
- [29] Orhan AI, Oz FT, Orhan K. Pulp exposure occurrence and outcomes after 1- or 2-visit indirect pulp therapy vs complete caries removal in primary and permanent molars. *Pediatr Dent*. 2010;32(4):347–355.
- [30] Leksell E, Ridell K, Cvek M, et al. Pulp exposure after stepwise versus direct complete excavation of deep carious lesions in young posterior permanent teeth. *Endod Dent Traumatol*. 1996;12(4):192–196. Aug
- [31] Dalpian DM, Gallina CS, Nicoloso GF, et al. Patient- and treatment-related factors may influence the longevity of primary teeth restorations in high caries-risk children: a university-based retrospective study. *Am J Dent*. 2018;31(5):261–266. Oct
- [32] Gurcan AT, Seymen F. Clinical and radiographic evaluation of indirect pulp capping with three different materials: a 2-year follow-up study. *Eur J Paediatr Dent*. 2019;20(2):105–110.

Appendix

Table A1 . Results of the literature search: additional information about clinical procedures.

Articles	Method	Time between appointments	Rubber dam during excavation	Type of restoration	Used lining material	Caries left after excavation
Bjorndal et al. 2010 [4]	Stepwise	8–12 weeks	No	1st: GI, 2nd: RC	Ca(OH) ₂	1st: wet, soft, discoloured dentine, 2nd: yellowish/greyish hard dentine
Labib et al. 2019 [25]	Stepwise	3–4 months	Yes	1st: GI, 2nd: RC	GI	1st: soft dentine, 2nd: firm dentine
Labib et al. 2019 [25]	Partial	—	Yes	RC	GI	Soft dentine
Khokhar et al. 2018 [8]	Partial	—	Yes	RC	RMGIC	Soft, wet carious dentine
Singh et al. 2019 [26]	Partial	—	Yes	RC	None, RMGIC, or Ca(OH) ₂	Light-brown soft dentine

GI: glass ionomer; RC: resin composite; Ca(OH)₂: calcium hydroxide; RMGIC: resin-modified glass ionomer cement.

Table A2. Reasons for exclusion after full-text screening.

Article	Reason for exclusion
Ali et al. 2018	Some teeth had severe symptoms.
Ali et al. 2020	Some teeth had severe symptoms.
Elchaghaby et al. 2020	Too young participants
Gurcan et al. 2019	Too young participants
Hamama et al. 2015	Extracted teeth
Hashem et al. 2015	Some teeth had severe symptoms.
Hashem et al. 2019	Some teeth had severe symptoms.
Jardim et al. 2020	Only restoration survival
Leksell et al. 1996	Some teeth not fully developed
Maltz et al. 2012	Participants of young age included, uncertain if fully developed teeth
Maltz et al. 2013	Participants of young age included, uncertain if fully developed teeth
Maltz et al. 2018	Participants of young age included, uncertain if fully developed teeth
Mathur et al. 2016	Lack of information about the age of participants.
Nie et al. 2015	Language
Orhan et al. 2010	Too young participants
Parvin et al. 2018	No clinical results
Torres et al. 2020	Not all teeth had caries
Valério et al. 2020	Participants of young age included, uncertain if fully developed teeth
Vega et al. 2018	Language