Direct Pulp Capping after a Carious Exposure Versus Root Canal Treatment: A Cost-effectiveness Analysis

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Abstract

Introduction: Excavation of deep caries often leads to pulpal exposure even in teeth with sensible, nonsymptomatic pulps. Although direct pulp capping (DPC) aims to maintain pulpal health, it frequently requires follow-up treatments like root canal treatment (RCT), which could have been performed immediately after the exposure, with possibly improved outcomes. We quantified and compared the long-term cost-effectiveness of both strategies. **Methods:** A Markov model was constructed following a molar with an occlusally located exposure of a sensible, nonsymptomatic pulp in a 20-year-old male patient over his lifetime. Transition probabilities or hazard functions were estimated based on systematically and nonsystematically assessed literature. Costs were estimated based on German health care, and cost-effectiveness was analyzed using Monte Carlo microsimulations. **Results:** Despite requiring follow-up treatments significantly earlier, teeth treated by DPC were retained for long periods of time (52 years) at significantly reduced lifetime costs (545 vs 701 Euro) compared with teeth treated by RCT. For teeth with proximal instead of occlusal exposures or teeth in patients >50 years of age, this cost-effectiveness ranking was reversed. Although sensitivity analyses found substantial uncertainty regarding the effectiveness of both strategies, DPC was usually found to be less costly than RCT. **Conclusions:** We found both DPC and RCT suitable to treat exposed vital, nonsymptomatic pulps. DPC was more cost-effective in younger patients and for occlusal exposure sites, whereas RCT was more effective in older patients or teeth with proximal exposures. These findings might change depending on the health care system and underlying literature-based probabilities. *(J Endod 2014;40:1764–1770)*

Key Words

Caries, dental, endodontics, health economics, public health, pulpal vitality

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The removal of deep caries lesions is often associated with risks for the integrity and vitality of the pulp (1), and although more selective excavation methods (ie, incomplete or stepwise excavation) might reduce the risk of pulpal exposure compared with conventional excavation attempting complete removal of carious dentin, such techniques are not yet widely adopted (2–4). Considering the high prevalence of deep caries lesions (5), the treatment of exposed pulps can be assumed to be daily routine for most practitioners. Thus, in case of exposure of a sensible and nonsymptomatic (ie, presumably healthy) pulp, dentists are faced with the decision to either perform direct pulp capping (DPC) or, anticipating the capped pulp to require follow-up treatments, to immediately initiate root-canal treatment (RCT).

Although teeth with DPC after pulpal exposure during caries removal often require follow-up treatments (6), RCT was shown to provide predictable outcomes (7, 8), with root canal–treated teeth seldom requiring further treatments (9). Nevertheless, dentists often perform DPC (3), attempting to maintain pulpal health and accepting the possible need for follow-up treatments. Such treatments usually involve RCT but possibly under changed clinical conditions compared with the initial treatment option. Directly capped pulps might cause pain, become necrotic, or become infected leading to the development of periapical lesions. These conditions have been found to reduce the probability of retaining the tooth after RCT in the long-term (8). Thus, there might be a conflict between attempting to maintain the presumed pulpal health, thereby postponing or obviating more invasive treatments, and predictably avoiding pain or early follow-up treatments. In addition, the costs associated with both therapies remain unknown, with DPC presumably being less costly initially, whereas RCT might avert follow-up treatments and thus reduce long-term costs.

The present study aimed to assess the cost-effectiveness of both direct capping and RCT for pulps being exposed during caries removal. Cost-effectiveness was evaluated for different subgroups and clinical situations, and the robustness of our findings was determined.

Materials and Methods

Model

We simulated the treatment of a deeply carious molar with a sensible, nonsymptomatic (ie, painless) pulp being exposed during caries removal. Note that we did not discriminate "carious" exposure (ie, in carious dentin) from "accidental" exposure (ie, in sound dentin) (10) because these were not reported separately in most studies. However, we did assess the uncertainty resulting from this nondiscrimination (see later). Pulp exposures with no association to caries lesions (ie, traumatic exposures) were not included. We compared DPC (ie, capping of the exposed pulp) using a medication (calcium hydroxide or, in sensitivity analyses, mineral trioxide aggregate [MTA]) and subsequent direct restoration with RCT (ie, vital pulpectomy) followed by a cast coronal restoration. The caries lesion was assumed to be extensive (ie, to involve both proximal and occlusal surfaces). All analyses were performed in the context of German health care.

A Markov model was constructed for both interventions (TreeAge Pro 2013; TreeAge Software, Williamstown, MA) consisting of initial and follow-up health states. The likelihood of teeth transitioning to the next health state was based on transition probabilities. Each transition was performed by traversing treatment states, thereby accruing costs. Simulation was performed in discrete 6-month cycles, with the sequence of events constructed according to current evidence and existing literature in the field (11).

Model validation was performed internally (by varying distributions and key parameters to check their impact on the results) and externally (by peer reviewing by an experienced health economist [M.S.]).

The model was based on the following assumptions:

1. DPC could be performed successfully or lead to pain or loss of pulpal vitality (ie, pulpal necrosis). Assuming the latter to be associated with bacterial infection, it could eventually lead to the development of a radiographically detectable periapical lesion.
2. In case of pain after DPC, RCT was to be initiated. Using sensitivity analyses, we additionally simulated the possibility that some teeth with pain might be extracted instead of attempting their retention.
3. Loss of sensibility might be detected by clinical testing, and pulp space infection with subsequently developing periapical lesion might be detected radiographically, both leading to RCT. We assumed that only a certain proportion of necrotic pulps would be detected per cycle.
4. Based on the different pre-existing conditions, 4 types of RCT were simulated: treatment of (1) a vital, painless pulp; (2) a vital, painful pulp; (3) a nonvital pulp in a tooth without a radiographically detectable periapical lesion; or (4) a nonvital pulp in a tooth with a periapical lesion. Treatment 1 was performed if RCT was initiated directly after pulpal exposure, whereas treatments 2–4 were performed if follow-up treatments were required after DPC.

In addition, failures of the restoration or the tooth (eg, secondary caries, fracture, or loss of the restoration) were modeled as described later. Periodontal complications were not simulated. Follow-up treatments involved re-restoration, restoration repair, orthograde root canal retreatment, apical surgery, and tooth removal and replacement with implant-retained crowns. Details regarding follow-up treatments have been described in more details elsewhere (11). Allocation to follow-up treatments was estimated from the literature, and guided by clinical experience. The model is summarized in Figure 1.

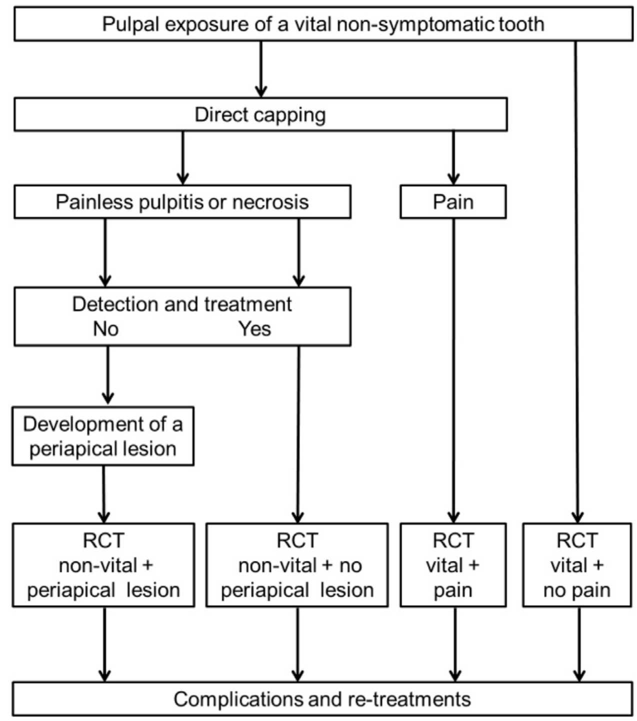

Figure 1. State transition diagram. A Markov model was used to simulate the lifetime of a tooth with an exposed, sensible, nonsymptomatic pulp. Pulpal complications could either cause pain or not. Those causing pain were assumed to receive RCT (RCT of a vital, painful tooth). Painless loss of pulpal health was assumed to be clinically detected with a certain probability, then receiving treatment (RCT of nonvital tooth without radiographically detectable periapical lesion). If teeth with lost pulpal vitality remained undetected, there was a certain probability of developing a periapical lesion. If teeth with periapical lesions were detected, treatment followed (RCT of a nonvital tooth with periapical lesion). Translation to the next state accrued costs (Table 2). Further complications (ie, failure of restorations) and follow-up treatments (nonsurgical and surgical retreatment of root canal–treated tooth, tooth removal, and replacement using implant-supported crowns) are not shown but have been described in detail elsewhere (11).

Estimation of Parameters

To estimate the transition probability (ie, hazard) after DPC, a systematic review of the literature was performed. One electronic database (PubMed) was screened for clinical studies reporting the clinical success or survival or failure of directly capped pulps in permanent human teeth treated for caries lesions. We included all pro- and retrospective studies published in English from 1971 onward. In addition, cross-reference–based hand searches were performed and an existing review consulted (6). Of a total of 104 screened studies, 18 were assessed full text, and 15 reports with a total of 2473 capped pulps were eventually included (Supplemental Figure S1 and Supplemental Tables S1 and S2 are available online at www.jendodon.com). Note that we controlled for the effects of including different study types and the between-study heterogeneity in sensitivity analyses.

Annual failure rates (AFRs) were extracted or calculated on the basis of information provided in the studies and effect estimates synthesized according to different time periods of follow-up after the initial treatment (ie, 0–2 years, 2–5 years, and >5 years after DPC). Weighting was performed according to sample size, and the mean AFR and 5%–95% percentiles were calculated as estimates (Supplemental Table S2 is available online at www.jendodon.com). To estimate transition probabilities after RCT of teeth with initially vital, painless pulps, data from an existing large-scale study were used (12). Note that these data were not retrieved by systematic review but were assumed to have relatively high validity because of the large number of teeth included and the practice-based setting involved. We controlled for the effects of possible parameter systematically and nonsystematically obtained data as described later. For vital, painful and nonvital teeth with or without periapical lesions receiving RCT, the obtained estimate was adjusted according to the literature (Table 1 and Supplemental Table S3; Supplemental Table S3 is available online at www.jendodon.com). Odds ratios were used for risk adjustment because rates of follow-up treatments were found to be relatively low, resulting in only limited risk inflation.

To eventually estimate the hazard per 6-month cycle ($h_{[c]}$) for both DPC and RCT, AFRs were used to calculate cumulative hazards, which were distributed along cycles assuming a constant hazard per reported time period (y). Hazard functions were then calculated by nonlinear least square regression of hazards per cycle and checked again by comparison with cumulative hazards and survival functions (SPSS 22; IBM, Chicago, IL). For follow-up health states, AFRs were extracted from the existing literature as described (11) and recalculated into hazards per cycle using the following formula:

$$h_{(c)} = 1 - (1 - \bar{a} \times y)^{(1/(2y))}$$

with $\bar{a}$ being the mean AFR for the respective time period y in years.

The model adopted a mixed public-private-payer perspective, which is characteristic in German health care. Cost calculations were mainly based on the Public and Private Dental Fee Catalogues, BEMA and GOZ (13). BEMA defines fee items within the public insurance,