Community Dent Oral Epidemiol 2008; 36: 392–400

Community Dentistry and Oral Epidemiology

The management of incipient or suspicious occlusal caries: a decision-tree analysis

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Balevi B. The management of incipient or suspicious occlusal caries: a decision-tree analysis. Community Dent Oral Epidemiol 2008; 36: 392–400. © 2007 The Author. Journal compilation © 2007 Blackwell Munksgaard

Abstract – *Objective:* To perform a comprehensive decision-tree analysis for the management of the suspicious/incipient occlusal lesion on a molar tooth. *Methods:* A quantitative decision tree was constructed to assess the expected utility value of three global strategies to dentally manage the incipient or suspicious occlusal carious lesion. *Result:* A preventive strategy offered an optimal expected utility value (0.98 utile) compared with the other two strategies of visual inspection (0.84 utile) or referring to one of four diagnostic tests (0.74–0.82 utile). *Conclusion:* Although the general conclusion of this analysis agrees with current recommendations, this analysis offers a more complete mathematical model that provides a unified value for each strategy (i.e. expected utility value) thus allowing for complex quantitative comparison between strategies. This paper provides a specific example of how decision-tree analysis can be a powerful tool in guiding dental practice.

Key words: bite-wings; caries; clinical decision making; decision tree analysis; diagnostic test; expected utility value; fluoride; sealant

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Submitted 1 March 2007;
accepted 13 July 2007

Caries is often a slow-grade disease process, allowing clinician to consider more conservative management approaches before resorting to conventional dental surgery. It continues, however, to be a perplexing clinical decision of when to, or when not to, aggressively treat incipient or suspicious carious lesion. As such, an emerging debate over the last decade has been to determine the most cost-effective and cost-utility strategies for managing the incipient/suspicious carious lesions (1).

Many authors have published their opinions or conclusions on how to manage such a clinical scenario. Anusavice and Hudson (2, 3) presented their opinions based on a nonsystematic review of the literature. Bader and Shugars (4) offered a clinical decision strategy based a systematic review of the current evidence to help guide clinician confronted with a suspicious occlusal lesion on a molar tooth. Although evidence-based, Bader and Shugars analysis falls short of being comprehensive because it did not consider the patient's preference, or utility, to the outcome of each management option.

Evidence-based dentistry aims to assist the clinician at making optimal decisions by considering the best available evidence, as well as, the clinical factors. Clinical factors to consider before readily applying research evidence are the generalizabiltity of the findings and the perceived value/benefit of the outcomes (i.e. health-state-utility) to the individual patient. In other words, the 'ideal treatment plan' is selected from a series of viable treatment options that are based on the best objective prognostic evidence available for any given treatment option against the backdrop of the patient's health-state utility of the outcome of each option.

Decision-tree analysis (DTA) combines these two factors; research evidence and patient preferences, with the objective of optimizing clinical decision making in a world of variability and uncertainty. The successful use of DTA in guiding medical practice suggests its application to dentistry could be beneficial (5–7).

The underlying premise of DTA is that the successes of a series of mutually exclusive outcomes are uncertain and that the decision maker

doi: 10.1111/j.1600-0528.2007.00419.x

has specific preferences for each individual outcome. This is based on the assumption that both the probability of each outcomes and its perceived benefit (i.e. utility) to the decision maker are quantitatively measurable (8–10).

Health-state utility are often measure in utile's. It is a value between a perfect health state of one [1] utile and the worst health state of zero [0] utile. One can think of the utile as the proportional value judgment a patient places on a nonideal health state relative to the ideal health state [having a value of one (1) utile] and the worst possible health state [having a value of zero (0) utile]. For example, a utility of 75 utile implies health state perceived to be about 75% of ideal health. Methods used to measure health-state utilities are describe elsewhere (8, 9, 11, 12).

The quantitative interpretation of a decision tree is determined by the expected yield of each decision. This is calculated by what is often referred to as 'folding back the tree' (8, 9, 13). This simply means that the final expected utility value (EUV) of each decision is the calculated weighted average of all probabilities and utilities associated with each branch at the decision node. Simply stated, the EUV means that if the decision maker were to carry out many similar decisions with the same probability of success and failure, and utilities, then the average utility to the decision maker would be given by the EUV. DTA is based on the grounds that the 'reasonable' decision maker, accepting that they live in a world of uncertainty, seeks to make an *a priori* choice that will maximize their EUV (14).

The objective of this paper is to perform a comprehensive DTA for the management of the suspicious/incipient occlusal lesion on a molar tooth.

Methods and methodology

Decision tree – construction

A decision-tree model was constructed to describe the possible strategies for the management of an incipient or suspicious occlusal carious lesion on a molar (Fig. 1). This decision model assumes that the patient will be follow-up by a dentist in a year.

When a dentist is suspicious of the carious nature on the occlusal pit or fissure of a permanent molar, they must choose between three global strategies:

A. *Visual diagnosis* – This options involves the dentist rely only on their visual diagnosis to treat or not treat the suspicious/incipient occlusal caries.
B. *Diagnostic test* – In this case, the dentists would elect to gather more information through one of four available diagnostic test currently available for clinical practice, before deciding to excavate caries or not.
C. *Preventive therapy* – In this strategy, the dentist, knowing it is a suspicious lesion, decides to treat with either a preventive resin sealant or fluoride varnish.

In clinical practice, a dentist is never absolutely certain of a patient's true condition. They must make 'a calculated guess' on the patient's condition along a grid of complete uncertainty (50% chance of being correct) at one end, and, almost absolute certainty (99.99% chance of being correct) at the other. Where the clinician is along this grid will depend on the accuracy and confidence they have in the information available to them at the time they make a diagnosis.

As the dentist is not absolutely sure if the lesion is active decay, they runs the hazard of incorrectly restoring a perfectly health tooth (IRT) if they visually misdiagnose the suspicious carious lesion as being active. Conversely, visually misdiagnosing a suspicious lesion as not being active when it actually is runs the risk of allowing the further spread of the infection into a symptomatic carious tooth (SCT) as in strategy A.

The negative consequences of Strategy A will depend on the risk that the lesion progresses to a symptomatic state. Similarly, the risk of Strategy C failing depends on the preventive ability of the sealant or the fluoride varnish to maintain a virgin tooth (VT).

In order for a clinician to improve their prognostic accuracy, the dentist may elect to seek more information through a diagnostic test (Strategy B). This brings the dentist to the next decision of choosing which test. Currently, four clinical test are available; (i) fiber-optic transilluminaiton (FOTI); (ii) bite-wing radiograph (BW's); (iii) laser florescence (DIAGNOdent); and (iv) electrical conductance (E-Con).

It is understood that no diagnostic test – with the exception of the gold-standard test, such as the histologic evaluation of the tooth – is perfect. They all have some margin of error associated with their ability to make a correct diagnosis. These uncertainties are reflected in the test's properties of

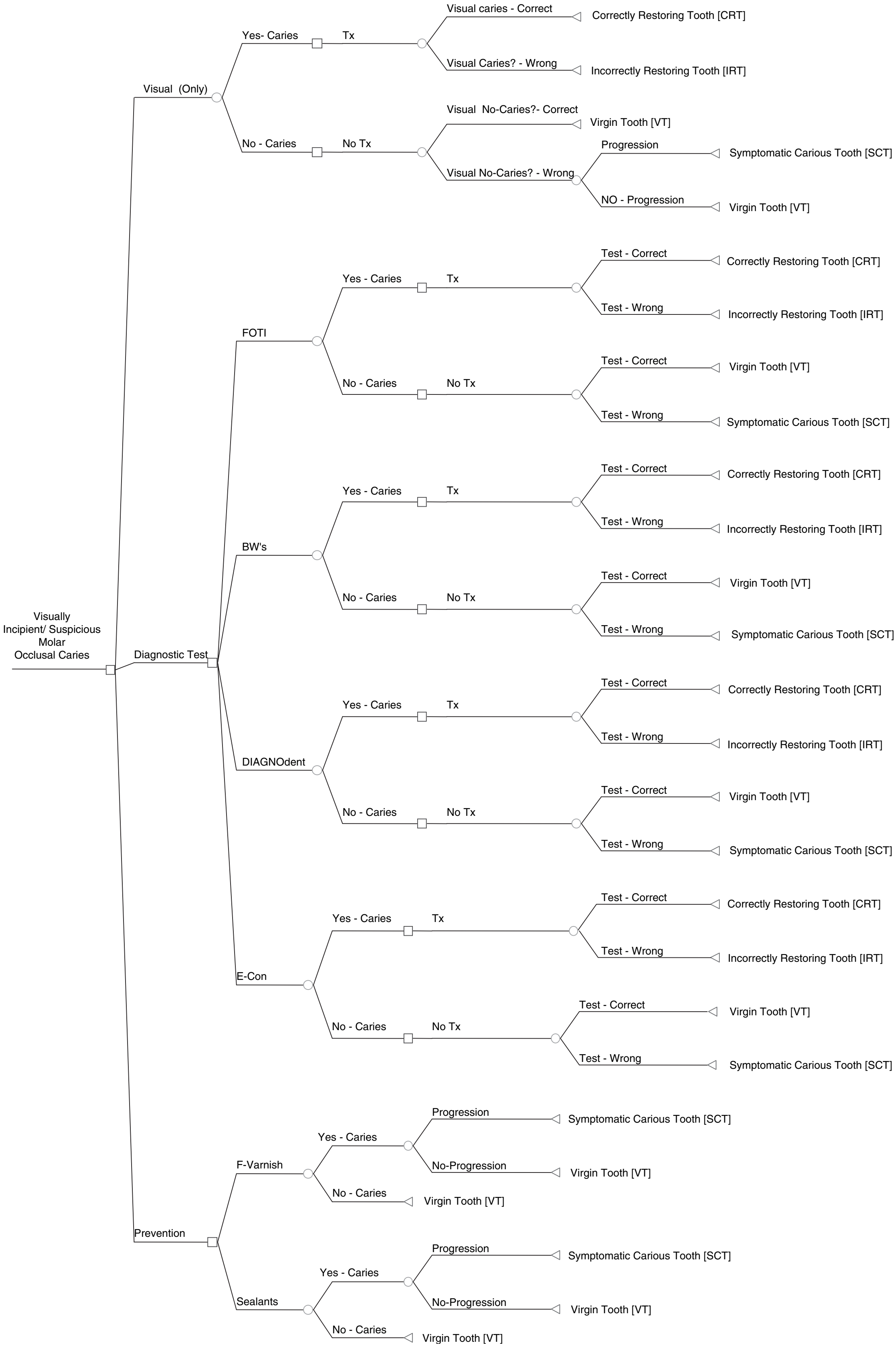

Fig. 1. Decision tree for the management of an incipient/suspicious occlusal caries. The square boxes indicate decision nodes, chance nodes are depicted by circles and the final outcome nodes are shown as triangles. (Tx, treatment; FOTI, fiber-optic transilluminaiton; BW's, bite-wing radiograph; DIAGNOdent, laser florescence; E-Con, electrical conductance; F-varnish, fluoride varinish).

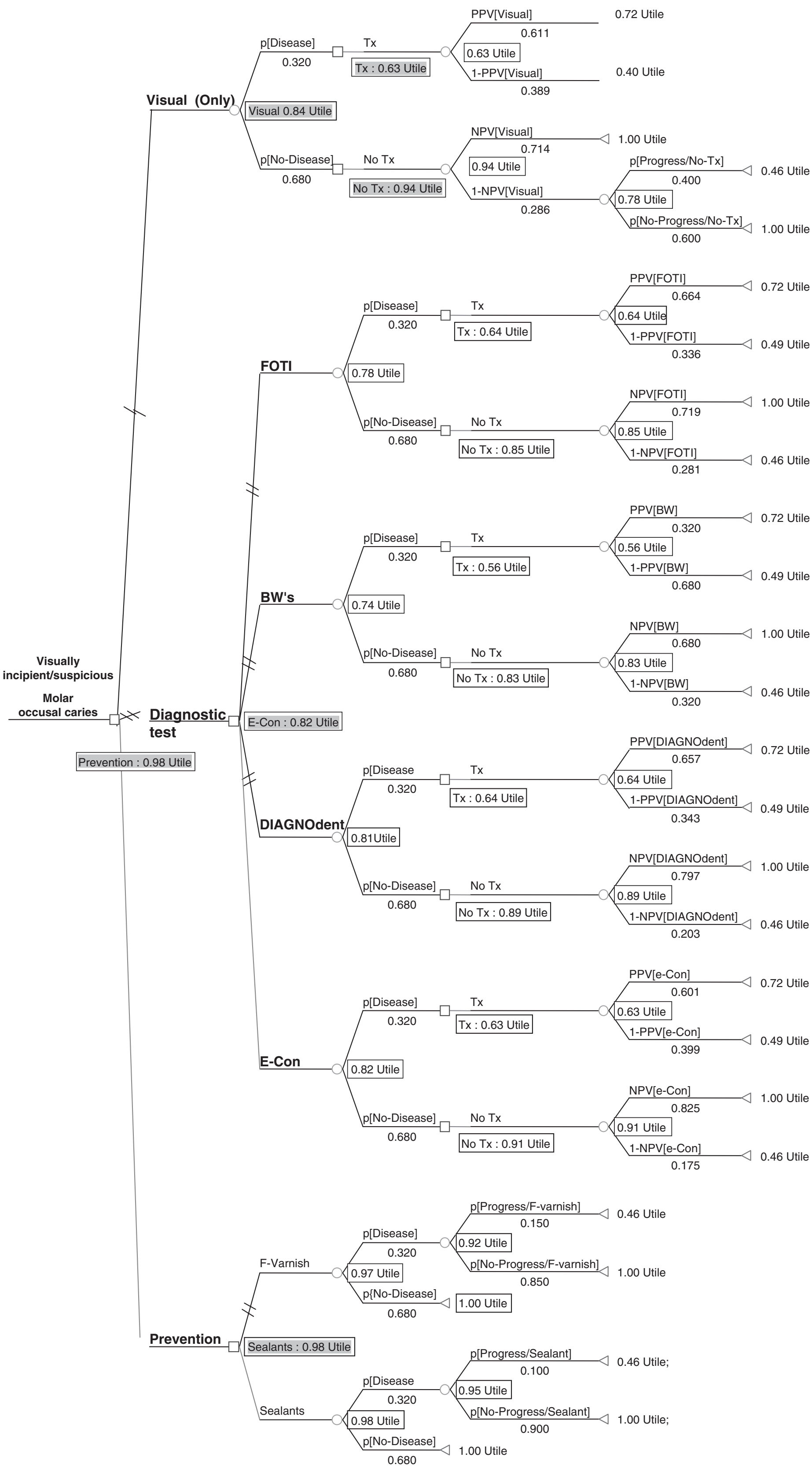

Fig. 2. Decision-tree analysis for the management of an incipient/suspicious occlusal caries on a molar tooth with a disease prevalence rate of 32%. (Shaded boxes are the EUV of that specific decision node).

Strategy	EUV (utile) calculation
Visual diagnosis	0.32 x [(0.611 x 0.72) +(0.389 × 0.49)] + 0.68 x [(0.714 x 1) + 0.286 x [(0.4 x ×0.46) + (0.6 x 1)] = **0.84**
❖ Tx	(0.611 x 0.72) +(0.389 × 0.49) = **0.63**
❖ No-Tx	(0.714 x 1) + 0.286 x [(0.4 x 0.46) + (0.6 x 1)] = **0.94**
Diagnostic testing	
❖ FOTI	0.32 x [(0.664 x 0.72) + (0.336 x 0.49)] + {0.68 x [(0.719 x 1) + (0.336 x 0.46)] = **0.78**
❖ BW	0.32 x [(0.32 x .72) + (0.68 x .49)] + 0.68 x [(0.68 x 1) + (0.32 x .46)] = **0.74**
❖ DIAGNOdent	0.32 x [(0.657 x .72) + (0.343 x .49)] + 0.68 x [(0.797 x 1) + (0.203 x .46)] = **0.81**
❖ E-Con	0.32 x [(0.601 x .72) + (0.399 x .49)] + 0.68 x [(0.825 x 1) + (0.175 x .46)] = **0.82**
Prevention	
❖ F- varnish	0.32 x [(0.15 x 0.46) + (0.85 1)] + (0.68 x 1) = **0.97**
❖ Sealant	0.32 x [(0.1 x 0.46) + (0.9 x 1)] + (0.68 x 1) = **0.98**

Fig. 2. Continued

sensitivity (Sn), specificity (Sp), positive predictive value (PPV), and negative predictive value (NPV) (8, 9).

It is assumed that the dentist will act according to the results of the diagnostic tests. If the test reads positive then the dentist will treat the tooth by excavating the caries and preparing the site for a conventional filling material, otherwise no treatment will be rendered. But the correctness of these actions will depend on the test's ability to identify disease given a positive test reading or the test's ability to identify a healthy site given a negative test result. These probabilities' are respectively referred to as the PPV and NPV. It is these values that are used in the DTA. A test's PPV and NPV are a function of the test's Sn and Sp, and the risk of the disease (i.e. prevalence) in the population.

Probability and utility estimates

Table 1 presents a summary of the data used to analyze the decision tree. Prevalence of occlusal caries and the Sn and Sp of each diagnostic test, as well as, the probability of the progression of an occlusal lesion involved in this decision tree were taken from Bader and Shugars' (4) review. The PPV's and NPV's were calculated from this data. Fyffe and Kay (12) assessed the health-state utility of 'four different tooth states', using the conditions of a perfectly healthy tooth and immediate dental extraction as the two health-state extremes.

Sensitivity analysis

A sensitivity analysis is necessary to see how robust the tree's conclusions are under different levels of uncertainty. A one-way sensitivity analysis was conducted by varying the prevalence, and thus the population risk, of an occlusal caries on a permanent molar.

Decision-tree analysis software

This decision model was analyzed with the use of TreeAge Pro 2006® (TreeAge Software Inc., Williamstown, MA, USA).

Results

Figure 2 presents the detailed DTA with each strategy's optimal EUV.

Folding-back the tree favors the preventive strategy of applying a sealant on suspicious occlusal caries, generating an optimal EUV of 98 utile. This is only slightly higher than the alternative preventive strategy of applying fluoride varnish, but 14–16 utile's more beneficial than just relying on a dentist's visual interpretation of the lesion or performing one of the four diagnostic test considered.

The EUV of each diagnostic test strategy vary, with BW having the lowest (i.e. 74 utile) and DIANGNOdent and E-Con have similar higher values of 81 utile and 82 utile respectively.

A sensitivity analysis demonstrates that the prevention strategy still hold up as the optimal decision even to significant changes in the prevalence of the disease (Fig. 3). The sensitivity curve's for the diagnostic test and visual diagnosis strategies never intersects with the preventive strategy's sensitivity curve, except when the disease prevalence in zero (i.e. p[D] = 0). This indicates that the optimal decision of executing the preventive strategy never changes along the range of the analysis.

Table 1. Model estimates of probabilities and utilities

Diagnostic test	Sn (mean)[a]	±95% CI[a]	Sp (mean)[a]	95% CI[a]	References	PPV calculated	NPV calculated
Visual	0.20	0.016	0.94	0.008	Ashley et al. (15) Fyffe et al. (16) Costa et al. (17)	0.611	0.714
BW	0.22	0.012	0.78	0.010	Wenzel et al. (18) Ashley et al. (15) Costa et al. (17)	0.320	0.680
DIANGNOdent	0.53	0.015	0.87	0.005	Lussi et al. (19) Shi et al. (20) Toniol et al. (21) Costa et al. (17) Baseren and Gokalp (22)	0.320	0.797
E-Con	0.64	0.001	0.80	0.010	Ashley et al. (15) Lussi et al. (19)	0.657	0.825
FOTI	0.21		0.95		Ashley et al. (15)	0.601	0.719
	Mean[a]	*±95% CI*[a]			*References*		
Prevalence	0.32	0.003			Ashley et al. (15) Fyffe et al. (16) Wenzel et al. (18) Lussi et al. (19) Shi et al. (20) Tonioli et al. (21) Costa et al. (17) Baseren and Gokalp (22)		
Prevention	*Progression of occlusal caries (mean)*[a]	*±95% CI*[a]			*References*		
Untreated incipient occlusal caries	0.40	0.029			(Included papers that used fluoride varnish with a follow-up of at least 12 months) Heller et al. (23) Grindefjord et al. (24) Florio et al. (25) Maltz et al. (26)		
Fluoride varnish	0.15	0.006			(Included papers that used fluoride varnish with a follow-up of at least 12 months) de Liefde (27) Florio et al. (25)		
Sealant	0.10	0.009			Handelman et al. (28) Harris et al. (29) Gibson and Richardson (30) Handelman et al. (31)		
Outcome	*Utility (utile)*				*References*		
Virgin tooth	1				Fyffe and Kay (12)]		
Correctly restored tooth	0.72						
Symptomatic carious tooth	0.46						
Incorrectly restored tooth	0.49				This value is derived by assuming the utility of putting the patient through unnecessary restorative treatment was about half way between the Fyffe and Kay's (12) measured utility of a symptomatic carious molar (SCT = 0.46) and the utility of an asymptomatic carious molar (=0.51)		

[a]Mean values and 95% CI calculations were weighted according to the size of the studies cited.
The weighted mean values of the diagnostic test's sensitivity (Sn) was calculated according to the following formula: $Sn(mean) = (Sn_{study-1} \times N_{study-1}) + (Sn_{study-2} \times N_{study-2}) + \ldots + (Sn_{study-n} \times N_{study-n}) = Sn(mean)$; where $Sp_{study-n}$ is the reported specificity in the specified included study-*n*, $N_{study-n}$ is the sample size of the included specified study-*n* and Sp(mean) is the weighted average of the specificity of all included studies. Also, the weighted mean values of the diagnostic test's specificity (Sp) was calculated according to the following formula: $Sp(mean) = (Sp_{study-1} \times N_{study-1}) + (Sp_{study-2} \times N_{study-2}) + \ldots + (Sp_{study-n} \times N_{study-n})$; where $Sp_{study-n}$ is the reported specificity in the specified included study-*n*, $N_{study-n}$ is the sample size of the specified included study-*n* and Sp(mean) is the weighted average of the specificity of all included studies.

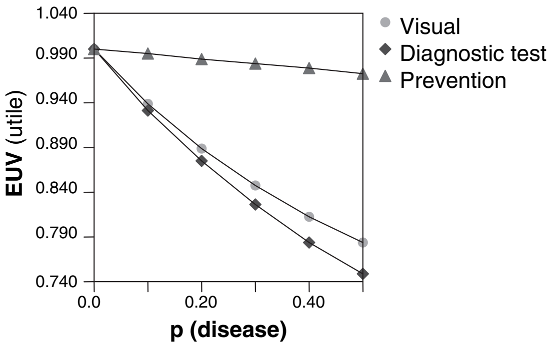

Fig. 3. One-way sensitivity analysis on effect of each strategy's expected utility value on varying the molar occlusal caries prevalence or risk of getting molar occlusal caries.

Discussion

All clinical decisions are made in a world of uncertainty. The rational decision maker will choose the course of action that maximizes their net desired expectation (i.e. EUV). This expectation is a balance between the chances of success of each strategy, and the patient's perceived value judgment (i.e. utility) of its outcome.

The analysis carried here found that in a world of uncertainty, a patient presenting with an incipient or suspicious caries on the occlusal surface of a molar would be better served with a sealant than no treatment, aggressive treatment or undergoing any further diagnostic testing. Although the conclusion is in agreement with Bader and Shrugar (4), this analysis offers a more complete mathematical model with a unified value (i.e. EUV), for each strategy. For instance, based only on EUV, the preventive strategy of applying a sealant is about 16% more favorable than the 'diagnostic test' or 'visual diagnoses' options.

If the costs of each outcome are known then EUV can be assessed in terms of cost-utility or cost-effectiveness. For example, if sealing the occlusal pit-and-fissure of a molar costs $10 and the cost of conventionally restoring is $100, then the cost per EUV is $10.52/utile [=$10.00/EUV (sealant) = $10.00/0.98] and $158.73/utile [=$100.00/EUV (Tx) = $100.00/0.630] preventive sealant and conventional filling options respectively. Therefore, the difference between these two strategies is significantly different (i.e. 15-fold) when they are assessed based on cost and patient preference than if they were compared on cost alone or patient's preference alone.

The problem with any analysis that calculates estimates from probabilities is subjected to the caveat of cumulative errors. A sensitivity analysis compensates this weakness by allowing the decision maker to observe the effect of the tree's decision by varying the value of any desired variable. DTA's capability of quantitatively testing the mathematical model to variation on specific significant variable is what makes it so useful in healthcare policy as well as clinical practice.

Nevertheless, this analysis depends on the quality of the data plugged into the model. I used a weighted average approach to generate a summary estimate for the prevalence, Sn and Sp's. Ideally a comprehensive meta-analysis of the literature would have been preferred. Such an analysis assess for heterogeneity between included studies and gives greater weight to those studies considered of higher quality. Weighted average approach assumed no random error of measurement in each study and simply weighted them in terms of the studies' sample size. Although limited, it offers a relative good estimate as indicated by the small confidence intervals, thus suggesting possible precision in the estimates.

However, caution should be taken when interpreting this decision model for prevalance rates above 40%. This is because the probabilities of progression of the occlusal caries rates for untreated incipient caries, pit-and-fissure sealants and fluoride varnish were estimated from empirical data in sample where the prevalence of molar occlusal caries was between 20–40%. These probabilities likely have a positive function to the prevalence of molar caries in the population. This would mean that the risk of the progression of incipient occlusal molar caries would be higher at higher prevalence rates than the empical estimates used in this analysis. This would reflect in a lower calculated EUV for the preventive strategies and a higher EUV for restorative treatment.

Nevertheless, in a population or individual where the risk of molar caries is about or <40%, this analysis appears to strongly favors a preventive strategy, particularly, the application of a pit-and-fissure sealant on a suspicious occlusal caries on a molar tooth.

Another weakness to this analysis is that the utility data from an only a single study was used. Although Fyffe and Kay's (12) study was based on 110 individuals randomly selected at a shopping mall in Scotland, they used the most reliable method to determine utility.

Also, it may be argued that their sample mix may not be generalizable to an individual clinician's patient profile. In such cases, the patient's specific utility can be easily quantified by the dentist using any one of a number of technique currently describe in the literature (8, 9, 11). This patient specific utility can then be inserted into this decision-tree model to determine their patient's specific EUV for each strategy. This allows the clinician to assist patients to optimize their selection between alternative treatment options by considering the objective research findings (i.e. prevalence, Sn and Sp, probability of treatment success in this decision model), and their specific health-state utility.

All the same, DTA like this one may help guide healthcare policy makers, as well as, third-party payer reimbursement schedules. For example, some private insurance companies and government social programs may limit their policy holder's eligibility of pit-and-fissure sealants to only a couple of years after the eruption of the first and second molars. This policy may deny reimbursement of a potentially cost-effective conservative management of incipient occlusal caries to adolescence and adults.

Although, the DTA may be popular in medical practice, its application to dental practice has not been. Yet, the benefit of DTA is that is combines the two factors considered the cornerstone of evidence-based dental practice; scientific evidence and patient preference.

In the 1997 a symposium on caries research recommended; 'Main research priorities for the coming 10 years are to conduct cost-effectiveness and cost utility studies of caries diagnostic tools, to continue to review the performances of diagnostic test, to transfer diagnostic knowledge and experience to the general practitioners particularly by constructing evidence-based guide-lines' (1). The decision-tree analysis presented here is a forward step in the direction of realizing this goal.

Acknowledgments

I wish to thank Dr Donald Brunette (University of British Columbia) for his editorial assistance.

Conflict or financial interest

None.

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