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Cost-effectiveness of selective caries removal versus stepwise excavation for deep caries lesions

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Abstract: A multicenter, randomized controlled clinical trial evaluated the effectiveness of two treatments for deep caries lesions in permanent molars - selective caries removal (SCR) to soft dentin with restoration in a single visit, and stepwise excavation (SW) - regarding pulp vitality for a 5-year follow-up period. The present study aimed to determine the cost-effectiveness of these treatments. Treatments were conducted in two Brazilian cities (Brasília and Porto Alegre). At baseline, 299 permanent molars (233 patients) were treated and 229 teeth (174 patients) were evaluated after 5 years. The discounted cash flow method was adopted. The total cost of each treatment was calculated, and the failure cost (endodontic treatment + restoration) was added to the final cost, according to the 5-year failure rates of each therapy (20% for SCR and 44% for SW). A public health service unit composed of three dentists in 4-hour work shifts was used to calculate the monetary value of the treatments, assuming a total of 528 treatments/month. Considering the 229 teeth evaluated after 5 years (115 SCR and 114 SW), SCR provided savings of 43% (amalgam) and 41% (resin composite) per treatment, compared to SW. The SCR technique provides benefits for public finances (direct economy) and for public health services (increase in the number of treatments performed). Considering that maximizing profit and reducing costs are powerful motivating factors for adopting a certain treatment, this study provides data to better support the decision-making process, regarding the management of deep caries lesions in permanent molars.

Keywords: Dental Restoration, Permanent; Dental Amalgam; Composite Resins; Dentition, Permanent; Cost-Effectiveness Analysis.

Introduction

When a new treatment is proposed, it is of foremost importance to be certain of its success rate and causes of failure. Once the effectiveness of the method or treatment has been established, the second point that needs to be addressed is the relationship between its effectiveness and its cost. The result of this analysis is essential to the decision-making process, since maximizing profit and reducing costs are powerful motivating factors driving dental practitioners and governments to adopt a certain treatment.

Contemporary clinical practice concerning deep caries lesion management aims to preserve the pulp in a healthy state with sustained vitality, and to develop minimally invasive therapies.[1] Based on these aims, two caries removal techniques have been proposed to reduce the risk of pulp exposure, stepwise (SW) and selective caries removal (SCR). These conservative approaches have been widely investigated for their pulpal outcomes,[2-8] and there is some evidence on restoration survival;[3,9,10] however, the literature on the cost-effectiveness of these strategies is scarce. Three studies based on simulation models and transition probabilities simulated the treatment of a molar with a deep caries lesion in young patients (aged 15 to 30 years) over the patients' lifetime. These studies used tooth retention, vitality, and cost as the outcomes, and indicated that selective excavation, compared with SW, has the highest probability of cost-effectiveness over a lifetime perspective.[11-13] To the best of our knowledge, no study has investigated the cost-effectiveness of this approach using data derived from a randomized clinical trial, and defining the need for endodontic treatment as a failure, a proximal event that is tangible to patients, health professionals, and the authorities.

In a multicenter, randomized controlled clinical trial (registration number at www.clinicaltrials.gov NCT00887952), two treatments for deep caries lesions in permanent molars were analyzed regarding therapy survival rates after a 5-year follow-up period. The SW treatment was compared with the SCR to soft dentin with restoration in a single visit in public health service units in Brazil. The aim of the present study was to determine the cost-effectiveness of these treatments by means of an economic analysis. We hypothesized that the single-visit approach is more cost-effective than the two-visit alternative.

Methodology

The study protocol was approved by the Federal University of Rio Grande do Sul Ethics Committee (protocol 18/05), the Porto Alegre Municipal Ethics Committee (protocol 27/06 and registration number 001000837067), the Conceição Hospital Ethics Committee (protocol 070/05), and the Brasilia University Hospital Ethics Committee (protocol 045/2005). The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. All participants or their legal guardians signed a written informed consent form. The manuscript of the study was reported following the CHEERS 2022 statement (Consolidated Health Economic Evaluation Reporting Standards).

Treatments were conducted in two centers located in the cities of Porto Alegre (South Brazil) and Brasília (Midwest Brazil), at either the Public Health Service units or at public universities, by 22 dentists under the supervision of the main researchers (MM, LMP, HDM, and JJJ). At baseline (2005 –2007), 299 permanent molars (from 233 patients) were randomly assigned to the test (SCR) or the control (SW) groups. Each of these groups was then divided according to the filling material: amalgam or resin composite. Participants were mainly adolescents, with a mean (± SD) age of 17.2 (± 10.9) years (median 14 years, minimum 6, maximum 53 years). For patients to be included in the study, they had to have at least one permanent molar with primary deep caries lesion (radiograph depth reaching half or more of the dentin thickness), with positive response to the cold test (−20°C refrigerated gas, Aerojet, Rio de Janeiro, Brazil), negative response to percussion, absence of spontaneous pain, and absence of periapical lesion (radiographic exam). Patients were excluded if they had cuspal loss or caries beneath the gingival margin. Further details on the sample, interventions, randomization, and blinding can be found elsewhere.[6]

All the treatments were performed under the same protocol, as follows: local anesthesia and rubber dam installation; access to the lesion using diamond burs, as needed; complete removal of carious tissue from the surrounding cavity walls with hand excavators and/or low-speed metal burs, according to the hardness-tactile criteria (harness probe); careful partial caries removal from the pulpal wall (only disorganized soft tissue was removed); cavity cleansing with distilled water and drying with sterile filter paper; group randomization. Teeth assigned to the control group (SW) received

indirect pulp capping with calcium hydroxide cement (Dycal, Caulk/Dentsply, Rio de Janeiro, Brazil), and temporary filling with a modified zinc oxide-eugenol cement (IRM, Caulk/Dentsply, Rio de Janeiro, Brazil). The cavity was then reopened after a median time of 90 days (25th percentile = 60 days; 75th percentile = 150 days; mean, 120 ± 120 days), the remaining soft carious tissue was removed, and the tooth was restored with glass ionomer cement (Vitro Fil, DFL, Rio de Janeiro, Brazil) plus amalgam (SDI, Bayswater WA, Australia) or resin composite (Tetric EvoCeram, Ivoclar/Vivadent, Liechtenstein). Teeth allocated to the test group (SCR) received immediate restoration with glass ionomer cement and amalgam or resin composite after caries removal.

Outcomes were defined as pulp sensitivity to the cold test and absence of periapical alterations, and these factors were adopted as the parameters indicative of pulp vitality (combined outcome). After 5 years (2011–2012), 229 teeth (from 174 patients) were evaluated, and showed 80% and 56% success rates in the test and control groups, respectively. At the 5-year recall, 57 restorations could not be evaluated: 28 teeth had not undergone the complete examination; 20 teeth allocated to the SW group had not received restoration with amalgam or resin composite (patients failed to attend the second appointment of the SW protocol); and 9 restorations had been replaced by another dentist for unknown reasons, or because the teeth had been extracted. Therefore, 172 restorations had been evaluated, 77 from the SW group and 95 from the SCR group. Regarding the filling material, 61 were amalgam restorations and 111 were resin composite restorations. The survival analysis for clustered data (Weibull regression model) showed that teeth treated with SCR presented a significantly lower risk of failure than teeth that received SW ($p < 0.001$).[6] An intention-to-treat analysis was performed using STATA software, version 12.0.

The discounted cash flow method was adopted to determine the cost-effectiveness of the treatments. From an economic point of view, a new treatment must offer or produce a positive net present value (NPV), which summarizes the projected flow of economic benefits and costs in terms of currency. This is a common method for evaluating capital projects in corporate finance and in the health area,[14-25] and can be obtained through the discounted cash flow method. All future cash flows are estimated and discounted to arrive at their present values; the sum of all future cash flows, both incoming and outgoing, is the NPV, which is taken as the value or price of the cash flows in question. A positive NPV indicates that the proposed intervention would provide a favorable return of investment; a negative NPV suggests that the project is not economically feasible from the perspective of the government or health center.[26] In the present study, a 9% annual discount rate was used, equivalent to the interest rate of a long-term federal bond.

Treatment costs were defined according to the cost catalogue published by the Federal Council of Odontology, which considers both fees and operating costs. The total costs of each treatment, according to different restorative materials (amalgam or resin composite) were calculated using the parameters shown in Table. The number of restored surfaces was considered in making the calculations, based on the prevalence of single/multi-surface restorations recorded in the clinical study (1 restored surface 90%; 2 or more restored surfaces 10%). Thus, the mean cost of an amalgam restoration was established as follows: single surface restoration cost of R$ 145.2, multiplied by 0.9 + multi-surface restoration cost of R$ 168.5, multiplied by 0.1 = R$ 147.53. The mean cost of resin composite restorations was calculated in the same manner: single surface restoration cost of R$ 166, multiplied by 0.9 + multi-surface restoration cost of R$ 218, multiplied by 0.1 = R$ 171.20. The lack of pulp vitality was defined as a failure; therefore, the amount in question consisted of the endodontic treatment cost for molars, plus an additional restoration. The cost of the failure was added to the calculated cost, according to the 5-year failure rate of each therapy (20% of the cost for the SCR group, and 44% for the SW group).

A hypothetical public health service unit composed of three dentists in 4-hour work shifts was used to calculate the monetary value of the treatments (SCR or SW). The number of treatments performed per day was experimentally established

Table. Total cost of the treatments in Brazilian reais (R$)* according to the restorative materials: amalgam (AM) or resin composite (RC).

Variable	Stepwise excavation		Selective caries removal	
	AM	RC	AM	RC
X-ray exams (periapical and bitewing)	38.28	38.28	38.28	38.28
Mean cost of the restoration	147.53	171.20	147.53	171.20
Cost of failure (endodontics + restoration)**	285.21	285.21	129.64	129.64
Temporary filling	82.80	82.80	0.0	0.0
Total (R$)	553.82	577.49	315.45	339.12

*1 R$ = 0.19 U$ (United States dollar); ** Considering the 5-year failure rates observed for each therapy (44% for SW and 20% for SCR).

at eight per dentist, totaling 528 procedures/month, considering 22 working days. The prevalence of deep caries lesions in permanent molars that fulfill the inclusion criteria of the study was set at 5%, based on data from the study sample selection. Therefore, the economy of the treatments was determined on a daily, monthly, and annual basis, considering 1.2 treatments/day (5% of 528 procedures/month = 26.4 deep caries lesions/month, 22 working days/month, 1.2/day). The values were expressed in reais (Brazilian currency) and United States dollars (United States currency). The year of conversion was 2023.

Results

The mean total cost of the SCR treatment was R$ 315.45 (US$ 60.00) and R$ 339.12 (US$ 64.68) for amalgam and resin composite restorations, respectively. As for the SW treatment, the mean total cost was R$ 553.82 (US$105.64) and R$ 577.49 (US$ 110.15) for amalgam and resin composite restorations, respectively. Therefore, the savings provided by the SCR treatment was 43% for amalgam and 41% for resin composite restorations. The daily economy represented by SCR was R$ 286.04 (US$ 54.56), a monthly economy of R$ 6,292.92 (US$ 1,200.32), and an annual economy of R$ 75,514.98 (US$ 14,403.83), irrespective of the restorative material. The monetary value of the SCR treatment in a public health center, using the discounted cash flow method was R$ 839,055.36 (US$ 160,042.60) (discounted rate of 9% annually). These results, together with the success rates of 80% for the SCR group and 56% for the SW group, indicated that SCR is a much more efficient treatment than SW after 5 years of follow-up.

Discussion

Using data derived from a 5-year randomized clinical trial, the present study showed that adopting SCR to manage deep caries lesions in permanent molars would reduce the treatment costs by approximately 40%, thus confirming the study hypothesis. In addition to the well-known biological benefits of this strategy,[3-6,10,27,28] and the likely long-term benefits of tooth retention,[11-13] our findings have provided evidence on its cost-effectiveness in a short-term perspective. To the best of our knowledge, this is the first study addressing this topic using a tangible event as the outcome, hence making the study findings more meaningful to patients, health professionals and the authorities.

Previous studies addressing the cost-effectiveness of SCR used tooth retention and vitality as the outcome.[11-13] As discussed by the cited authors, who adopted similar models for assessing the cost-effectiveness of treatments, "it is a late outcome and hence rather distant from the initial decisions. This partially explains the limited differences between comparisons; a wide range of further factors nivellate [balance out] the initial differences over time."[11] In this sense, it is important to point out that the need for endodontic treatment – adopted to define failure in the present study – is a clinical

event intricately linked to the treatment under investigation (caries excavation technique), and less susceptible to factors out of the researcher's control. From the authors' point of view, the results of this study may contribute to adopting SCR in routine clinical practice for deep caries management, since it provides benefits in a matter of months or a few years, as well as longer "tooth expectancy" over decades. We recognize that tooth retention is the most valuable endpoint in dental research; however, it is also important to measure the monetary value of the treatments and the economy gained from the proposed treatment. The need for endodontic treatment has been described by Elderton as a significant step towards tooth loss in the restorative cycle[29]. Findings of this nature gain major importance in populations with limited access to endodontics, since these restrictions may result in early tooth extractions.

In this study, the cost of the failure was considered as the endodontic treatment followed by a direct restoration. However, the economy gained by using SCR would be even greater if considering that other types of restorations are needed after an endodontic treatment, depending on the quality/characteristics of the tooth remnant. For example, full cuspal coverage, posts or crowns are typically indicated for posterior teeth, since they provide resistance to fracture.[30-34] All these options are more expensive than a direct restoration, and would significantly increase the costs of a failure, and improve the economy gained by performing SCR treatment.

An additional consideration is that SCR treatments are completed in one session, instead of the two required by SW, thereby increasing the dentist's time availability. As a result, the overall number of treatments performed in the public health centers would increase, and dental care services could be extended to a broader portion of the population. Although this aspect was not explored in the present study, the improvement in patient comfort and time should also be considered. Future studies should address this topic.

This study had some limitations that need to be addressed. One is that the analysis model did not consider the costs related to the patient, such as time spent on treatment, or the possibility that dental rehabilitation is more expensive than expected. Furthermore, the results should be applied more directly to the Brazilian public health system, and not to Brazilian private dental clinics or to other countries.

In conclusion, performing SCR in one session provides benefits for public finances (direct economy), and for public health services (increase in the number of treatments performed), because of its higher success rates and substantial economy.

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