Cost-effectiveness of Single- Versus Multistep Root Canal Treatment

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Abstract

Introduction: Single-visit root canal treatment requires fewer visits and reduces treatment time and material use compared with multiple-visit treatment. However, it might result in a higher risk of complications. We aimed to assess the long-term cost-effectiveness of single- versus multivisit root canal treatment using a model-based approach. Methods: A mixed public-private-payer perspective in German health care was adopted. Permanent teeth were simulated over the lifetime of 40-year-old patients. Different tooth types and preoperative conditions were modeled. Teeth could experience endodontic and nonendodontic complications. The risk of endodontic complications after single- versus multiple-visit treatment was estimated based on systematically collected data and adjusted depending on the preoperative conditions. The health outcome was tooth retention time. Costs were calculated based on the German dental fee catalogs and the Monte Carlo model-based approach. Results: For nonvital molars without periapical lesions, single-visit treatment was minimally less costly (1703 Euro vs 1729 Euro) and more effective (19.9 vs 19.8 years) than multiple-visit treatment. This cost-effectiveness ranking also applied to vital molars or those with periapical lesions. In single-rooted teeth, multiple-visit treatment was less costly (1667 vs 1770 Euro) and more effective (18.9 vs 15.1 years). Conclusions: The overall cost-effectiveness difference between treatments seems limited. The resulting cost-effectiveness differs in subgroups of teeth, whereas data supporting such subgroup analyses are scarce. Practical aspects in scheduling treatments as well as patients’ and dentists’ preferences should be considered for decision making. (J Endod 2016;42:1446–1452)

Key Words

Decision making, endodontic, health economics, Markov model, pain, tooth loss

An increasing number of studies have found single-visit root canal treatment (ie, combined instrumentation and canal obturation in 1 visit) to be a possible alternative to conventional multiple-visit endodontics, which uses 2 or more visits and usually places a medication into the root canal to allow canal disinfection between visits (1). Given the reduced number of visits and the associated treatment efforts (eg, no repeated application of anesthetics, no intermediary restorations, and no canal medication) as well as material costs, single-visit treatment might be attractive from a patient’s, dentist’s, and payer’s perspective. However, it might also result in higher risks of complications like swelling, sinus tract formation, or periapical bone resorption because single-visit treatment might not be as effective as multiple-visit treatment for disinfecting the root canal system (1–4). The comparative effectiveness of both treatments might be further modified by the preoperative conditions of the pulp (vitality and symptomatology) as well as periapical health (4). There are currently no American (American Association of Endodontists) or European (European Society of Endodontology) guidelines available recommending one or the other procedure; however, the European Society of Endodontology quality guidelines state that multiple-visit treatment is rarely needed for vital teeth (5).

In summary, the initial treatment costs might be lower in single- compared with multiple-visit treatment. However, single-visit treatment could also be less effective long-term, with complications generating costs for retreatments. The resulting long-term cost-effectiveness of single- versus multivisit root canal treatment is currently unknown. The present study aimed to assess this cost-effectiveness using a model-based approach.

Methods

Setting, Perspective, Population, and Horizon

This study adopted a mixed public-private-payer perspective in the context of German health care. We modeled a population of 40-year-old male individuals with 1 permanent molar with a nonvital asymptomatic pulp and without a radiographically detectable periapical lesion. Age and sex determined the remaining lifetime and, thus, the period of modeling. Modeling younger/older or female individuals would have changed the period of modeling and thus increased or decreased absolute differences between groups without having a significant impact on strategy rankings. We assumed retention of the tooth via root canal treatment to be justified (eg, to avoid tooth-bound
gaps or shortened dental arches). The tooth was assumed to be root canal treated and followed over the patient’s lifetime (TreeAge Pro 2013; TreeAge Software, Williamstown, MA). To avoid clustering effects, only 1 tooth per mouth was simulated. Tooth type, vitality, symptomatology, and periapical conditions were varied in sensitivity analyses to account for clinical heterogeneity.

Comparators
We compared single-visit versus multiple-visit root canal treatment. Single-visit treatment comprised access cavity preparation, instrumentation (using hand and/or rotary instruments), and obturation (root canal filling using lateral condensation) in 1 visit. Multiple-visit treatment was assumed to perform access cavity preparation and large parts of the instrumentation in the first visit and finalization of preparation as well as root canal filling in the second visit. We assumed calcium hydroxide to be placed within the canals between visits as medication. No third visit was performed. Regardless of the treatment group, we assumed teeth to be treated under rubber dam isolation. Before treatment, a clinical and radiographic assessment including sensitivity (vitality) testing was assumed. For vital teeth, local anesthetics were assumed to be applied. After treatment, molars were provided with a coronal cast restoration. (In the sensitivity analysis on single-rooted teeth, a porcelain-bonded crown was placed.)

Model and Assumptions
Simulations were performed in discrete 6-month cycles. Construction of the model (Fig. 1) was performed according to the clinical routine, current evidence (see later), and a previous study using a similar methodology (6). Model validation was performed by varying distributions and key parameters to check their impact on the results. In the base case, treatments were performed in a nonvital upper or lower, possibly painful molar with 3 root canals without radiographic signs of periapical bone resorption. These assumptions were submitted to various sensitivity analyses, exploring cost-effectiveness in single-rooted teeth, those with vital pulps, teeth with periapical lesions, and teeth without any preoperative pain. Note that we could not assess the impact of specific single-rooted tooth types or treatments in a different dental arch given that insufficient data were available.

For treated teeth, we separately modeled endodontic and nonendodontic (restorative, periodontal, and surgical) complications (Fig. 1). The risk of endodontic complications differed between treatment groups and further depended on the preoperative conditions (tooth type, vitality, symptomatology, and presence of radiographically detectable periapical lesions). All complications were assumed to lead to retreatments including nonsurgical (orthograde) or surgical retreatment (apical surgery) as well as extraction as a last resort. Nonpulpal complications included decementations of crowns or secondary caries or fracture, leading to crown recementation, renewal, or extraction accordingly. A proportion of extracted teeth were replaced using an implant-supported single crown. In the base case scenario, this proportion was 50% but varied in sensitivity analyses.

Health Outcomes
The health outcome was tooth retention years (ie, the mean time a tooth was retained in a patient’s mouth), reflecting long-term complications and assumed need for retreatment. Tooth retention years were determined based on the applied model, with teeth translating between health stages depending on transition probabilities until some teeth eventually required removal.

Transition and Allocation Probabilities
Transition probabilities were estimated as follows. Risks of endodontic complications after single- versus multiple-visit root canal treatment were estimated based on systematically collected data. Two authors (F.S. and G.G.) independently screened 1 database (PubMed via Medline) for clinical controlled studies comparing both treatments. Studies need to have randomly allocated patients to treatments or needed to have indicated that although no randomization was used, allocation was not biased by indication and so on. Studies needed to report on complications in both groups, allowing the estimation of relative risks. The search was performed by combining the following search term blocks using Boolean operators: patients AND (first or second or third or 1st or 2nd or 3rd or one or two or three or single or multi or multiple) AND (visit or appointment or session) AND (endodontic or root canal), yielding 338 entries. These were complemented with cross-referencing from bibliographies. From the identified articles, 59 were retrieved as full texts, and 9 studies (10 articles) were included (Supplemental Table S1 and Supplemental Figure S1 are available online at www.jendodon.com). Based on these studies, we extracted the risk of complications in single- versus multiple-visit treated teeth. Moderator variables were extracted as well. All studies had used calcium hydroxide as medication during multiple-visit treatment. Random effects meta-analysis was performed to estimate risk ratios and 95% confidence intervals for the risk of complications after single- versus multiple-visit treatment (Supplemental Table S2 is available online at www.jendodon.com).

To allow risk of complications to vary time dependently (accounting for higher risks shortly after treatment compared with long-term), data from a large German study that had mined an insurance database were used (7). Overall, 555,067 root canal–treated teeth had been followed, allowing the estimation of 3-year survival of teeth. Survival estimates had been reported separately for single- versus multirooted teeth and vital versus nonvital teeth. Three events (nonsurgical, surgical retreatment, and extraction) had been reported on, allowing the estimation of allocation probabilities (the proportion of teeth receiving 1 of these retreatments). Reported survival at years 1, 2, and 3 were transformed into hazards and distributed along the reporting period (in 6-month cycles) to estimate a hazard function. Because this hazard function applied to all assessed teeth, we adjusted it accordingly (Supplemental Table S3 is available online at www.jendodon.com) for nonvital molars (base case), nonvital single-rooted teeth, vital molars (7), and nonvital molars with periapical lesions (4).

The resulting hazard functions were conservatively assumed to apply to teeth that had received multiple-visit treatment. Note that this assumption could distort our estimates. The per-cycle hazards for single-visit treatment were adjusted according to the described risk ratios. Hazards of further endodontic complications (ie, after nonsurgical or surgical retreatment) as well as nonendodontic hazards (ie, complications of crowns and technical and biological complications of placed implants and implant-supported crowns) were derived from systematically compiled data (Table 1). Allocation probabilities were built on the described studies as well as previous cost-effectiveness analyses (6, 12).

Resources and Costs
Cost calculations were based on the German public and private dental fee catalogs Bewertungsmaßstab and Gebührenordnung für Zahnärzte (GOZ) (13). Fee items allow the estimation of costs occurring to payers (12). The majority of patients in Germany (87%) are enrollees of the statutory insurance (14). For these, most fee items can be drawn from Bewertungsmaßstab, and only few items not covered by the...
public insurance are drawn from GOZ, with patients or their private additional insurance covering for these costs. Although our estimates do not fully apply to privately insured patients (where all items are drawn from GOZ), estimated costs have been found to differ very limitedly when estimated from private or public catalogs (15, 16). Opportunity costs of patients’ time in treatment were not accounted for. Similarly, different material costs were not accounted for because these are assumed to be covered by the reimbursed fee.

Discounting
Future costs and effectiveness were discounted at 3% per annum (17). Discount rates were varied to explore the impact of higher or lower discounting.

Currency and Price Date
Costs were estimated in 2015 Euro.
Analytical Methods

Monte Carlo microsimulations were performed for analysis, with 1000 independent individuals (teeth) being followed over the average expected lifetime of patients (18). Incremental cost-effectiveness ratios (ICERs) were used to express cost differences per gained or lost effectiveness when comparing treatments. To introduce parameter uncertainty, we randomly sampled transition probabilities from uncertain parameters, with uncertainty being expressed as 95% confidence intervals or ranges. Based on these, triangular distributions of parameters were constructed and used for probabilistic sensitivity analysis (19). Convergence was checked by inspecting sampling distributions.

Using estimates for costs (c, in Euro) and effectiveness (e, in years), ICERS, expressing cost differences per effectiveness differences, were calculated. Note that ICERS indicate differences in the more costly compared with the less costly treatment; positive ICERS indicate additional costs per additional effectiveness and negative costs additional costs per decreased effectiveness.

Costs and effectiveness were used to estimate the net benefit of each strategy combination via the formula net benefit = c × e – c × e, with c denoting the ceiling threshold of willingness to pay (ie, the additional costs a decision maker is willing to bear for gaining an additional unit of effectiveness) (20). If λ > Δc/Δe, an alternative intervention is considered more cost-effective than the comparator, despite possibly being more costly (19). We used the net benefit approach to calculate the probability of a treatment being acceptable regarding its cost-effectiveness for payers with different willingness to pay ceiling thresholds. A number of univariate sensitivity analyses were performed to explore the impact of uncertainty and heterogeneity.

Results

Study Parameters

Estimated effectiveness parameters (ie, relative risks and transition probabilities) can be found in Table 1. The underlying meta-analysis and subgroup estimations can be found in Supplemental Tables S2 and S3 (available online at www.jendodon.com). Relative to multiple-visit treatment, single-visit treatment was minimally more effective (lower risk of complications) for nonvital and vital molars with or without periapical lesions. Using only data from studies that investigated teeth without preoperative pain, the effectiveness of single-visit treatment increased. In contrast, for single-rooted teeth, single-visit treatment was found less effective than multiple-visit treatment.

Details on cost calculation can be found in Supplemental Tables S4–S11 (available online at www.jendodon.com). Single-visit treatment was minimally less costly than multiple-visit treatment in nonvital teeth; this cost advantage was higher in vital teeth.

Base Case Scenario

The base case was a nonvital molar without a periapical lesion. Single-visit treatment was minimally less costly (1703 vs 1729 Euro) and more effective (19.9 vs 19.8 years) than multiple-visit treatment (Table 2). Regardless of a payer’s willingness to pay threshold,
single-visit treatment had a high chance of being the most cost-effective treatment (Fig. 2A).

**Sensitivity Analyses**

The cost-effectiveness differed only marginally in vital molars (Table 2, Fig. 2B). The cost-effectiveness ranking was reversed in single-rooted teeth, with multiple-visit treatment being less costly (1667 vs 1770 Euro) and more effective (18.9 vs 15.1 years). Note that only 1 study supported the relative risk estimate for this analysis. In teeth without pain, single-visit treatment had large cost and effectiveness advantages (Fig. 2C). This was confirmed in teeth with periapical lesions (Fig. 2D). Varying discount rates had only a limited impact. Varying the ratio of replaced versus nonreplaced teeth had a great impact on treatment costs but did not affect effectiveness. Varying allocation probabilities (assuming more teeth to be retreated and not extracted) had only a minimal impact on the resulting ICER, whereas both costs and effectiveness increased.

**Discussion**

Although single-visit root canal treatment requires less time and materials, thereby showing initially lower treatment costs, it has clinical implications too. On the one hand, immediate obturation after disinfection prevents recontamination of the root canal system between appointments (21), whereas, on the other hand, no medication is placed. Such medication is supposed to disinfect the root canal system even further and reduce the risk of postoperative

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**Table 2.** Mean (Standard Deviation) Cost-effectiveness of Different Strategies in the Base Case and Sensitivity Analyses

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Single visit</th>
<th>Multiple visit</th>
<th>ICER (ΔEuro/Δyears)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Costs (Euro)</td>
<td>Effectiveness (y)</td>
<td>Costs (Euro)</td>
</tr>
<tr>
<td>Base case</td>
<td>1703 (45)</td>
<td>19.9 (0.5)</td>
<td>1729 (45)</td>
</tr>
<tr>
<td>Vital molar</td>
<td>1709 (45)</td>
<td>21.1 (0.6)</td>
<td>1754 (45)</td>
</tr>
<tr>
<td>Single-rooted tooth</td>
<td>1770 (47)</td>
<td>15.1 (0.4)</td>
<td>1667 (44)</td>
</tr>
<tr>
<td>Nonvital molar without pain</td>
<td>1539 (42)</td>
<td>23.7 (0.7)</td>
<td>1729 (45)</td>
</tr>
<tr>
<td>Nonvital molar with lesion</td>
<td>1791 (44)</td>
<td>17.6 (0.4)</td>
<td>1826 (49)</td>
</tr>
<tr>
<td>0% discount rate</td>
<td>1722 (44)</td>
<td>20.1 (0.5)</td>
<td>1755 (47)</td>
</tr>
<tr>
<td>5% discount rate</td>
<td>1673 (43)</td>
<td>19.7 (0.5)</td>
<td>1697 (43)</td>
</tr>
<tr>
<td>0% replaced</td>
<td>721 (21)</td>
<td>19.9 (0.5)</td>
<td>744 (21)</td>
</tr>
<tr>
<td>100% replaced</td>
<td>2674 (52)</td>
<td>19.9 (0.5)</td>
<td>2704 (53)</td>
</tr>
<tr>
<td>50% and 30% nonsurgical and</td>
<td>1808 (47)</td>
<td>22.1 (0.8)</td>
<td>1835 (47)</td>
</tr>
<tr>
<td>surgical retreatment</td>
<td></td>
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</tr>
</tbody>
</table>

ICER, incremental cost-effectiveness ratio.

The less costly option (in bold) was also always less costly (ie, dominant, resulting in negative ICERs).

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Figure 2. Net benefit analyses. We plotted the probability of single- and multiple-visit treatment being acceptable in terms of their cost-effectiveness on the willingness to pay threshold of a payer. By increasing the willingness to pay, combinations with higher effectiveness, but also higher costs, become more acceptable. (A) Base case, (B) vital molar, (C) nonvital molar without preoperative pain, and (D) molar with periapical lesion.
pain and long-term complications (22). The latter is increasingly debated. Although some studies have found calcium hydroxide medications to have antibacterial effects, others have not (23–26). The same applies to such medication reducing the risk of pain after treatment (27). Consequently, the importance of further factors like the preoperative tooth or pulp condition as well as dentists’ endodontic skills should be considered when deciding for or against single-visit root canal treatment (21). This study investigated a further aspect to possibly consider; the cost-effectiveness of single- versus multiple-visit root canal treatment.

We found single-visit treatment to be less costly in the majority of analyses. One should note that the initial cost saving is obvious because repeated application of a rubber dam or (if required) anesthetics is not needed and neither are root canal medication or intermediary restorations. Besides, single-visit treatment is faster, reducing staff and opportunity costs (ie, those for patients being occupied in the dental chair, which we did not assess in this study). However, these cost savings are not reflected in detail in German health care because there is, for example, no separate fee item for an intermediary restoration, and material costs or longer treatment times are not charged separately but are supposed to be covered by the applied fee. Thus, it is important to highlight that the cost difference may vary between settings. For example, considering the mean hourly chair time costs to be 230 Euro (as is the case in Germany) (28) and assuming multiple-visit treatment to require only 15 minutes longer than single-visit treatment, the resulting cost difference is 58 Euro. That is significantly more than the estimated additional 13.95 Euro charged for a medication and the 18.80 Euro for a second application of a rubber dam and anesthetics in our study. Therefore, we consider our estimated differences in initial treatment costs to be conservative.

To account for this and to explore the effects of heterogeneity on our findings, we assessed how different preoperative conditions (pulp vitality, symptomatology, and periapical conditions) affect the cost-effectiveness of both treatments. We found single-visit treatment to have greater cost-effectiveness advantages in vital compared with nonvital teeth, whereas this was reversed in single-rooted versus multi-rooted (molar) teeth. Both findings are grounded on the different costs and clinical effectiveness when treating subgroups of teeth. For vital teeth, multiple-visit treatment requires repeated application of anesthetics, which increases costs. In vital teeth, obturation directly after instrumentation and disinfection are recommended to prohibit infection of the originally noninfected root canal system (21, 22). Consequently, single-visit treatment is not only initially less costly but also more effective, which increases the cost savings long-term as well. Based on our estimates, single-visit treatment has great cost-effectiveness advantages in vital teeth.

For single-rooted teeth, this was reversed, with multiple-visit treatment being more cost-effective. Although root canal treatment seems generally less effective in single-rooted teeth (4, 29), it is not fully plausible why single-visit treatment should be as effective or even superior to multiple-visit treatment in multi- but not single-rooted teeth. It should be highlighted that only 1 high-risk study compared both treatments in single-rooted teeth (30). Thus, the resulting cost-effectiveness estimates should be interpreted with caution.

For teeth with radiographically detectable periapical lesions, the disinfecting root canal medication between multiple treatment visits should theoretically be beneficial. In such case, initial cost savings in the single-visit group could be compensated by the increased risk and retreatment needs compared with multiple-visit treatment (6, 31). Our finding indicates this was not the case; the advantages of single- versus multiple-visit treatment seem to apply for teeth with periapical lesions as well.

A number of further sensitivity analyses were performed. We found discounting to have only a limited impact on cost-effectiveness. In contrast, replacement of teeth was an important driver of costs. That can be expected because many complications after endodontic treatment were assumed to lead to extraction, which is the case under the tenets of the German public health insurance (where, for example, nonsurgical retreatment is not covered at all). It should be noted that this might not be the case in settings where incentives for tooth retention are in place. Accordingly, we varied allocation probabilities in a sensitivity analysis and found longer retention times if conservative retreatments were performed more often. Interestingly, this also increased costs because such tooth retaining retreatments (like nonsurgical retreatment or apical surgery) are relatively costly.

This study has a number of limitations. First, our model is a simplification of clinical reality where decisions are made individually for each patient and not according to transition probabilities. The model also followed a single tooth for ease of technical implementation and interpretation. However, patients might have more than 1 tooth requiring endodontic therapy. It is likely that in this case some costs might be distributed between treated teeth. However, we do not consider such distributional effects to have great relevance or change our main findings (16). In a patient-level model, teeth might also be replaced using fixed dental prostheses (bridges) and not implants, which again would impact costs (but also initiate further cycles of retreatments in abutting teeth). Second, our study was built on systematically collected data, which were quantitatively and qualitatively limited. A more comprehensive search (involving other databases) might yield slightly different findings. Given the paucity of data for supporting our scenario analyses, the risk of type I error is high, and the respective findings should be interpreted with caution. Third, and as discussed, our findings apply only to German health care because both the cost estimates and the allocation probabilities were derived especially for Germany. Moreover, we did not account for costs occurring for lost productivity during dental visits or costs for any drug consumption as a result of pain because such data are unavailable. Last, and possibly most important, we assumed both treatment options to be interchangeable. That will not be the case in many clinical situations in which dentists’ or patients’ time or other restrictions will guide the decision for or against 1 of these treatments.

In conclusion, single-visit treatment is very likely to generate reduced initial treatment costs compared with multiple-visit treatment. Greater ambiguity remains as to the different effectiveness of both treatments. Within the limitations of this study, the overall cost and effectiveness differences between treatments seem limited. The resulting cost-effectiveness is likely to differ between subgroups of teeth, whereas data supporting subgroup analyses are scarce. Practical aspects in scheduling treatments as well as patients’ and dentists’ preferences should be considered for decision making.

Acknowledgments
The authors deny any conflicts of interest related to this study.

Supplementary Material
Supplementary material associated with this article can be found in the online version at www.jendodon.com (http://dx.doi.org/10.1016/j.joen.2016.06.013).

References