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A preliminary study applying decision analysis to the treatment of caries in primary teeth

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SUMMARY

Objective. To determine an optimal treatment strategy for carious deciduous teeth.

*Setting***.** Manchester Dental Hospital.

Design. Decision analysis

Method. The likelihoods of each of the sequelae of caries in deciduous teeth were determined from the literature. The utility of the outcomes from non-treatment and treatment was then measured in 100 parents of children with caries, using a visual analogue scale. Decision analysis was performed which weighted the value of each potential outcome by the probability of its occurrence. A decision tree "fold-back" and sensitivity analysis then determined which treatment strategies, under which circumstances, offered the maximum expected utilities.

Results. The decision to leave a carious deciduous tooth unrestored attracted a maximum utility of 76.65 and the overall expected utility for the decision "restore" was 73.27 The decision to restore or not restore carious deciduous teeth are therefore of almost equal value. The decision is however highly sensitive to the utility value assigned to the advent of pain by the patient.

Conclusions. There is no clear advantage to be gained by restoring deciduous teeth if patients' evaluations of outcomes are taken into account. Avoidance of pain and avoidance of procedures which are viewed as unpleasant by parents should be key determinants of clinical decision making about carious deciduous teeth.

Key words: decision analysis, primary teeth, caries, treatment.

INTRODUCTION

The recommendations for treatment and restoration of carious deciduous teeth have been the subject of a great debate and are largely based on empiricism rather than evidence. In Great Britain 39% of 5-year-old children have evidence of caries in dentine. The mean number of decayed teeth in those who have dentinal decay is 3.99 although the overall mean when caries free children are included is 1.57. Although there has been little change in caries experience over the last decade, fewer teeth have been restored and the Care Index has fallen (14.3 % in 1999/2000, compare to 11% in 2005/2006) (1-3). The evidence therefore suggests that the recommendation issued by British Society of Paediatric Dentistry, which states that "children with active caries in deciduous teeth requires a combination of prevention, restoration and sometimes extraction. Stainless steel crowns and appropriate pulp management are to be encouraged" (4) are not being followed, at least at this stage of childhood. It seems instead that rather than following a fixed guideline, dentists make their own subjective decisions when faced with restoring dental caries in their child patients. Presumably these decisions are based on whether they believe that the risks and costs (to the patient) outweigh the benefits or vice versa. No one has yet attempted to evaluate patient preferences in these circumstances and as health care evolves towards being more patient centered, it is increasingly important to consider and document the patient's perspective in health care decisions (5).

One method of quantifying patient preferences for particular treatment options is utility measurement. By using decision analysis in conjunction with utility measurement the maximally beneficial

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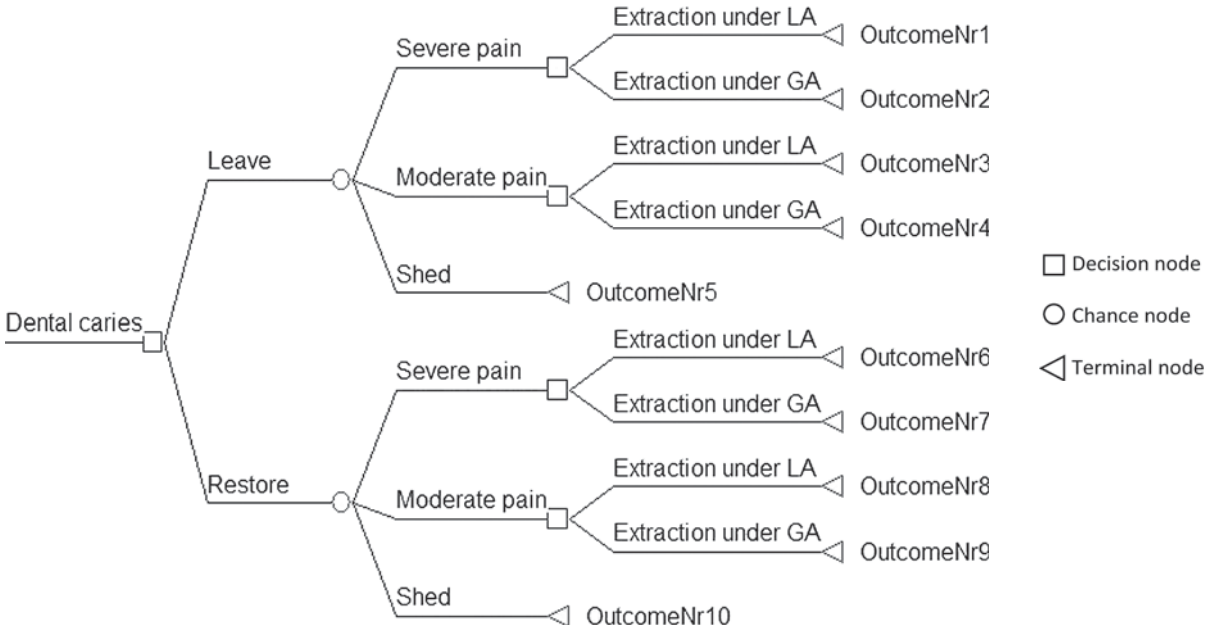

Fig. 1. Decision tree for the decision to restore a carious deciduous tooth.

decision can be determined. Such a methodology takes account of the fact that, when making decisions about carious deciduous teeth, uncertainty cannot be eliminated. Recognizing that it exists and developing strategies to manage and minimize its negative effects is the key to good treatment decision making. However, good decisions can only be made if there is enough information available to the clinician about the probability of outcomes. Equality, the value attached to different outcomes by patients must be understood in order to optimize clinical decision making. The probability of an outcome occurring should be weighted by its value to the patient, in order that health care decisions offer patient-perceived improvement in quality of life.

The analysis presented does not cover every available treatment but instead explores the sequelae of the most commonly used treatment modalities. The most common treatments of decay in deciduous teeth are to restore with plastic restorations with or without pulp treatment or to leave unrestored (6). Therefore these options are the ones explored in the study.

This paper examines the outcomes of treatment of deciduous teeth, and the value of those outcomes to the parents of child patients. By utilizing a decision analytic approach an optimal strategy for dentist and patient when planning treatment for deciduous carious teeth is calculated.

METHOD

Decision Analysis

In order to examine the best strategy when faced with a carious deciduous tooth, a decision tree was constructed. The decisions to be made, and all possible consequences of those decisions were represented in a diagrammatic manner (Figure 1). Decision nodes (square boxes) indicate points at which the decision maker has a choice. In contrast, chance nodes (circles), indicate points at which several events may occur, but these are not under the control of the decision maker.

The final events, or outcomes of the decision, are depicted by triangles in Fig. 1 and rectangles in Fig. 2. These are all the outcomes which can potentially occur as a result of the decision. The decision tree is analysed by multiplying the probability of an outcome occurring, by the value of that outcome to the patient. The results of these multiplications are then added together for each alternative arm from the decision node. This gives the overall utility value which can be expected from each alternative choice.

The maximum expected utility is the highest utility score a node attracts. This indicates the decision which will give the best ratio of benefit to risk. It therefore demonstrates which choice has the maximum probability of improving quality of life in the sample population.

Sensitivity analysis then allows the robustness of the maximum expected utility to be checked. Thus, a sensitivity analysis confirms or denies whether the optimal decision stays the same when circumstances change i.e. if probabilities at chance nodes, or the utility at outcome nodes, change. In this case, for example, the probability of pain after restoration can be decreased or increased (a probability which is likely to be dependant on the depth of the lesion).

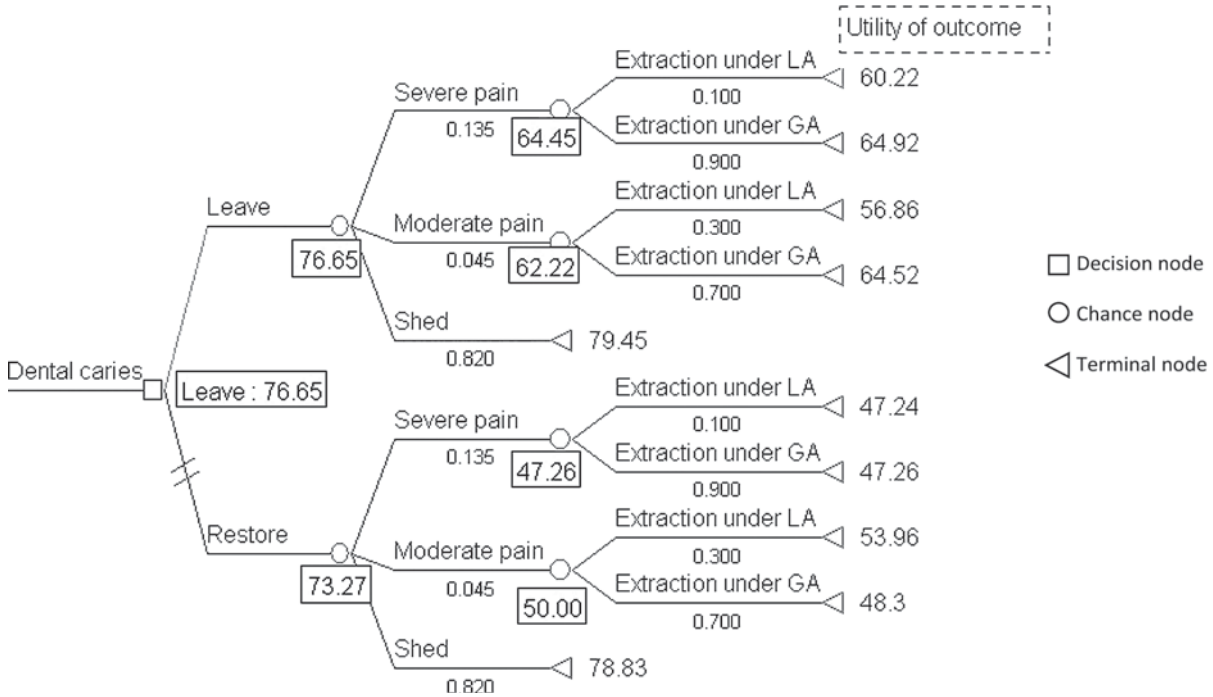

Fig. 2. Decision tree for the decision to restore a carious deciduous tooth with results

Determination of utility values

Data from 100 parents of 5-8 year old children attending Manchester Dental School participated in the utility measurement study. Each participant was given a short introduction about the nature of the study and the questionnaire. Participants answered the questionnaire whilst waiting for their child's dental appointment. The utilities of possible outcomes were measured using a standard visual-analogue scale (VAS). Parents were asked to assign a value to each of the 10 potential outcomes. These are shown in Table 1. In addition five questions were asked to determine the child's previous dental treatment and any experience of pain. This was done so that the effect of previous dental history on the evaluation of outcomes could be examined in further analyses. The response rate to the questionnaire was 98%. Two participants were unable to complete the questionnaire due to lack of time. The study and the questionnaire had been approved by the North Manchester Research Ethics Committee (Approval No 06/Q1406/27).

Calculation of probabilities

A search of the available data in the published literature was used to determine the probability of each potential outcome arising from caries in a deciduous tooth. The PubMed database was used, using search terms: "caries, deciduous, child, primary, progression" in different combinations. A final search of references from retrieved articles was undertaken. The literature revealed that there are many data and much evidence about the consequences and sequelae of restoring teeth, but very little data have ever been published regarding the natural history of teeth which are carious and left unrestored. In fact only two authors (7, 8) have published data about the consequences of not restoring carious deciduous teeth (Tables 2 and 3). Tickle's study (8) shows no difference in the probability of pain regardless of whether the tooth was filled or not. Levine et al. (7) make an evaluation of "pain risk" based on the child's age at the time at which the carious deciduous tooth was diagnosed. Severity of pain was estimated using evidence from Shepherd (9) who showed that pain resulted in children not playing in 26.7%, not eating in 73.3%, not sleeping in 31.1% and missing school in 11.1% of children. The sample, on whom this pain measurement was carried out, was a group of children who had experienced pain in the previous month. Eating or sleeping disturbance was classed as a consequence of severe pain.

RESULTS

The sample consisted of 100 parents. Of these 27% were parents of 5-year-olds, 19% were parents of 6-year-olds, 22% of 7-year-olds and 32% had 8-year-old children. At the time of completing the questionnaire 53% of these children had had experience of restorative treatment, 47% had no experience of restorative treatment.

Table 1 shows the descriptions of the potential outcomes used in the decision analysis and gives the

mean value assigned to them by the parents plus the range and standard deviation.

Of the 100 parents involved in the study 49% reported that their child had not previously experienced pain. One-way-ANOVA analysis showed that the difference in utility values between age groups and between those with different pain histories were not statistically significant ($p>0.05$).

After the probabilities derived from the literature review had been used to weight each outcome utility in the decision tree, and the tree had been analysed (folded back), the decision to leave a decayed deciduous tooth restored attracted the maximum expected utility. The MEU for the decision "leave" was 76.65, and for the "restore" was 73.27 (Figure 2).

Table 1. Descriptions of potential outcomes mean utility values assigned by parent + standard devices

Outcome	Description	Mean Utility Value	S. D.
Outcome 1	Your child had a decayed baby tooth. The tooth has been severely painful. Your child was anxious, complaining of pain, cried occasionally. She or he ate only soft food for one day. She or he didn't sleep at all through the night. The next day you went to your dentist. The dentist injected a local anaesthetic and removed the painful tooth.	60.2	31.2
Outcome 2	Your child had a decayed baby tooth. The tooth has been severely painful. Your child was anxious, complaining of pain, cried occasionally. S/he ate only soft food for one day. S/he didn't sleep at all through the night. The next day you went to your dentist. The dentist said it needed to be removed and sent you to a specialist. You went to the dental hospital. Your child was "put to sleep" and the painful tooth was removed.	64.9	34.0
Outcome 3	Your child had a decayed baby tooth. The tooth has been painful, but your child was coping with the pain although complaining of it. You went to your dentist. The dentist injected a local anaesthetic and removed the painful tooth. Your child was worried by the experience but not particularly distressed.	56.9	29.4
Outcome 4	Your child had a decayed baby tooth. The tooth has been painful, but your child was coping with the pain although complaining of it. You went to your dentist. The dentist said it needed to be removed and sent you to a specialist. You went to the dental hospital. Your child was "put to sleep" and the painful tooth was removed.	64.5	34.5
Outcome 5	Your child had a decayed baby tooth. You noticed that he tooth was decayed but it never caused any pain or problems and the tooth eventually fell out without any problems.	79.5	25.3
Outcome 6	Your child had a decayed baby tooth. You went to your dentist. The dentist gave your child an injection and the decayed tooth was cleaned and filled. The treated tooth then became severely painful. Your child was anxious, complaining of pain and cried occasionally. He ate only soft food for one day. He didn't sleep for a night. The next day you went to your dentist. The dentist gave your child an injection and removed the painful tooth.	47.2	32.1
Outcome 7	Your child had a decayed baby tooth. You went to your dentist. The dentist gave your child an injection and the decayed tooth was cleaned and filled. The treated tooth then became severely painful. Your child was anxious, complaining of pain, cried occasionally. He ate only soft food for one day. He didn't sleep for a night. The next day you went to your dentist. The dentist said it needed to be removed and sent you to a specialist. You went to the dental hospital. Your child was "put to sleep" and the painful tooth was removed.	47.3	34.6
Outcome 8	Your child had a decayed baby tooth. You went to your dentist. The dentist gave your child an injection and the decayed tooth was cleaned and filled. The treated tooth then became painful, but your child was coping with the pain although complaining of it. You went to your dentist. The dentist injected a local anaesthetic and removed the painful tooth.	54.0	29.7
Outcome 9	Your child had a decayed baby tooth. You went to your dentist. The dentist gave your child an injection and the decayed tooth was cleaned and filled.. The treated tooth then became painful, but your child was coping with the pain although complaining of it. The next day you went to your dentist. The dentist said it needed to be removed and sent you to a specialist. You went to the dental hospital. Your child was "put to sleep" and the painful tooth was removed.	48.3	34.5
Outcome 10	Your child had a decayed baby tooth. You went to your dentist. The dentist gave your child an injection and the decayed tooth was cleaned and filled. The tooth was fine afterwards and eventually fell out like baby teeth do.	78.8	27.3

Table 2 shows the literature from which the probabilities were derived for the various outcomes following non-restorative treatment and Table 3 for the restorative outcomes. The tables indicate the minimum probability cited in the literature, for the occurrence of each of the outcomes. It can be seen that in Table 2 the minimum estimate of the probability of severe pain occurring was zero. That is, in at least one of the papers, moderate and severe pain never occurred when teeth were left unrestored. Table 2 also shows that a minimum of a third of unrestored deciduous teeth exfoliate without ever having caused pain and the figure has been reported as reaching 100%. In contrast the literature showed that in other studies, up to 50% of teeth left unrestored resulted in severe pain, and up to 17% ended moderate pain.

The table indicates the mean of the values cited for each outcome in the literature.

Similarly Table 3 indicates that the estimates from the literature for the lowest number of teeth causing severe or moderate pain after restoration was zero but that up to 88% of restored teeth exfoliate naturally without causing any pain.

Figure 2 illustrates the decision tree when it is populated by the probabilities derived from the literature and the utility values derived from the study of parents. It shows the value of leaving and restoring deciduous teeth to be almost equal (76.65 and 73.27 respectively)

Figure 3 illustrates the results of one of the sensitivity analyses run on the tree. This diagram is an illustration of the effect of systematically altering the probability of painless exfoliation of an unrestored tooth. This diagram indicates that leaving a tooth unrestored is the "best" decision (attracts the highest utility value) if the probability of teeth exfoliating painlessly without treatment is greater than 60%. If the likelihood of a decayed tooth exfoliating painlessly is less than this value then the decision attracting the maximum expected utility is restoration of the tooth.

Figure 4 shows a similar sensitivity analysis, but in this case it is the effect of the probability of a tooth exfoliating painlessly after being restored which is being examined. The diagram shows that restoring a tooth is always the better option if there is greater than 93% chance that, after restoration, the tooth will be pain free and exfoliate naturally. If this probability falls below the 93% value, the maximum expected utility, using the values assigned by the patients in this study, is achieved by leaving the tooth unrestored, if all other factors remain constant.

Table 4 indicates all of the variables to which the decision was sensitive. This table therefore lists all the variables for which a sensitivity analysis (as in Fig 3 & 4) could have been plotted, and the table indicates the probability or utility value at which the optimum decision changes from "not restore" to "restore". The table also shows the probability

Table 2. Probabilities of outcomes following Non-restorative Treatment of a Carious Deciduous Tooth

Outcome	Probability			Reference
	Minimum	Maximum	Values used in decision tree	
Unrestored with severe pain	0	0.5	0.135	Levine et al., 2003 (10); Levine et al., 2002 (7); Tickle et al., 2002 (6); Shepherd et al., 1999 (8)
Unrestored with moderate pain	0	0.17	0.045	Levine et al., 2003 (10); Levine et al., 2002 (7); Tickle et al., 2002 (6); Shepherd et al., 1999 (8)
Unrestored then exfoliation without pain	0.33	1	0.82	Levine et al., 2003 (10); Levine et al., 2002 (7); Tickle et al., 2002 (6)

Table 3. Probabilities of Outcome following Restorative Treatment of a Carious Deciduous Tooth

Outcome	Probability			Reference
	Minimum	Maximum	Values used in decision tree	
Restored with severe pain	0	0.135	0.135	Tickle et al., 2002 (6); Shepherd et al., 1999 (8)
Restored with moderate pain	0	0.045	0.045	Tickle et al., 2002 (6); Shepherd et al., 1999 (8)
Restored tooth exfoliating without pain	0.88	1	0.82	See in references 11-23

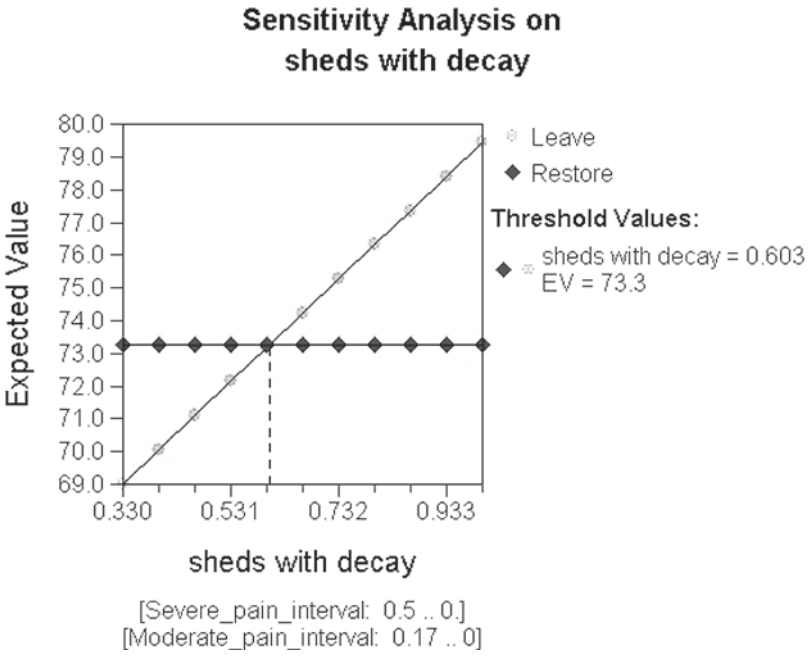

Fig. 3. Decision tree for the decision to restore a carious deciduous tooth

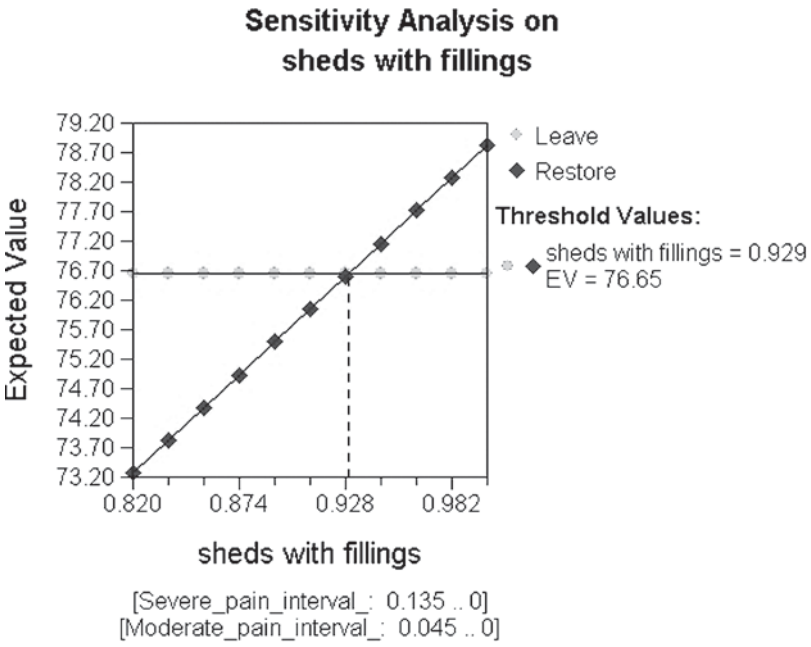

Fig. 4. Sensitivity Analysis on probability that a restored deciduous tooth will be shed without pain

values from the literature for each of the listed outcomes and the mean utility value for each of the listed outcomes.

The table illustrates that even a 5% probability of severe pain after restoration makes non-restoration the 'preferred', or most valued decision. However if the probability of severe pain from a non-restored tooth exceeds 21% then restoration becomes the preferred option.

The table also shows that the decision is sensitive to some of the utility values assigned by parents, as well as to the probability of 'chance' events. Table 4 shows that the "best" decision about whether to restore depends on how parents value GA extractions, and how patients value their child remaining pain free.

DISCUSSION

This study represents the first attempt to measure the values expressed by parents about dental treatment in a quantative way. The utility values derived have a face validity i.e. they appear to make sense and 'fit' with the way we would probably expect most people to interpret the world.

Treatment of carious deciduous teeth can lead to bad or good outcomes and positive or negative experiences for the child involved. Some patients may find dental treatment highly stressful although the majority probably do not. With carious deciduous teeth, many exfoliate without causing any major disturbance, although serious pain and negative experiences can also result from leaving a decayed deciduous tooth untreated. Wise decisions take account of the likelihood of the various outcomes and results and the value put upon them by the recipient of care.

In this study, to avoid ethical issues raised by describing hypothetical negative outcomes to children attending for dental care, the value put on the potential outcomes by the children's parents, rather than the child, were used.

This study suggests that for an "average" patient with "average" utility values, the decision to restore a carious deciduous tooth is not preferable to leaving it unrestored. This is not the case if the probability of pain is high when teeth are left unrestored. The literature shows that pain is relatively uncommon when teeth are left unrestored. (6, 7, 10)

The values applied in the decision analysis were derived from a population who, because the sample was drawn from a secondary care service, are not necessarily representative of the general population. However, decision analysis is a modelling technique, which allows us, through the use of sensitivity analysis, to ask a priori counterfactual questions. i.e. "what if things were not as they are or have been measured to be" The sensitivity

analyses explore how the optimum decision is affected if the values held by an individual are not similar to the ones measured in the sample. Thus, whilst parents of children attending a general dental practitioner might place quite different utilities on the outcomes the decision model presented is still entirely apposite, because sensitivity analysis can indicate the preferred decision for all values of probability or utility. The decision analysis shows that if the likelihood of an unrestored tooth remaining pain-free (until exfoliation) exceeds 60% leaving the tooth unrestored is the preferred option. Again, estimates from previous studies would suggest that the onset of pain in unrestored decayed teeth is much lower than this. Therefore, because fillings have, in themselves, a disutility to patients and parents (11), this analysis suggests that restorations should only be placed if there is near certainty that the filling will be the only treatment required until exfoliation.

Similarly, the analysis also shows that dentists should be certain that there is a greater than 40% probability that pain will intervene if they do not fill a tooth, before they should choose to restore.

These findings actually reflect how many practitioners behave. It is common, indeed it is taught in dental schools, that a decayed tooth near to exfoliation should not to be restored. This received wisdom is a reflection of the implicit probabilistic reasoning which a practitioner subconsciously undertakes each time s/he makes a clinical decision about a deciduous teeth. The analysis presented here therefore simply makes explicit the implicit estimates of probabilities, and value judgements, that a practitioner makes during a normal working day.

The results indicate that for patients who hold utility values close to the mean values for the group, the choice between restoration and non-restoration is a very difficult one unless they can have a high degree of certainty (>93%) that a restoration will not fail. This result might explain why specialists who place restorations of the highest quality, which seldom fail, advocate restoration on every occasion. However, for those practising in less than ideal circumstances, i.e. with time pressures, uncooperative children, difficulties with isolation, the choice not to restore is sometimes a very rational one, as restorations placed in such circumstances will probably have a greater than 7% chance of failure. In such circumstances, in terms of patient perceived utility, the best option is to leave the tooth unrestored.

Clearly there is a need for better quality data to be generated to improve the decision analysis model presented here. Prospective randomized controlled trials using standardized procedures for restoration and accurate measurements of pain and other outcomes are needed in order to improve the robustness

Table 4. Descriptions of potential outcomes mean utility values assigned by parent + standard devices

Variable to which tree is sensitive	Threshold value	Range of values in literature or mean utility value shown in parantheses	Source
Probability of severe pain following restoration	0.053	0 – 0.135	Tickle et al. 2002 (6), Shepherd et al. 1999 (8)
Probability of tooth exfoliating without pain following restoration (Figure 4 illustrates)	0.93	0.82 - 1	References 6, 7, 11-23
Probability of severe pain if no restoration placed	0.30	0 – 0.5	Levine et al. 2002 (7), Tickle et al. 2002 (6)
Probability of moderate pain if no restoration placed	0.1	0 – 0.17	Levine et al. 2002 (7), Tickle et al. 2002 (6), Shepherd et al. 1997 (8)
Probability of tooth exfoliating without pain if no restoration placed (Figure 3 illustrates)	0.603	0.33 - 1	Levine et al. 2002 (7), Tickle et al. 2002 (6)
Utility of GA specialist extraction after restoration	77.1	(47.2)	Survey of patients parents
Utility of GA specialist extraction after no restoration	37.1	(64.9)	Survey of patients parents
Utility of exfoliation without pain when left decay	75.3	(79.4)	Survey of patients parents
Utility of exfoliation without pain when restored	76.6	(78.8)	Survey of patients parents

* the threshold value is the valued of a variable at which the “best” decision changes from “leave” to restore

of the model. However, the usefulness of the model lies in its ability to ask the "what if" questions.

Thus, although this, and other studies have shown that there are substantial deficiencies in the literature, decision analysis is a methodology whose value lies in its ability to examine the universality of the conclusions drawn. i.e it allows examination of optimal decision making when circumstances change, or are proven via new data, to be different from the circumstances assumed in the model.

The sensitivity analyses presented show which treatment offer best benefit the patient when the "chance" of both "good" and "poor" outcomes are considered. These analyses show that across the range of values given by the literature, and the range of values given by the members of the public, (Table 4) the results of the decision analysis are robust i.e. circumstances have to be extreme before the conclusions drawn from this modelling exercise become unreliable.

CONCLUSIONS

This decision analysis suggests that at least for some patients, the option to leave deciduous teeth unrestored is a good one. However, the most important conclusion which can be drawn from the data presented is that in-depth and individual communication with parents and as far as possible, patients, is essential in order to understand how they value both good and bad outcomes, and processes. The study reveals the need to consider with the families involved, the benefits and risks of treatments, with a view to eliciting each patient's own individual view of their, and their child's ability to cope with the various potential procedures, events and "end-results".

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