ADA CE Program

A practical approach to evidence-based dentistry: IX

How to appraise and use an article about economic analysis

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NINTH IN A SERIES

In the previous 8 articles in this series, we introduced the process of evidence-based dentistry,[1] how to search for evidence to inform clinical practice,[2] and how to use a research report to inform clinical decisions regarding questions of therapy,[3] harm,[4] diagnosis,[5] systematic reviews,[6] clinical practice guidelines,[7] and qualitative research.[8] In this article, we will explain how to use an economic analysis to inform clinical and policy decision making in dentistry. We will introduce and describe the basic concepts needed to understand economic analysis, and we will explain how to critically appraise such studies.

Supplemental material is available online.

BOX 1

Clinical scenario.

One of your patients, a first-year college student, came to ask for your opinion regarding his third molars, which have not erupted yet. He explained that a friend of his just had 2 of his mandibular third molars extracted and is planning to extract the remaining 2 because he was told that the early, prophylactic removal of third molars is less traumatic than the "inevitable late extraction of infected third molars," and that it prevents future teeth crowding. Your patient does not have dental benefits, and he is concerned about his out-of-pocket expenses for extracting these teeth and whether such expenses would be worth the potential benefits and risks of the procedure. You realize that, to answer your patient's question, you need to find an economic analysis whose authors considered both short-term and long-term risks, benefits, and costs for third-molar extraction. You decide to conduct a literature search and a critical appraisal to inform the decision.

This article has an accompanying online continuing education activity available at: http://jada.ada.org/ce/home.

ABSTRACT

Background and Overview. In everyday practice, dentists face clinical decisions for which they need to consider both treatment consequences (that is, benefits and harms) and costs. Economic analysis is a study design in which investigators evaluate and compare the costs and consequences of different treatment alternatives within a defined period. A critical appraisal of such studies includes an assessment of the risk of bias, results, and applicability of the study. The authors provide the concepts and guidelines that dentists can apply to critically appraise economic analyses.

Practical Implications. Dentists who wish to inform their clinical decisions regarding questions that involve both treatment consequences and costs can use these guidelines to understand the different types of economic analyses and to decide what type of economic analyses to search for, as well as to critically appraise any economic analyses identified.

Key Words. Evidence-based dentistry; economic analysis; cost-effectiveness; decision model; critical appraisal.
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WHY ECONOMIC ANALYSIS IN DENTISTRY?

The economic burden of oral health care is significant, with a reported $111 billion spent on dental care in the United States and $11.7 billion in Canada in 2012.[9,10] Public health agencies invest significant resources in oral health care programs that amounted to $9 billion in 2012 in the United States.[9] Although most of the programs offered are assessed with respect to their effectiveness, whether they represent a good "value for the money" rarely is investigated.

Clinicians daily make treatment decisions not only on the basis of information about the benefits or harms but also on the basis of costs. With a patient's best

interest in mind, a clinician needs to assess whether the expected treatment benefits justify the resources used. For example, imagine that you want to buy more advanced 3-dimensional (3-D) dental imaging equipment for your practice; does this possible purchase represent a good value for money spent? Or imagine yourself as a policy maker who must decide if the $2 million set aside for a public dental program should be directed toward an oral health prevention program for children or toward a program for adults who have low incomes and who are edentulous. Patients also need to invest their resources (for example, personal income, time off work) in interventions that will provide them with the best value for the money. Over time, such decisions are likely to get more, rather than less, difficult: the projected demographic changes in countries with high and low levels of income, our ever increasing demand for better care, and increasingly costly health care innovations will continue to strain our already scarce health care resources. All these aspects illustrate the importance of investigating an intervention's effectiveness and safety in conjunction with its efficiency, the balance of costs, and (positive and negative) health consequences.

There are different types of economic analysis that can evaluate the efficiency of a dental intervention. If the dentist is only interested in the overall cost of treating a particular condition, he or she can use a cost analysis, taking into account all resource utilization during and after treatment. This is, however, not a full economic analysis as it does not compare alternative treatments. If the dentist is interested in both the benefits and the costs of 2 or more treatments, a full economic analysis in the form of cost-effectiveness, cost-utility, or cost-benefit analyses would be a more appropriate source of evidence (Table 1[11-14]). In all these types of economic analyses, treatment costs are measured in monetary units.

Cost-effectiveness analysis. In a cost-effectiveness analysis (CEA), treatment consequences (that is, benefits and harms) are measured in natural units, such as number of teeth extracted, gingival bleeding rates, or tooth survival. The main outcome of a CEA is the incremental cost-effectiveness ratio (ICER) (that is, the additional cost per additional unit of effect of a candidate intervention compared with an alternative). The results of a CEA can assist clinicians only in making decisions between treatments that share the same clinical effect.

Cost-utility analysis. In a cost-utility analysis (CUA), treatment consequences are measured in quality-adjusted life-years (QALYs), which is a combined measure of the duration and quality of life.[15] The advantage of this type of analysis is its transferability, as it offers the means to make comparisons across different interventions and different diseases using a common measure (for example, cost per QALY for oral health prevention versus cost per QALY for hypertension prevention). Because of this advantage, CUA is the most common form of economic analysis.

CUA also has limitations: the QALY can be insensitive to improvements in health-related quality of life achieved with dental interventions owing to the fact that few dental interventions are lifesaving or extend life. Furthermore, given that in most settings dental care is paid out of pocket or through private insurance, the need for prioritizing the allocation of resources across dental strategies (for example, investing in a caries prevention program for children or in an oral cancer awareness campaign) is limited. For these reasons, CUAs are rarely used in dentistry.

Cost-benefit analysis. In a cost-benefit analysis (CBA), the treatment consequences are evaluated in monetary terms, providing a direct estimate of whether consequences exceed costs.[15] CBA is the least used form of economic analyses, with only few examples in dental literature.

TRIAL-BASED VERSUS DECISION MODEL–BASED ECONOMIC ANALYSES

Economic analyses can be conducted alongside clinical studies (trial based) in which investigators collect patient-level data on health care resource use and costs, along with effectiveness outcomes.[16] These clinical studies include randomized controlled trials (RCTs), observational studies, patient registries, and administrative databases.[17] Constraints of a trial-based economic analysis include the facts that the duration for which costs and outcomes are assessed is limited to the actual study duration, information originating from other similar studies on the treatments of interest is ignored, and collecting data for economic analysis alongside a trial is often resource-intensive.[15,17]

Alternatively, decision models can be used to estimate the long-term (or lifetime) costs and consequences of health care interventions (see Figure 1[15,18] for a simplified example of a decision tree). A decision model is a statistical tool that allows clinicians to compare the costs and benefits of 2 or more alternative clinical decisions while considering the probability of events occurring over a selected period (that is, the time horizon).

BOX 2

The economic analysis you found.

During your search, you found that the prophylactic extraction of disease-free, impacted third molars remains controversial. The American Association of Oral and Maxillofacial Surgeons, for example, supports the removal of "erupted and impacted third molar teeth even if the teeth are asymptomatic, if there is presence or reasonable potential that pathology may occur caused by or related to the third-molar teeth."[19] In contrast, the investigators of several systematic reviews did not find sufficient evidence to support removal over retention.[20-22] You read that annually in the United States, approximately 10 million third molars are extracted from approximately 5 million people, with total costs exceeding $3 billion.[23] You found an economic evaluation that compared removal versus retention of asymptomatic, disease-free mandibular third molars, using a decision model.[18] In the abstract of the study, the investigators reported that the probability estimates for different clinical outcomes were obtained from a comprehensive literature review, and the treatment costs were obtained from the National Health Service hospitals in Wales, United Kingdom. The effect of each clinical outcome was assessed among 100 patients attending a single dental hospital. The authors concluded that mandibular third-molar retention was more cost-effective than removal.[18] You obtain the article and conduct a critical review of the methods and results.

CRITICALLY APPRAISING AN ECONOMIC ANALYSIS TO INFORM CLINICAL DECISIONS

Economic analyses can be critically appraised using 3 steps: assessing the risk of bias, assessing the results, and assessing their applicability to your patients' care.[24] Below, we describe each of these steps.

1. How serious is the risk of bias? The main research question of an economic analysis should define the patient population, the treatment alternatives, the perspective of evaluation, the type of analysis, and the time horizon for which costs and consequences are to be evaluated. Ideally, economic analyses should compare the new intervention with all standard treatment alternatives.[15] For logistical reasons, however, this is not always feasible. Whatever treatments authors have chosen to compare, we suggest assessing 3 risk-of-bias criteria: consideration of subgroups, accurate measurement of consequences and costs, and consideration of timing. Table 2[12,25-28] presents examples of assessments of the risk of bias in economic analyses. In a critical appraisal process, it is important to evaluate if the new intervention has been compared with a relevant alternative, and if the time horizon of the study was sufficiently long to see the expected costs and consequences of treatments. Components of assessments of the risk of bias in economic analyses that could create a risk of bias are discussed in more details below.

1a. Are results reported separately for relevant patient subgroups? Similar to clinical effectiveness studies, results of economic analyses can vary widely between different patient subgroups. Such variations can be explained by differences in treatment consequences or costs in these subgroups.[29] For example, implant-supported dentures may be more cost-effective than conventional dentures in patients who are edentulous and younger than 60 years but not cost-effective for patients

who are 85 years and older, and ignoring this difference can result in misleading interpretation of the results. The subgroups for economic analysis should be defined at the study planning stage and should be reported with the rationale for their selection (for example, to explore heterogeneity in results, to determine policy relevance, or on the basis of a literature review). Once defined, all results should be analyzed for selected subgroups separately.

1b. Were consequences and costs measured accurately? In an economic analysis, the evidence on consequences (that is, clinical effectiveness, safety) may come from a single RCT or an observational study, or, more appropriately, from evidence synthesis (that is, systematic review). The quality of outcomes of an economic analysis depends on the quality of the effectiveness evidence on which it relies. For that reason, systematic collection of the best, unbiased evidence on consequences is important. In previously published articles in this series, we have covered all major issues related to the risk of bias to establish treatment effectiveness,[3] harm,[4] and diagnostic accuracy.[5] Here, we discuss issues pertaining to costs.

The cost components (that is, resources utilized) included in an economic analysis should reflect the perspective assumed. Hence, once you identify the perspective of the economic analysis in the reviewed article, you need to critically appraise whether all relevant cost components have been considered. For example, investigators of a study evaluating from a societal perspective the cost of establishing a community-based oral health promotion program by health educators who do not have an oral health background should consider not only the costs of training the educators (for example, hourly salary, space rental fees, costs of education materials)[30] but also the productivity losses of the participants who attend the sessions. After identifying the cost components and the frequency of their use, unit costs are applied to obtain an estimate of the total costs associated with each patient.

1c. Did investigators consider the timing of costs and consequences? The consequences and costs of health care interventions can occur at different times. For example, although most of the costs for establishing an oral health education program in schools occur at the time of the program launch, the benefit of caries prevention may occur several years later. Investigators of a CEA comparing 2 alternative approaches for such a program should consider this differential timing of costs and benefits.

As a society and as individual people, we prefer to have resources available to us now, and not later, either because we can invest these resources and receive benefits over time or simply because we prefer good things now to good things later. Time preferences, therefore, play a significant role both in making individual decisions and in influencing public policy.[31]

To adjust for these differential time preferences, especially when the study's time horizon is long, we

TABLE 1

Types of economic analyses.

TYPE OF ECONOMIC ANALYSIS	MEASUREMENT OF COSTS	MEASUREMENT OF EFFECTIVENESS	EXAMPLE RESEARCH QUESTIONS
Cost Analysis	Monetary units	None	What is the cost of periodontitis management at a public sector specialist periodontal clinic settings in Malaysia for the first year of periodontal therapy, from the societal perspective?*
Cost-Effectiveness Analysis	Monetary units	Natural units (for example, teeth extracted, gingival bleeding rates, or tooth survival)	What is the cost-effectiveness of implant-supported overdentures, implant-retained overdentures, and complete dentures in patients who are edentulous at 3 years of follow-up, from the patients' perspective?†
Cost-Utility Analysis	Monetary units	Quality-adjusted life-years	What is the cost-utility of 3 preventive strategies (that is, no prophylaxis, oral penicillin, and oral cephalexin) in patients with prosthetic joints who are undergoing dental treatment to prevent late prosthetic joint infections at 1 year follow-up from the patients' perspective?‡
Cost-Benefit Analysis	Monetary units	Single or multiple health outcomes valued in monetary terms (for example, willingness to pay)	What is the value of a 4-year caries preventive program among 19-year-olds from a societal and a dental health care perspective?§

* Source: Mohd-Dom and colleagues.[11]
† Source: Zitzmann and colleagues.[12]
‡ Source: Jacobson and colleagues.[13]
§ Source: Oscarson and colleagues.[14]

devalue benefits and costs that accrue later, relative to those that occur earlier. This process of devaluing is called "discounting," and economic analysts apply a discounting rate to costs and outcomes. Most economic evaluation guidelines recommend using either a 3% or a 5% per year discounting of future costs and outcomes to present values.[15] It is, however, debatable if the costs and consequences should be discounted in the same way.[31]

BOX 3

Your assessment of the risk of bias of the economic analysis you identified.

The authors of the study you identified[18] did not specify any subgroups, although they could have considered age and smoking status on the basis of the literature. Effectiveness was estimated by asking patients to rate different scenarios after tooth removal or retention, using a visual analog scale, which is the least preferred method to evaluate health preferences. Furthermore, the variability around the average effectiveness scores was not presented. Only aggregate costs by scenario and by health care resource use were presented, which limited your ability to see, for example, medication costs (eTable,[18] available online at the end of this article). The overall time horizon for costs and benefits was not specified, and discounting was not considered. Bearing in mind the identified limitations, you proceed to read the results.

2. What are the results? To evaluate the results from an economic analysis, you should examine the mean differences in effectiveness and cost between the treatments and the variation around these differences. Conclusions about the cost-effectiveness of the interventions can be made after considering willingness to pay for an incremental cost per unit of benefit. Table 3[12,25,32] and indirectly, Figure 2[12] (as cited in Table 4) present examples and charted information that describes how to critically appraise results of economic analyses.

2a. What were the incremental costs and effects of each strategy? We will facilitate discussion in this section using the example of CEA by Zitzmann and colleagues[12] who compared implant-supported overdenture prostheses (4 implants), implant-retained overdentures (2 implants), and complete dentures (20 patients in each of the 3 groups) from the patient's perspective in Switzerland, to assess whether implant treatment in the mandible represents value for money spent.[12] The effectiveness was measured in quality-adjusted prosthesis-years (QAPY), a composite estimate of duration of prosthesis use and perceived chewing ability (as measured by a visual analog scale between 0 [the worst possible state] and 1 [the best possible state]). If a patient, for example, reported best possible chewing ability for all 3 years, the QAPY equaled 3. On the basis of the results of the study, at 3 years, the average QAPYs per patient were 0.86, 1.46, and 1.57, and the average costs were 2,525 Swiss francs (CHF), CHF 6,935, and CHF 15,805 (CHF 100 = US $61 in 2000) for conventional dentures, implant-retained overdentures, and implant-supported overdentures, respectively.[12]

Table 4[12] displays the ICER of implant-retained overdentures versus complete dentures, and implant-supported overdentures versus complete dentures However, you should not simply look at the ICER value, as it may be deceiving. The ICER is an estimate. Therefore, an intervention that is more effective and more costly than the control treatment can have the same ICER as an intervention that is less effective and less costly than the control. Instead, you first need to evaluate whether the differences in costs and in effectiveness are large enough to have clinical and policy-relevant impact. Next, the differences in costs and effectiveness should be

interpreted using a cost-effectiveness plane as shown in Figure 2.[12]

2b. Do incremental costs and effects differ between subgroups? In reviewing an economic analysis, you need to consider if the observed benefits, harms, and costs may be different between some patient subgroups. For example, the cost-effectiveness of dental recall examinations may depend on a patient's risk factors. A decision model that evaluated the cost-effectiveness of different recall frequencies of routine dental checks in children found that moving from a 6-month to a 3-month recall frequency provided only a small benefit in terms of tooth decay and was associated with significantly higher costs.[33] In contrast, moving from 6-month recall schedule to less frequent visits (for example, annual visits or visits every 18 months) increased the risk of dental decay with some cost savings. The cost-effectiveness results, however, were different across the 4 risk-subgroups that included combinations of patients with differing socioeconomic status (that is, manual or nonmanual workers) and patients living in an area with water fluoridation.[33]

2c. How much does allowing for uncertainty change the results? Economic analyses often combine evidence from different sources to reach an estimate of incremental cost-effectiveness. Because these parameters are sample estimates, they are characterized by uncertainty, known as parameter uncertainty. In addition, the decisions regarding the assumptions of the analysis and the selection of the source of input evidence contribute to the overall uncertainty related to the results of an economic analysis. One advantage of incorporating uncertainty in economic analysis is understanding the consequences of decision making in the presence of uncertainty.[34]

The effect of uncertainty on the outcomes of the economic analysis usually is studied by making varying assumptions about benefits and costs and examining the impact of these different assumptions on the results (that is, sensitivity analyses). In 1-way sensitivity analyses, authors vary only a single variable at a time; in multiway
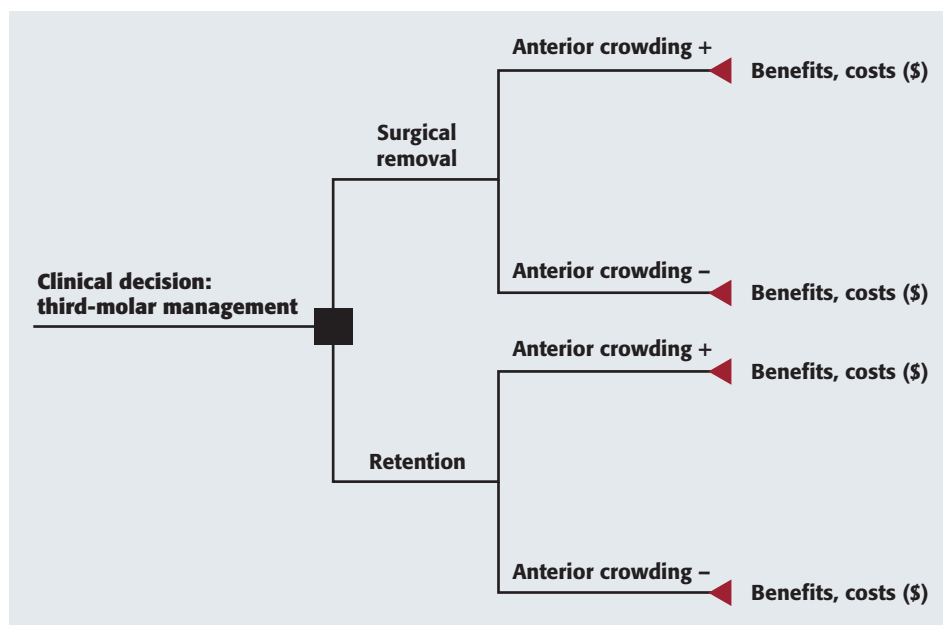

Figure 1. Example of a simplified decision model comparing surgical removal or retention of third molars. Decision models combine information from multiple sources (for example, randomized controlled trials, literature searches, administrative databases, and expert opinions) to reconstruct the clinical pathways for each alternative intervention under conditions of uncertainty over the time horizon.[15] These models are more suited to evaluate long-term costs and consequences of treatments. This example decision tree considers only 1 adverse consequence (that is, anterior crowding). A decision tree in which adverse consequences are considered more extensively can be found in the study by Edwards and colleagues.[18]

sensitivity analyses, they vary more than 1 variable simultaneously. For example, Kim and colleagues[35] investigated the cost-effectiveness of endodontic molar retreatment compared with fixed partial dentures and single-tooth implant alternatives for a failed endodontically treated tooth. They investigated the sensitivity of the analyses results on the probability of functional retention (that is, the survival probability) and on the cost input parameters. They concluded that if the survival probability was lower than 77%, the nonsurgical retreatment would become a less cost-effective option compared with the extraction of the failed endodontically treated tooth with the replacement of the same tooth with a fixed partial denture or single implant–supported restoration.

Parameter uncertainty usually is incorporated in economic studies using a probabilistic sensitivity analysis. For example, in a CEA of 1- and 2-step incomplete and complete excavations for the treatment of deep caries lesions, the authors conducted a probabilistic sensitivity analysis to obtain a distribution of economic analysis outcomes.[27] To achieve this, they first assigned a distribution around each parameter in the model, which represented the uncertainty around the true value of the parameter. Subsequently, they randomly sampled a large number of values from these distributions and calculated the economic outcomes for each set of

TABLE 2

Critically appraising the risk of bias in studies of economic analysis.

QUESTIONS	EXAMPLES	EXPLANATIONS
Are results reported separately for relevant patient subgroups?	"The objectives of this study are to examine the utilization of dental sealants and its determinants, evaluate the incremental effectiveness and expenditure associated with sealant placement after correcting the potential selection issue, and explore the differences in sealant's cost-effectiveness among subpopulations… . Children at relatively high caries risk, as well as children who visited dentists for preventive care more than once a year, had greater odds of receiving sealants."[*]	In this study, the authors specified subgroup analysis at the study planning phase and included it as part of the study aim. The authors further supported the subgroup analysis by conducting a literature review and by comparing the characteristics of children who visited dentists for preventive care and who either received or did not receive sealants. The cost-effectiveness was evaluated for the full sample and for the selected subgroups. The risk of bias is low on the basis of this criterion.
Were consequences and costs measured accurately?[†]	"For each patient, the costs of delivering treatment were recorded by a research nurse… . Laboratory costs were recorded as part of normal hospital policy…. All of the dental materials used were recorded and given a unit price … [and] the amount of time spent in the dental surgery for each appointment was measured using a stop watch… . The total number of clinical appointments was recorded, including unscheduled postoperative care, and the total clinical time calculated for each patient. The cost of professional time per patient was estimated using the highest point of the salary scale for the community dental service in Ireland (€85 185). Based on this salary, the hourly rate for a clinician providing care was €44.37 per hour for 240 8-hour working days per year."[‡]	In this cost-effectiveness analysis, the authors compared the partial removable dental prosthesis and the shortened dental arch for older patients who were partially dentate in a randomized controlled trial that had 12 months of follow-up. The analysis was conducted from the "perspective of a publicly funded body."[‡] The authors described the cost components that were accounted for (that is, laboratory costs, dental materials, clinic visits, and time and cost of professional care) and only some of the sources for unit costs. For example, it is unclear how dental material costs were obtained. Moreover, the reporting of results was not transparent, as authors presented the total costs per patient only without information on frequency of use and unit costs.[‡] These limitations entail high risk of bias for this criterion.
Did investigators consider the timing of costs and consequences?	"Costs were calculated in Euros and future costs discounted at 3% per annum… . No such discounting was performed for future effectiveness, since it remains unclear whether and how to discount years of tooth retention."[§]	In this study, the authors used a decision model approach to evaluate the cost-effectiveness of 1- and 2-step incomplete and complete excavations for caries. They assessed the benefits (that is, tooth retention and vitality) and costs over the patient's lifetime. The authors applied a 3% discounting rate to account for differential timing of costs. Effectiveness measures were discounted neither in their main analysis nor in sensitivity analyses. This limitation may indicate a high risk of bias for this criterion.

* Source: Ouyang.[25]
† Authors' note: The accuracy of measuring consequences has been covered in previously published articles in this series; here we discuss only costs.
‡ Source: McKenna and colleagues.[26]
§ Source: Schwendicke and colleagues.[27]

sampled values. The distribution of the calculated costs and effects captured the underlying uncertainty. The results of probabilistic sensitivity analysis usually are represented using a cost-effectiveness acceptability curve (Figure 3[12]).

BOX 4

Your assessment of the results of the economic analysis you identified.

By reviewing the results of the study you identified,[18] you found that the incremental cost of a mandibular third-molar extraction versus retention was £56 (£1 = US $0.61 in 1997), and the incremental effectiveness was −6.2 units (for more details, see the eTable,[18] available online at the end of this article). Subsequently, the extraction was more costly and less effective than the retention; hence, it was not cost-effective. For costs, effectiveness and the incremental cost-effectiveness ratio, the authors presented only their point estimates without variability around the estimates, limiting your ability to judge how uncertain these estimates were. The sources of probability values for events in the model or their ranges were not reported. The authors conducted some sensitivity analyses, but you could not find the list of variables and their values for these analyses. Although the authors reported that the model was sensitive to the probability of pericoronitis being 40%, periodontal disease being 17%, and nonrestorable caries in the second molar being 22%, they did not discuss under which conditions these values could be expected, except for in smokers.[18]

3. How can I apply the results to my patient care?
After you completed the evaluation of the risk of bias and results of the economic analysis, you will need to assess whether the observed treatment benefits are worth the risks and costs (that is, resource consumption), and whether you can expect similar results in your practice setting.

3a. Are the viewpoints and setting used in the study relevant to my context? Economic analyses can be conducted from different viewpoints or perspectives depending on the type of decision that needs to be made. For example, the costs and consequences can be evaluated from the perspective of a patient, a health care institution (for example, hospital, dental practice), a health care provider (for example, dentist), a third-party payer (for example, private or state insurance), or society in general. The viewpoint of analysis defines which health consequences (that is, benefits and harms) and costs need to be collected for the study. For an economic analysis to be valid, the perspective of the analysis has to match the study's research question. For example, an economic analysis conducted from the patient's perspective should consider patient-important outcomes (for example, health-related quality of life, chewing

TABLE 3

Critically appraising the results of economic analyses.

QUESTIONS	EXAMPLES	EXPLANATIONS
What were the incremental costs and effects of each strategy?	"For the total follow-up period, the mean cost per child in the experimental group was €496.45 and in the control group was €426.95. The mean incremental cost was €69.50 (95% CI*: 28.25, 110.75). The mean number of DMF† increment surfaces was 2.56 in the experimental group and 4.60 in the control group. The mean incremental effectiveness was 2.04 averted DMF surfaces (95% CI: 1.26, 2.82). The ICER‡ was €34.07 per averted DMF surface."§	The authors conducted a cost-effectiveness analysis alongside an RCT¶ that compared an individually designed, patient-centered preventive program for caries with basic prevention as standard of care in dental clinics in Pori, Finland.§ The authors presented incremental costs and benefits for each treatment arm and the ICER, with accompanying CIs. The full presentation of incremental costs and effectiveness allows the reader to plot the results on a cost-effectiveness plane.
Do incremental costs and effects differ between subgroups?	"The results from a subgroup analysis show that sealing children at high risk for caries appears to be highly cost effective. In contrast, sealing children at low risk for caries would be much less cost effective... There is no significant difference in ICERs between sealing younger children and sealing older children."#	In this study, the authors found that the cost-effectiveness of sealant applications was different by caries risk and by frequency of use of preventive care, but not by age. They concluded that sealant application should not be uniform because it is not always cost-effective.
How much does allowance for uncertainty change the results?	"The cost-effectiveness plane, based on probabilistic sensitivity analysis, showed that for almost all bootstrapped resamples (99.9%) the experimental caries-control regimen was more effective, but more costly. There was very little uncertainty because the bootstrap replications did not straddle other quadrants in the cost-effectiveness plane... The curve for acceptability of cost-effectiveness reveals that if the willingness of society to pay for an averted DMF surface is, for example, €40, the probability of an experimental caries-control regimen being considered cost-effective is about 65%..."§	The authors of this study evaluated the robustness of the ICER by using 5,000 bootstrapping** resamples and found that in almost all resamples the ICER was in the same quadrant (quadrant 1 as per Figure 2). Next, the authors plotted a CEAC†† in which the probability of being cost-effective was calculated for different values of willingness to pay for an averted DMF surface. Clinicians can use CEAC to see what would be the probability of the described intervention being cost-effective for the threshold values they consider reasonable for their practice.

* CI: Confidence interval.
† DMF: Decayed, missing, and filled.
‡ ICER: Incremental cost-effectiveness ratio.
§ Source: Hietasalo and colleagues.[32]
¶ RCT: Randomized controlled trial.
\# Source: Ouyang.[25]
** Bootstrapping is a technique used to quantify the uncertainty around a random variable based on computer simulations.
†† CEAC: Cost-effectiveness acceptability curve.

ability) and costs (for example, insurance premiums, out-of- pocket costs), whereas an economic analysis from the provider's perspective should consider provider-important outcomes (for example, implant success rate, improvements in work environment). Oftentimes, the same economic analysis is conducted from multiple perspectives.

The perspective defines also the cost components that need to be considered in the economic analysis. Dental care–related costs largely can be grouped as direct dental costs (for example, cost of professional time, medications), direct nondental costs (for example, transportation costs for dental visits), and indirect costs (for example, time off work, travel time to seek care, reduced productivity because of the disease, caregiver costs).[15] An economic analysis from the patient's perspective, for example, may consider all relevant dental and nondental costs incurred by the patient in the form of out-of-pocket payments as well as the indirect costs because of lost productivity. In comparison, an economic analysis from the dentist's perspective may consider costs associated with establishing the practice and material costs. Therefore, an economic analysis performed using a patient's perspective may not be

applicable to policy makers, because it may be missing important components to consider. Conversely, the results of an economic analysis that adopted a health policy perspective may not be transferrable when considering the cost-effectiveness of an intervention at a patient's level.

Likewise, it is necessary that the setting used in the study is similar enough to the setting in which the results are going to be applied. For example, unit costs for health care resources can be obtained from national formularies, administrative databases, or literature reviews, or through expert opinion. There could be significant variations in the unit costs and charges across different settings. Take the case of the fee for a unit of time for a dental hygiene visit, which can vary significantly depending on the clinic location. You should evaluate whether the authors explicitly stated how they itemized costs, which unit costs were applied and why, and which currency exchange rate was applied. This information also will help you to transfer the results from the setting of the published analysis to your setting. Although the results of treatment effectiveness or harm are relatively transferrable between settings and countries, this is not true for costs. As a result, the same treatment that could
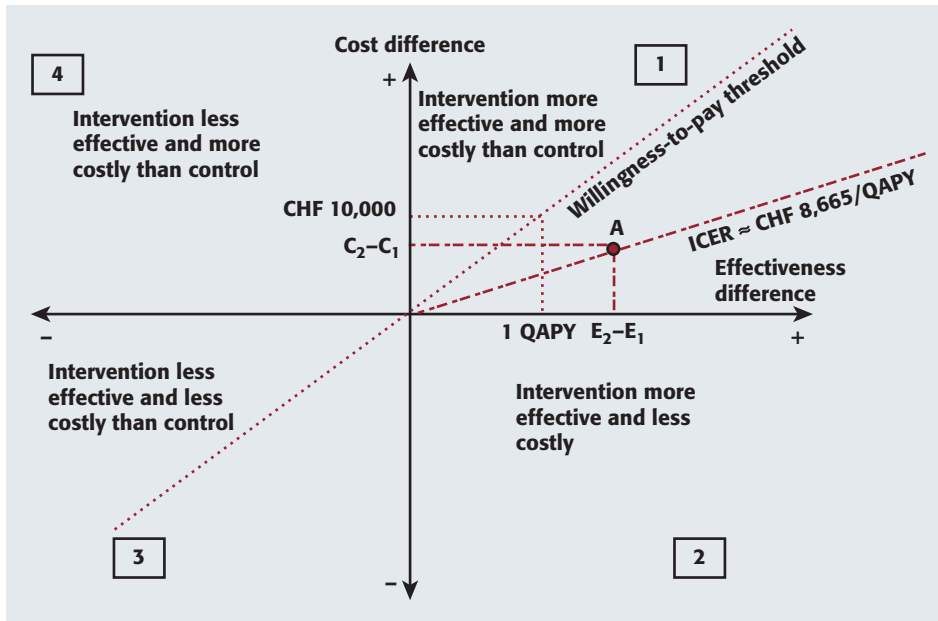
Figure 2. Cost-effectiveness plane for "complete denture versus implant-retained overdentures" comparison.[12] There are 4 quadrants on a cost-effectiveness plane in which the horizontal line represents the differences in effectiveness and the vertical line represents the differences in costs. Any intervention that is more effective and more costly than the control will have an incremental cost-effectiveness ratio (ICER) located in quadrant 1 and will need a threshold estimate (that is, willingness to pay) to decide if it is cost-effective. An intervention that is more effective and less costly than the control (quadrant 2) always will be a dominant strategy. In contrast, an intervention that is less effective and more costly than the control (quadrant 4) always will be dominated by the control treatment. To decide whether an intervention that is less costly and less effective than the control (quadrant 3) is cost-effective, you need to decide how much loss in effectiveness is acceptable, in comparison with benefiting from cost savings. In this example, E_1 and E_2 are the effectiveness estimates for complete denture. C_1 and C_2 are the cost estimates for implant-retained overdentures. The slope of the line connecting the cost-effectiveness plane origin to point A represents the ICER or the incremental unit cost per incremental unit of effectiveness (that is, 8,665 Swiss francs [CHF] per quality-adjusted prosthesis-year [QAPY]) for the comparison of "implant-retained overdentures versus conventional dentures."[12] If, for example, the maximum willingness to pay for treating edentulism is CHF 10,000 per 1 QAPY, then using implant-retained overdentures would be cost-effective.

3b. Are the treatment benefits worth the risks and costs? We already know that after plotting the incremental costs and benefits on the cost-effectiveness plane, any ICER that falls in quadrant 2 (indicating that the intervention is more effective and less costly than control) means that the new intervention should be adopted into practice, and any ICER that falls in quadrant 4 (indicating that the intervention is less effective and more costly than a control) indicates the opposite (Figure 2[12]). Most of the innovations however, cost more than the treatment alternatives in the practice and result in ICERs falling into quadrant 1. For these interventions, clinicians need to critically appraise if the extra benefits are worth the extra costs when the new treatment is adopted into the practice. In a CEA, clinicians

be considered to be a resource-saving treatment in 1 setting could be considered to be a resource-consuming treatment in another setting.

can compare the incremental cost per unit of incremental effectiveness with other similar alternatives in practice. Another option would be to compare the ICER against a

TABLE 4

Incremental costs, incremental effectiveness, and incremental cost-effectiveness ratio.*

STRATEGIES	AVERAGE 3-YEAR COST PER PATIENT, IN CHF,[†] C[‡]	AVERAGE 3-YEAR QAPY[§] PER PATIENT, E[¶]	INCREMENTAL COSTS, ΔCHF	INCREMENTAL EFFECTS, ΔE (QAPY GAINED)	ICER,[#] ΔC/ΔE (CHF/QAPY)
Complete Denture	$C_1 = 3{,}675$	$E_1 = 0.86$	NA**	NA	NA
Implant-Retained Overdentures	$C_2 = 8{,}874$	$E_2 = 1.46$	$C_2 - C_1 = 5{,}199$	$E_2 - E_1 = 0.60$	$C_2 - C_1 / E_2 - E_1 = 8{,}665$
Implant-Supported Overdentures	$C_3 = 17{,}837$	$E_3 = 1.57$	$C_3 - C_2 = 8{,}963$	$E_3 - E_2 = 0.11$	$C_3 - C_2 / E_3 - E_2 = 81{,}482$

* Source: Zitzmann and colleagues[12] (base-case analysis with 3-year follow-up and 0% discount rate). Costs were estimated in 2000 Swiss francs (CHF) (CHF 100 = US $61).
† CHF: Swiss franc.
‡ C: Incremental costs.
§ QAPY: Quality-adjusted prosthesis-year.
¶ E: Incremental effectiveness.
\# ICER: Incremental cost-effectiveness ratio.
** NA: Not applicable.

threshold value (that is, willingness to pay) that society is willing to pay for 1 unit of outcome. The relevance of these threshold values, however, is still widely debatable.[36] Establishing a monetary threshold for a unit of effectiveness (for example, willingness to pay for 1 year of best possible chewing ability or 1 QAPY) is not an easy task; the threshold values differ by outcomes, they are not always transferrable between countries, they may change over time, and they can vary depending on who decides on the value (for example, patients with the condition, representatives from general population, health care providers). To increase the applicability of findings, authors use CEACs in situations for which the probability of an intervention being cost-effective is plotted against a range of thresholds, as shown in Figure 3.[12]

Figure 3. Cost-effectiveness acceptability curve (CEAC) comparing implant-retained overdentures versus conventional dentures. CEAC graphically represents the probability of the intervention (implant-retained overdentures) being cost-effective compared with the control (conventional dentures). This probability is plotted against the range of maximum willingness-to-pay thresholds for 1 unit of effectiveness (that is, quality-adjusted prosthesis-year [QAPY]). For example, the probability that implant-retained overdentures are more cost-effective than conventional dentures is 60% if the threshold is 10,000 Swiss francs (CHF) per QAPY and 86% if the threshold is CHF 20,000 per QAPY. *Source:* Zitzmann and colleagues.[12]

To fully appreciate the results of an economic analysis, clinicians need to first have an understanding of the notion of opportunity costs. Let us go back to our example in the introduction of this article. If you decide to buy a new piece of 3-D dental imaging equipment for your practice, and assuming that you have a fixed budget, you will have to reduce spending by the same amount in a different sector (for example, reducing staff). The benefits are foregone because the expenditure reduction associated with your decision is known as the opportunity cost. Therefore, clinicians always should think about what the opportunity cost of adopting a new treatment into practice would be and how they or society could have otherwise spent this money.

3c. Can I expect similar costs in my setting?
Assuming a similar patient population, similar interventions, and a similar expected effectiveness with the economic analysis under review, you need to carefully consider if you can expect similar costs in your practice. To reiterate, total costs in any economic analysis are calculated by multiplying the frequency of utilized cost components by their unit cost. Differences in health care resource utilization frequency between settings and countries can arise because of variable, nonstandardized
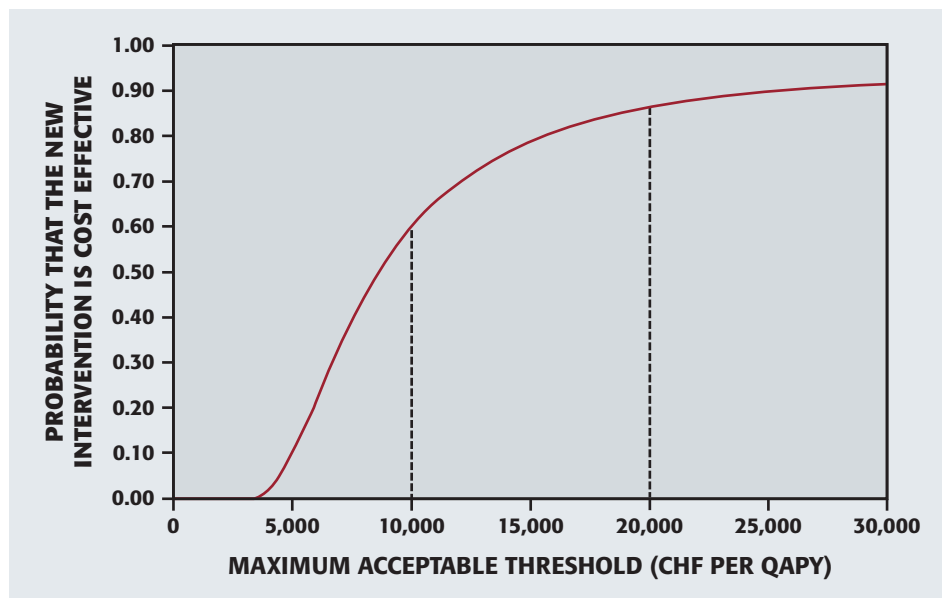
practice patterns, patient and clinician preferences, health systems' funding sources, and the availability of services.[24] If you expect similar health care resource use rates from your patients, then you should review whether the unit costs in your setting are similar to what were applied in the economic analysis. If the unit costs are different and the authors were transparent in terms of reporting, you can recalculate the total costs by applying the unit costs that are more typical for your setting.

BOX 5

Your assessment of the applicability of economic analysis you identified.

After assessing the applicability of the economic analysis,[18] you conclude that although retention appears to be dominant over surgical removal by being more effective and less costly, there are some limitations in the study that may reduce the level of direct applicability of the results to your patient setting (for example, a single health care payer perspective versus a fee-for-service perspective). The authors' viewpoint in the study was that of National Health Service hospitals rather than an individual patient perspective or a societal perspective.[18] This perspective does not match very well the perspective of your first-year college student.

CONCLUSION
As technologies continue to develop, the need for and the number of economic analyses will increase. Clinicians

need to be equipped with adequate knowledge to critically appraise these studies and make the best decisions that will benefit both patients and society in general. ∎

BOX 6

What you say to your patient.

You explain to your patient that in the absence of disease, retaining the impacted third molars versus removing them prophylactically are 2 strategies aiming at different outcomes, and hence, comparing these choices is a difficult task. You tell your patient that on the basis of your review of the literature, which focused on assessing an economic analysis conducted by authors in the United Kingdom whose study had methodological limitations,[18] third-molar retention may be more cost-effective than prophylactic removal. You recommend that the patient carefully consider his preferences before making a final decision.

SUPPLEMENTAL DATA

Supplemental data related to this article can be found at: http://dx.doi.org/10.1016/j.adaj.2015.06.021.

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eTABLE

Example of the critical appraisal of an economic analysis study.*

GUIDE	COMMENTS
1. How serious is the risk of bias?	
1a. Are results reported separately for relevant patient subgroups?	No subgroups were specified by the authors. They specified that evidence is scarce regarding the impact of age on surgical morbidity and cited an article that, in fact, reported that the incidence of surgical complications after removal of impacted mandibular third molars was significantly higher in those patients who were older than 24 years compared with patients younger than 24 years.
1b. Were consequences and costs measured accurately?	Unclear. To evaluate consequences, the authors constructed scenarios for each clinical pathway in the decision tree (22 in total). Then, they surveyed 100 consecutive patients from a single oral surgery clinic, asking them to rate each scenario on a 100-millimeter VAS,[†] in which 0 mm represented "Things could not be worse" and 100 mm represented "I would not be bothered at all." Mean effectiveness scores then were calculated for each scenario. A VAS is a unidimensional measure and is limited in estimating health preferences. For each possible clinical outcome after extraction, retention, or both, the authors estimated direct costs to NHS[‡] hospitals, including costs of diagnostic and surgical equipment, pharmaceutical and surgical supplies, staff costs, and overhead and other equivalent annual costs. Only aggregate costs were presented by cost category (for example, it was unclear what was considered "consumables" or "staff costs"). The sources of unit costs and the year of costs (1997) also were presented.
1c. Did investigators consider the timing of costs and consequences?	No. The costs of third-molar extraction mostly occur immediately and benefits occur later, whereas the opposite may be true for retention. This was not considered by the authors, and no discounting of costs or benefits was applied. Moreover, the model time horizon was not specified at all.
2. What are the results?	
2a. What were the incremental costs and effects of each strategy?	The incremental cost was £56, calculated by subtracting the cost of third-molar retention (£170) from the cost of third-molar extraction (£226). The effectiveness, which was measured by patients' ratings of clinical scenarios on a VAS from 0 to 100 mm, was equal to 63.3 in the removal alternative and 69.5 in the retention alternative. This resulted in an incremental effectiveness of −6.2. Because the third-molar extraction was less effective and more costly than the retention, it was the dominated alternative. Thus, the mandibular third-molar retention was more cost-effective than removal.
2b. Do incremental costs and effects differ between subgroups?	There were no defined subgroups or subgroup analysis.
2c. How much does allowance for uncertainty change the results?	The variability related to the estimates of costs, effectiveness, and ICER[§] were not presented, making it impossible to evaluate their precision. The authors specified that the probability of each outcome was calculated as the mean of all incidences from all relevant literature, without referencing literature and providing actual values. It was unclear which type of sensitivity analyses were conducted and using which values but the authors stated that the ICER was sensitive to specific probability values for pericoronitis, periodontal disease, and unrestorable caries in the second molar.
3. How can I apply the results to patient care?	
3a. Are the viewpoints and setting used in the study relevant to my context?	No. Although the authors aimed to establish the cost-effectiveness from "both the health care provider and patient perspective," they considered only the direct costs to NHS hospitals. Furthermore, the authors never specified the patient population to whom this economic analysis could apply, and they presented only aggregate costs (for example, total cost of consumables for pain management), which limited the transferability of costing to other settings.
3b. Are the treatment benefits worth the risks and costs?	This topic was not discussed because the removal of the third molar appeared to be less effective and more costly than its retention (**Authors' note:** Figure 2 shows that this is the dominated strategy in quadrant 4 on the cost-effectiveness plane). The authors did not discuss what would be an acceptable threshold for a unit of effectiveness if the extraction appeared to be more effective and more costly.
3c. Can I expect similar costs in my setting?	Unclear. The costs were estimated from the perspective of NHS hospitals. It is highly possible that the health care resource utilization and unit costs would be different in other countries in which prophylactic third-molar extraction is not covered by state insurance, and in which most of the extractions are conducted in community-based dental clinics that are run by individual dentists.

* Source: Edwards and colleagues.[18]
† VAS: Visual analog scale.
‡ NHS: National Health Service.
§ ICER: Incremental cost-effectiveness ratio.