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ORIGINAL ARTICLE

Cost-effectiveness of pulp capping and root canal treatment of young permanent teeth

Joséphine Brodén[a,b], Thomas Davidson[c] and Helena Fransson[a]

[a]Department of Endodontics, Faculty of Odontology, Malmö University, Malmö, Sweden; [b]Department of Endodontics, Swedish Public Dental Service, Specialist Clinic Kaniken, Uppsala, Sweden; [c]Centre for Medical Technology Assessment, Department of Medical and Health Sciences, Linköping University, Linköping, Sweden

ABSTRACT

Objective: To contribute with information on cost-effectiveness of pulp capping and root canal treatment of posterior permanent vital teeth in children and adolescents with pulp exposures due to caries.

Material and methods: Cost-effectiveness by means of a Markov simulation model was studied in a Scandinavian setting. In a simulated 12-year-old patient, treatment of pulpal exposure of a permanent tooth, either by the initial treatment pulp capping or root canal treatment, was followed for 9 years until the patient was 21. The model was based on outcome data obtained from published literature and cost data based on reference prices.

Results: In the simulated case, with the annual failure probalility (AFP) of 0.034 for pulp capping, the total cost for an initial treatment with pulp capping and any anticipated following treatments during the 9 years, was 367 EUR lower than for a root canal treatment as the initial treatment. After an initial treatment with pulp capping 10.4% fewer teeth, compared with initial root canal treatment, were anticipated to be extracted. Pulp capping was thus considered to be the cost-effective alternative. The sensitivity analyses showed that the AFP of a tooth requiring a root canal treatment after an initial pulp capping needed to be 0.2 before root canal treatment may be considered being the cost-effective treatment.

Conclusions: This model analysis indicated initial treatment by pulp capping to be cost-effective compared to root canal treatment in children and adolescents with pulp exposures due to caries.

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Introduction

Despite the accepted approach of minimally invasive restorative dentistry, excavation of deep caries can lead to a pulp exposure, even with stepwise excavation [1]. In a Scandinavian randomized clinical trial comparing stepwise and immediate complete caries excavation, pulpal exposure was recorded in 17.5% of the 156 teeth randomized to stepwise excavation [2]. The aim of treatment of carious exposures in the permanent teeth of children should ideally be to retain the tooth in a healthy state throughout life. In clinical practice, there are two main approaches to the treatment of an exposed vital pulp: pulp capping (direct pulp capping and partial pulpotomy) and root canal treatment (also referred to as a pulpectomy). Pulp capping is the less invasive approach: the aim is to maintain the vitality of the tooth by application of a capping material to the exposed pulp. Pulpectomy is more invasive: the vital pulp tissue is extirpated, the walls are mechanically debrided and the root canal space is obturated. At present, little is known about the relative cost-effectiveness of these two treatment options in cariously exposed young permanent teeth in Scandinavian conditions.

Different outcomes can be expected for the two treatment approaches when performed in children and adolescents compared to adults, and data from studies performed in adults cannot directly be transferred to children and adolescents [2,3]. In a previously published systematic review of the treatment of carious exposures of young permanent teeth, it was concluded that there were no high-quality studies and no study directly comparing pulp capping and root canal treatment. The best available evidence stated that as an alternative to root canal treatment, the success rates for pulp capping were high, ranging from 64% to 100% [4]. As pointed out earlier, there seems to be a difference in the outcome of pulp capping between younger and older individuals; the success rates are higher for younger individuals [5–7].

Data on root canal treatments in children and adolescents are rare; one study of patients aged between 8 and 15, demonstrated complete healing in 36% (10/28) of the teeth [8]. Another study on permanent traumatized incisors demonstrated a success rate of 78.6% (92/117) when pulpectomy was performed in children 8–16 years [9]. An epidemiological study of root-filled teeth in adolescents and young adults treated in the Swedish Public Dental Service in Malmö,

CONTACT Joséphine Brodén josephine.broden@regionuppsala.se Avdelningen för endodonti, Specialisttandvården Kaniken, Box 1813, Uppsala, SE-751 48, Sweden

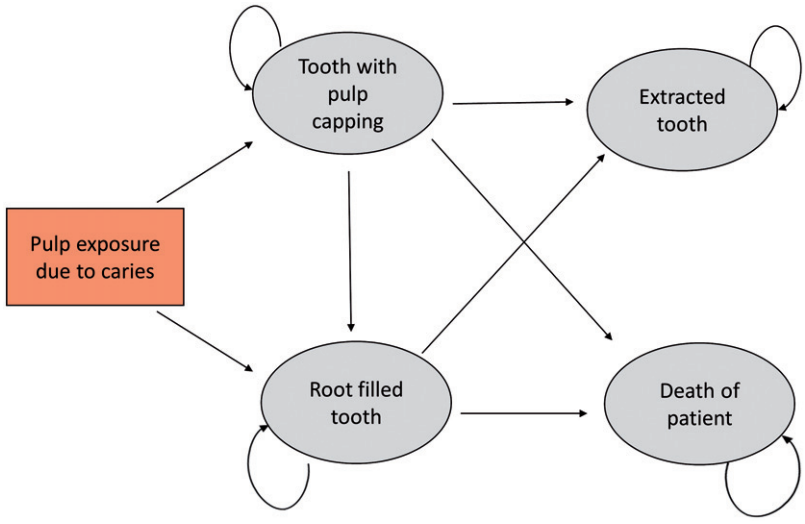

Figure 1. Transition diagram of the possible transitions between the health states in the model. Cycle length is one year. The patient can move in the direction of the arrow. The end point in the model is one of the two health states 'extracted tooth' or 'death of patient'.

Sweden, showed apical periodontitis in 52%, compared with 25% in a Swedish adult population [10,11]. The high prevalence of apical periodontitis could be explained by the poor technical quality of the root fillings, leading to leakage and infection of the root canal. Half the teeth were inadequately sealed, with short root fillings or overfilling. One suggested explanation for the higher frequency of failure after endodontic treatment of young permanent teeth compared to the adult population is that young teeth have relatively wide root canal lumens that are more difficult to clean and seal properly than the narrower root canals in older teeth [10].

A study of the Swedish general population reported that 12% of root-filled teeth had been extracted within 10 years of endodontic treatment [12]. Root-filled teeth are more commonly extracted than non-root filled teeth [13]. This problem is even more evident in children with young permanent teeth with roots that are not fully developed. These roots have thin dentinal walls and this increases the risk of root fractures [14].

Health economic evaluations are assuming an increasingly important role in healthcare, because in times of limited resources, decisions must be made about optimal allocation. The cost-effectiveness analysis, deals with the costs and the consequences of a specific procedure, for example, an item of dental treatment, and provides a comparative analysis of the treatment alternatives. The purpose of a health economic evaluation is to aid decision-makers in the most efficient allocation of healthcare resources. Economic evaluations intended to inform decision-making should include all relevant evidence and compare all appropriate treatment options. One approach is to use analytic modelling. The input data can, for example, be retrieved from previously published clinical trials [15]. This way of studying treatment alternatives for carious exposures without conducting a new clinical trial has been published by Schwendicke and Stolpe using a model with a 20-year-old male over a lifetime in a German context [5]. To contribute with information on the most effective treatment of young permanent teeth with a pulp exposure due to caries in a Scandinavian setting, the aim of this study was to compare the cost-effectiveness of pulp capping and root canal treatment of cariously exposed posterior permanent vital teeth in children and adolescents.

Material and methods

The study follows the reporting requirements from the Consolidated Health Economics Evaluation Reporting Standards [16].

The simulation model

The two different treatment options, pulp capping and root canal treatment, were studied in a simulation model, a Markov model. The model was made from the care provider's perspective and the effect was measured in avoided extractions. In a Markov model, the patient can be allotted to only one health state at a time and the model has no memory of which health state the patient was in before the current health state [17]. The starting point of the model, built in Microsoft Excel (Microsoft Excel 2016MSO (16.0.10325.20036) 64 bit version), was a 12-year-old child with a pulpal exposure due to deep caries in a vital permanent first molar. A simulated cohort of 1000 similar teeth was followed in the model. The treatment alternatives, pulp capping, and root canal treatment were analysed. Extraction was not an initial treatment option. The cycle length in the model was 1 year. Initially, the patient was allotted to the health state 'tooth with pulp capping' or to the health state 'root-filled tooth' (Figure 1). After assessment one year later, the patient could remain in one of these health categories or, based on the evidence of the success of the different treatments reported in the literature, the patient could transition to another health state. The endpoint was one of the two health categories 'extracted tooth' or 'death of patient'. The patient was followed for 9 years, that is, until the patient was 21 years old, which was the cut-off for receiving free dental care for children and young adults in Sweden in 2017.

Outcomes

The probability of transitioning to a different health state was calculated on the basis of treatment successes and failures reported in the literature. A systematic review had been conducted to evaluate the available evidence on pulp capping and root canal treatment of young cariously exposed teeth with vital pulps. The literature search was complemented with an updated search in Pubmed for articles published between 30 November 2012 and 30 June 2017 for the purpose of this present study, but no additional studies were added to the result of the original search. Ten original scientific studies were included in the review where four of the included studies described direct pulp capping and six studies described a partial pulpotomy. The follow-up time for direct pulp capping was 12–108 months and for partial pulpotomy 12–140 months. The materials used for the pulp capping procedures included different preparations of calcium hydroxide and grey mineral trioxide aggregate (MTA) [3,18–26].

Data on extractions, new fillings, and retreatments were retrieved on all root-filled teeth reported to the Swedish Social Insurance Agency during 2009, with a follow-up of 5 years. Subgroup data on extractions of root-filled teeth in 20- to 24-year-olds (1121 patients), were used and for data on new fillings and retreatments of root-filled teeth, all age groups in the registry were used. For other treatment failures such as loss of composite fillings in non-root filled teeth, the best available evidence was searched for, see Table 1 for all references.

The annual failure rates (AFR) from the collected literature and data from the Swedish Social Insurance Agency [27,28] were used to calculate the annual failure probabilities (AFPs). The formula for calculating the AFPs was $1-p^{(1-y)}$, where p represents the probability of survival and y represents the year of follow-up. A constant AFP for the entire follow-up period was calculated. For example, if 88% of the fillings in vital teeth survived for 8 years, the AFP would be $1-0.88^{(1-8)}=0.016$. The AFP after a pulp capping was calculated from the mean value of the AFR collected from the studies in the systematic review (Table 2). The probability of extraction or root filling of a tooth with failed pulp capping was calculated from data from two studies on pulp capping In cases where the pulp capping procedure failed, 89% were treated by root filling and 11% were extracted [6,29]. This relationship was applied to the data on success for pulp capping gained from the systematic review [4]. The reason for applying this relationship was that the fate of the teeth with failed pulp cappings was not always reported in the included studies in the systematic review. Using data derived from Statistics Sweden, age-based standard mortality for Sweden was used to calculate standard mortality. The standard mortality for the different age groups ranged from 0.008% for 12-year-olds to 0.038% for 20-year-olds [30]. The AFPs for the initial treatments and all anticipated following treatments during the 9 years are presented in Table 1. The results are presented as the difference in costs (EUR) and the difference in the percentage of extracted teeth.

Costs

The costs were calculated in Swedish kronor (SEK): the exchange rate with the Euro was €1 = 9.5 SEK (25 September 2017). The costs were discounted by 3% annually (0% and 5% are tested in sensitivity analyses) [31]. In the model, a certain percentage of the simulated cohort will transition from one health state to another. This generates a treatment cost, for example, the cost for an additional filling or the cost for an extraction. Some patients will remain in the same health state during the nine years and this will only generate the cost of the initial treatment. The model generates the average cost for the 1000 simulated patients in the simulated cohort.

The costs of the initial treatments and the costs of some possible other treatments that could be anticipated during each cycle length (retreatments, new composite fillings and extractions) were calculated from the reference prices settled by the Swedish Board for Dental Benefits (Table 3). Since there was no pre-defined reference price for pulp capping, the cost for a composite filling on a molar tooth was used. For retreatment, the predefined fee for root canal treatment by the Swedish Board for Dental Benefits was used. The cost for a composite filling on a molar tooth was added to the cost for initial root canal treatment and for retreatment.

Sensitivity analyses

Since the data underlying the model were based on studies with evidence regarded as low, it would be of interest to investigate how other data would affect the results. Therefore, a sensitivity analysis was undertaken in which some of the input values were varied, in order to investigate their impact on the results. Different discounting rates were used as well as higher AFPs after pulp capping. The AFP for pulp capping was altered to 0.05. This means 5% failed pulp cappings every year: 4.4% would undergo a root canal treatment and 0.6% would be extracted. This was to be compared with the base case AFP of 0.03 for teeth with failed

Table 1. All anticipated additional treatments after pulp capping and root canal treatment procedures of permanent posterior teeth. Average AFP from the literature, for example, the AFP of 0.004 shows that pulp capping leads to extractions in 0.4% of the cases every year.

	Transition to				
Transition of	RCT	Extraction	Retreatment	New Composite Filling	Death
Pulp capping AFP[source]	0.03 [4,6,29]	0.004 [4,6,29]		0.016 [35]	0.00008–0.00038 [30]
RCT AFP[source]		0.018 [27*]	0.0048 [28]	0.07 [28]	0.00008–0.00038 [30]

RCT: Root Canal Treatment; AFP: Annual Failure Probability.
*Unpublished data.

Table 2. Reported success rates of teeth with pulp cappings from the studies included in the previously published systematic review.

	Year of follow up										
Author year	1	2	3	4	5	6	7	8	9	10	11
Barrieshi 2006											
Success	1.00	1.00	–	–	–	–	–	–	–	–	–
AFR	0.00	*0.00*	–	–	–	–	–	–	–	–	–
Bogen 2008											
Success	1.00	1.00	1.00	1.00	0.98	0.98	0.98	0.98	0.98	–	–
AFR	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	*0.003*		–
Farsi 2006											
Success	0.93	0.93	–	–	–	–	–	–	–	–	–
AFR	0.07	*0.03*	–	–	–	–	–	–	–	–	–
Mass 1993											
Success	0.97	0.94	0.91	0.91	–	–	–	–	–	–	–
AFR	0.03	0.03	0.03	*0.02*	–	–	–	–	–	–	–
Mass 2011											
Success	0.96	0.94	0.94	–	–	–	–	–	–	–	–
AFR	0.04	0.03	*0.02*	–	–	–	–	–	–	–	–
Mejàre 1993											
Success	0.97	–	–	0.94	–	–	–	–	–	–	0.94
AFR	0.03	–	–	0.02	–	–	–	–	–	–	*0.01*
Moritz 1998											
Success	0.78	0.78	–	–	–	–	–	–	–	–	–
AFR	0.22	*0.12*	–	–	–	–	–	–	–	–	–
Nosrat 1998											
Success	–	1.00	–	–	–	–	–	–	–	–	–
AFR	–	*0.00*	–	–	–	–	–	–	–	–	–
Olivi 2007											
Success	1.00	1.00	1.00	0.63	–	–	–	–	–	–	–
AFR	0.00	0.00	0.00	*0.11*	–	–	–	–	–	–	–
Qudeimat 2007											
Success	0.98	0.94	0.92	–	–	–	–	–	–	–	–
AFR	0.02	0.03	*0.03*	–	–	–	–	–	–	–	–

The AFP for pulp capping, 0.034, was calculated from the mean values of the AFR at the last reported follow up of all studies, marked in italics [4].

Table 3. Fees (in Euros) for initial treatment and for all anticipated following treatments which a permanent posterior tooth might go through during 9 years.

Intervention	Fee (Euros)
Pulp capping	156
Root canal treatment	575
Composite filling	156
Endodontic retreatment	575
Extraction	174

€1 = 9.5 SEK (25 September 2017).

Table 4. The average costs (in Euros) for one simulated patient and the simulated percentage of teeth extracted after initial intervention by pulp capping or root canal treatment after a carious exposure in a permanent posterior tooth.

Treatment	Costs (Euros)	Extractions (%)	ICER
Pulp capping	334	4.7	Dominant
Root canal treatment	701	15.1	Dominated

ICER: Incremental cost-effectiveness ratio. The dominant treatment is the cost-effective alternative. Exchange rate €1 = 9.5 SEK (25 September 2017).

pulp cappings needing root canal treatment or an extraction (Table 1). A worst case scenario was also analyzed, in which the AFP for pulp capping was 0.2. This means 20% failed pulp cappings every year: 17.8% would undergo a root canal treatment and 2.2% would be extracted.

Results

The model disclosed that pulp capping was cost-effective (dominant) compared to root canal treatment. The costs and the effects are presented in Table 4. During the 9 years of follow-up in the model, 10.4% fewer teeth were extracted after initial treatment by pulp capping than by root canal treatment. The incremental costs showed a reduction of 367 EUR, which means that the cost for a tooth initially treated by pulp capping and followed up in the model for 9 years, was 367 EUR less than for teeth initially treated by root canal therapy.

In the sensitivity analyses (Table 5), pulp capping was the dominant treatment in all scenarios except in the worst case scenario, in which there were only minor differences between the two treatments with respect to both the cost and the percentage of extracted teeth. The worst case scenario was the only one in which an initial root canal treatment may be considered being the cost-effective treatment.

Discussion

This analytical model compared the cost-effectiveness of two conventional treatment options for cariously exposed vital pulps and was based on the best available information. Pulp capping was found to be the cost-effective alternative. The model included data from a systematic review and from a large body of Swedish data on young patients with root-filled teeth, which, along with other data, generated relevant data on the effects of the two procedures. The results can support decision-making about the management of carious exposures in vital teeth in these young patients. The effect was measured in terms of the proportion of extractions prevented. In research into the treatment of pulpitis and apical periodontitis, a successful outcome has conventionally been

Table 5. Sensitivity analyses based on the impact of four parameters: discounting the costs by 0% and 5%, altered AFP for a pulp capping to 0.05 and a worst case scenario in which the AFP for a pulp capping is 0.2.

	Pulp capping		Root canal treatment		Cost-effectiveness
Sensitivity analyses	Cost (Euros)	Extractions (%)	Cost (Euros)	Extractions (%)	ICER
Costs discounted 0%	361	4.7	720	15.1	Pulp capping dominant
Costs discounted 5%	319	4.7	690	15.1	Pulp capping dominant
AFP pulp capping 0.05	396	6.6	701	15.1	Pulp capping dominant
AFP pulp capping 0.2	709	16.7	701	15.1	5 EUR / % avoided extractions

Exchange rate €1 = 9.5 SEK (25 September 2017).

based on follow-up observations: the absence of clinical signs of infection and radiographic evidence of periapical healing [32]. Another outcome, tooth survival, has been used in some more recent studies [27,33].

In the model, a 12-year-old patient was followed for 9 years, until the age of 21. In Sweden, the dental care for children is fully tax-funded, in the year 2017 the age limit for free dental care was set to 21 years. The results showed that when all anticipated following treatments were included, there were fewer extractions of teeth initially treated by pulp capping than by root canal treatment. This is not fully consistent with the results of Schwendicke and Stolpe who modelled a 20-year-old in German settings [5]. In contrast to the findings of the present study, tooth survival was found to be the same, regardless of the initial treatment. The discrepancy in results might be due to the fact that the present model was based only on younger individuals. Schwendicke and Stolpe found that in patients aged >40 years, direct pulp capping was more expensive and less effective than root canal treatment [5]. This is consistent with other studies finding pulp capping to be less effective in older patients [7,34].

A weakness with analytical modelling is that the results are completely dependent on data that can be derived from scientific studies or from registers. If there is limited data, the results will be uncertain. The sensitivity analyses allow to test what happens to the results when some of the uncertain parameters are changed. The results did not differ much in the sensitivity analyses presented in Table 4. The worst case scenario tested how much it was needed to augment the AFP of teeth with pulp cappings to tip the scale towards ranking root canal treatment as the more cost-effective treatment. The AFP needed to be at least 0.2 to tip the scale, this means 20% failed pulp cappings every year. This is similar to the results of a retrospective study of pulp capping of carious exposures in patients aged 10–70: after 5 years the AFP was 0.18 [29].

In the present model, there was no weighting according to sample size, nor was it made probabilistic. A probabilistic model deals with statistical uncertainty. In this study, the calculations were based on several studies of low quality and this is the source of uncertainty of the results. A probabilistic analysis would not strengthen the results. The systematic review highlighted the lack of high-quality studies on the treatment of carious exposure in young permanent teeth. Even after an exhaustive literature search, studies with evidence rated as low had to be used in the model. The studies on pulp capping had follow-up periods of 1–9 years. Because of the limited data on children and adolescents, no distinction was made between occlusal and proximal caries. In the study by Schwendicke and Stolpe, direct pulp capping was reported to be inferior to root canal treatment of teeth with proximal carious exposures [5].

The literature search having failed to identify any studies on root canal treatment after carious exposure, registry data on root-filled teeth in 20- to 24-year-olds were used. In the registry, there was no information about the treatment procedures or about the preoperative status of the pulp or periapical tissue before the root filling [27]. The AFR for the extraction of root-filled teeth were retrieved from the same large sample of young individuals 20–24 years comprising all root canal treatments reported to the Swedish Social Insurance Agency during a calendar year. After 5 years, 91.3% of the root-filled teeth had survived [27]. Similar findings were reported by Ng et al. 2011 in a study mainly on adults: tooth survival was 95% four years after primary root canal treatment and retreatment [33].

The same Swedish Social Insurance Agency database was used to obtain data on the AFP of root-filled teeth undergoing retreatment and a new filling, but included patients from all age categories 20 years and older (248,299 teeth) [28]. The AFP for composite fillings on non-root filled teeth was calculated from a Scandinavian study on 2881 children with posterior composite restorations in permanent teeth followed for up to 8 years [35]. This data did not include teeth with pulp cappings. However, cavity base materials were used in 73.4% of the restorations. As the same materials often serve the purpose as capping materials, the effect of the pulp capping on the survival of the composite fillings should be comparable to an ordinary deep filling with a cavity base material.

It was assumed in the model that the patients would not receive a crown or another indirect restoration during the 9 years. In the Swedish tax-funded dentistry for children and adolescents, it is very rare with crown restorations, in an epidemiological study from the city of Jönköping, 0% of the teeth in the group consisting of 20-year-old patients had a tooth with a crown in 2013 [36].

The model did not calculate differences in cost for various pulp capping materials such as calcium hydroxide and mineral trioxide aggregate or other tricalcium silicate-based cements. The cost for a pulp capping was based on the cost for a composite filling on a molar tooth and no extra costs for material were added.

One randomized controlled trial included in the systematic review compared the effect of calcium hydroxide and mineral trioxide aggregate on the clinical success rate of partial pulpotomy treatment in permanent molars. The reported outcomes were 91% success for calcium hydroxide and 93%

for mineral trioxide aggregate, the sample size of 51 patients was insufficient to detect a difference in treatment effect [24]. A systematic review from 2017 on different materials for direct pulp capping concluded that there is insufficient data to recommend the use of a specific material for pulp capping [37].

Even though our model identifies pulp capping as the cost-effective alternative, no attempts to explore to what extent the different treatment alternatives influence the patient's quality of life was done. Thus the model is limited. However, because of the limited evidence currently available in the literature, it was not possible to calculate the effect on quality of life. For future development of the model, it would be desirable to be able to measure patient-related outcomes. Future studies might also explore more treatment options for teeth with pulpal exposures, such as extractions and orthodontic treatment, preferably based on reliable data.

The conclusion from this health economical model performed in Swedish settings, was that initial treatment by pulp capping indicated to be cost-effective compared to root canal treatment in children and adolescent with a pulp exposure due to caries in a permanent posterior tooth.

Disclosure statement

No potential conflict of interest was reported by the authors.

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ORCID

Joséphine Brodén http://orcid.org/0000-0001-9300-2520
Thomas Davidson http://orcid.org/0000-0002-9393-2573
Helena Fransson http://orcid.org/0000-0003-4290-2283

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