Birmingham &
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Oral Health Guidance – Economic analysis of oral health promotion approaches for dental teams

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Abbreviations

ADHS	Adult Dental Health Survey
BBC EAC	Birmingham and Brunel External Assessment Centre
BOP	Bleeding on probing
CBA	Cost Benefit Analysis
CC	Conventional crown
CCA	Cost Consequence Analysis
CDB	Conventional dental bridge
CDHS	Children's Dental Health Survey
CEAC	Cost Effectiveness Acceptability Curve
CI	Calculus Index
CP	Chronic Periodontitis
CPH	Centre for Public Health
CUA	Cost Utility Analysis
D	Decayed
DCE	Discrete choice experiment
DMF	Decayed, Missing and Filled
DMFS	Decayed, Missing and Filled surfaces
DMFT	Decayed, Missing and Filled teeth
DOP	Depth of Pocketing
EDDN	Extended Duties Dental Nurse
FS	Filled and otherwise sound
FU	Filled unsound, with carries and/or failed restoration
G	Gingivitis
GA	General anaesthetic
GI	Gingival Index
GOF	Goodness of fit
H	Healthy Sites
ICER	Incremental Cost Effectiveness ratio
ISPOR	International Society of Pharmacoeconomic and Outcomes Research
LOA	Loss of attachment
M	Missing

MRS	Marginal rates of substitution
MS	Mutans streptococci
NICE	National Institute for Health and Care Excellence
NYEAC	Newcastle and York External Assessment Centre
OHIP	Oral Health Impact Profile
PHG	Public Health Guideline
PL	Plaque
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSA	Probabilistic sensitivity analysis
PSSRU	Personal Social Service Research Unit
QALY	Quality Adjusted Life Year
QATY	Quality Adjusted Tooth Year
RCT	Randomised Controlled Trial
RD	Removable denture
RPD	Removable partial denture
S	Sound and untreated
STI	Single tooth implant
UDA	Unit of Dental Activity
WTP	Willingness to pay

Executive Summary

Introduction

NICE commissioned the Birmingham & Brunel Consortium External Assessment Centre (BBC EAC) to carry out a review of economic evidence and economic analysis to inform the development of a guideline on oral health promotion approaches for dental teams. The guideline aims to provide advice on how dental teams can effectively and cost-effectively convey oral health promotion advice to adults and children who visit the dentist, including: verbal information; practical demonstrations; printed information such as leaflets and posters; and the use of new media.

The aim of the research presented in this report was to examine the cost-effectiveness of methods for dental health practitioners and their teams to deliver oral health promotion messages.

It consisted of three interrelated strands of work:

- A systematic review of published economic evaluations of methods for dental teams to convey oral health promotion advice.
- A public preference survey to elicit willingness-to-pay (WTP) valuations for oral health outcomes for adults and children.
- Economic modelling to evaluate the costs and consequences of methods for dental teams to convey oral health promotion advice.

Review of cost-effectiveness evidence

Methods

The review was conducted in accordance with the methodology laid out in the 2014 edition of *Developing NICE guidelines: the manual* ('NICE Guidelines Manual').[1] A systematic search to identify relevant studies for this review was carried out using a range of databases appropriate to the topic including Medline, Embase, Econlit, Science Citation Index and The Cochrane Library databases. Searches used appropriate MESH terms and key textwords, for the period 1994 to August 2014. Supplementary searches of grey literature comprised searches of the Open Grey database, general searches of the internet to locate government and local authority and other policy and strategy documents and searches of 19 relevant websites.

Records were screened by two reviewers (CM/JF) using the information available in the title and abstract (where provided). Citations with a title but no abstract were assessed for relevance based on the title only. To ensure a high degree of inter-rater reliability when assessing relevance, the two reviewers independently screened a sample of 20 studies against the inclusion criteria and discussed any relevant issues before screening the rest of the studies independently. There were no disagreements between the reviewers. Full copies of the papers selected at the screening search were requested. On receipt, the selection criteria were applied to each full paper by one reviewer (JL) and checked independently by another (CM).

Included were any cost-consequences, cost-benefit, cost-utility, cost-effectiveness or cost-minimisation analyses of adults and children in the general population where strategies aimed to convey oral health promotion advice were compared to no or minimal intervention or usual care. Outcomes included dental practitioners' or patients' knowledge of oral health behaviours, numbers of dental caries, decayed, missing or filled teeth or surfaces, periodontal disease, oral cancer and quality of life.

The applicability (of the study to the current English context) and quality of each included paper was assessed using the NICE template checklist for economic studies. One reviewer completed the checklist (JL) and this was checked by the second reviewer (CM), with differences marked up and discussed.

Data were extracted from each included study using cost-effectiveness evidence tables, and drawing on the template provided in the NICE Methods Guide (2012). The data extracted included study design, setting, population, intervention and control, cost sources, outcomes and modelling methods. The economic evaluations were too heterogeneous to support meta-analysis and are reported as a narrative. Study characteristics, applicability and methodological quality were summarised and the results are discussed. The results were synthesised into evidence statements grouped by intervention, reflecting the balance of the evidence, its strength (quality, quantity and consistency) and applicability.

Results

The search yielded a total of 3,589 records, after removing duplicates. Of these, 47 papers were assessed for eligibility based on full text. Of the full text articles reviewed, 37 were excluded from our review and 10 were included. An additional paper was reviewed because it was included in the Plymouth Report even though it was formally excluded from our systematic review.

All included studies reported estimates of resource use and/or costs associated with oral health education interventions in the context of comparative experimental or observational studies. Papers were categorised according to participant age at baseline and intent of the intervention.

Three studies evaluated programmes to deliver oral health promotion messages to carers of children, starting in the first year of life. One good quality economic evaluation (Pukallus et al 2013) [2] based on a non-randomised study in a socially disadvantaged area in Australia estimated that oral health advice delivered by an oral health therapist over the telephone when the child was aged 6, 12 and 18 months would save approximately £70,000 (2012 UK £) and prevent 43 caries per 100 infants over 6 years of follow up. Two other studies provided some supportive evidence of reductions in caries and associated cost savings for interventions in this age group: Kowash et al (2006) evaluated a three-year programme of education delivered at home by oral health educators in a deprived area of Leeds; and Holst and Braune (1994) evaluated a programme of oral health information for high-risk children in a small-town clinic in Sweden.

Evidence for the cost-effectiveness of preventive programmes for children above the age of one was more equivocal. One study evaluated an intervention for children aged 1-6 at high risk of caries in deprived areas in the Northwest of England (Blinkhorn et al 2003). Although participants in the intervention practices had fewer caries after two years of follow up, there was no statistically significant difference from control practices. Minimal cost information was provided in this paper. Another study (Wennhall et al 2010) evaluating oral health education delivered by a dental nurse in an outreach facility in a deprived area of Sweden did find a statistically significant reduction in caries incidence at a modest additional cost (€30 per child), compared with a non-randomised control group. Vermaire et al (2014) evaluated the cost-effectiveness of a 'non-operative' caries treatment and prevention programme in children aged 6, recruited in a large dental clinic in the Netherlands. This study estimated an incremental cost per decayed, missing or filled surface prevented of €30 from a healthcare perspective, and €100 from a societal perspective. However, there was a high degree of uncertainty over these results. Another study in older children, aged 11-12 with at least one active caries lesion recruited from dental clinics in Finland (Hietasalo e tal 2009) estimated the cost-effectiveness of a preventive programme delivered by dental hygienists. They estimated an incremental cost per DMFS avoided of €34. This intervention included a package of oral health advice, preventive treatment and free materials.

Only three of the identified economic studies related to interventions for adults. Hugoson et al (2003 and 2007) evaluated three different programmes of oral health promotion for young adults recruited in dental clinics in Sweden. All three programmes were associated with significant improvements in plaque and gingival indices, compared with control. However, the intensive 'Karlstad' programme (up to 18 visits over 3 years) was not significantly better than more basic individual or group based programmes. Although costs for the interventions were not reported, the time input from dental hygienists and patients was greater for the Karlstad programme. Jönsson et al (2009, 2010 and 2012) evaluated an individually-tailored programme of oral health education based on cognitive behavioural principals and motivational interviewing delivered by dental hygienists to adults undergoing a programme of non-surgical treatment for chronic periodontitis. The reported that treatment was more successful in the intervention group compared with standard care, but rather more expensive. The incremental cost per successfully treated case was approximately £242. Finally, a culturally-tailored programme of oral health information delivered by lay educators at social clubs for older immigrants in Australia was reported to achieve better gingival health compared with usual care at a hospital periodontal clinic, at an additional cost.

Valuation study

Methods

Given the paucity of data on quality of life associated with oral health conditions and concerns over using generic measures such as EQ-5D or SF-6D, we conducted a valuation survey to value the prevention of oral health problems. A Discrete Choice Experiment (DCE) including a cost attribute was designed and conducted to estimate respondents' 'willingness-to-pay' (WTP) to avoid specific oral health problems. The objective of the valuation study was to obtain values for oral health states that could inform economic modelling.

The first stage of the DCE was to identify the attributes (or characteristics of oral health outcomes and/or promotion messages to value) and levels of those attributes for inclusion in the survey. This was informed by: health states expected to be included in the economic model and a focussed literature review. Two sets of attributes and levels were developed for separate surveys: one set relating to oral health outcomes for adults and another for children. As the valuation study was conducted in parallel to the review of effectiveness of oral health promotion messages, it was not possible to determine which specific oral health outcomes would have sufficient evidence for inclusion in the economic model at the outset of the study. However, based on other effectiveness reviews on oral health and advice from the team conducting the review, we expected outcomes would include measures of Decayed, Missing and Filled Teeth (DMFT), Decayed, Missing and Filled Surfaces (DMFS), measures of gum problems and dental pain. The focussed literature search aimed to identify papers reporting primary research using WTP and DCE methods to value oral health states or oral health interventions, and to further inform attribute selection.

A pairwise choice design was adopted. The combinations of attributes and levels selected to present to respondents was based on a D-optimal design conducted using nGene software v1.1.1. Approval from Brunel University London Ethics Committee was obtained. Cognitive interviews were conducted using a 'think aloud' technique to check understanding of the survey questions. The main survey was administered via an on-line UK general population panel audience via SurveyMonkey. Quotas were set against census data for age and gender. Only parents of at least one child under the age of eighteen were asked to answer the survey questions about oral health in children. The study aimed to recruit a total sample size of 1000 people.

The experimental design pre-specified a multinomial logit model, with dummy variables representing categorical variables and the cost attribute specified as a continuous variable. The estimated coefficients of the model indicate the relevant importance of the different attributes on individual preferences. It was hypothesised that all coefficients would be negative indicating decreasing preference for more severe problems. A level of statistical significance of 0.05 was assumed.

Willingness to pay was calculated using the marginal rates of substitution (MRS) between the cost parameter coefficient and the coefficients for the other attributes. Thus, the MRS of attribute Y (cost) for attribute X is the amount of attribute Y (cost) that an individual is willing to exchange for a change in attribute X. The impact of income and age on average WTP was assessed by analysing data separately for different subgroups of respondents defined according to their reported income or age.

Results

Literature review: The literature search to identify potential attributes and levels identified a total of 51 papers, of which 22 papers were potentially relevant based on review of titles and abstracts. After review of full text, 17 papers reporting 16 studies were included. All included papers reported estimated WTP associated with oral health states or interventions using DCE or WTP methods. On review, none of the descriptions of attributes or scenarios used in the included studies were relevant to our study as they focussed on oral health treatments rather than oral health states. Nevertheless, the estimates of WTP for oral health treatments from studies conducted in the UK, other European countries and North America were considered informative for the range of values for the cost attribute to include in our survey. The WTP estimates ranged from £22 to £55 for a visit to a dental clinic to £870 to £1206 for a single tooth implant.

Attributes and levels: The review did not identify relevant attributes related to oral health states, therefore the attributes selected focussed on key outcomes expected to be identified in the effectiveness review: DMFT, DMFS, pain and gum problems. Previous research has identified that the location of the affected tooth affects people's preferences. Therefore, in the study of adult oral health, teeth were described as anterior (front), pre-molar or molar. For children's oral health, a distinction was made only between baby (primary) teeth and permanent teeth. The levels of the teeth attributes were described as 'no problems', 'decay without pain', 'decay with pain' and 'teeth requiring removal'. An attribute related to gum problems for adults was also included described as 'no problems' and 'some problems'. Informed by the findings of the literature review, the levels of the cost attribute ranged from £10 to £800 (£10, £50, £150, £300, £500, £800).

Survey design and pilot survey: A table was developed to provide respondents with information on the implications of the specific oral health conditions reflected in the attributes, and possible treatments. An analysis of Adult Dental Health Survey (ADHS) 2009 data was conducted to obtain information on possible implications: frequencies and associations of responses to the Oral Health Impact Profile (OHIP) questionnaire were calculated for different oral health problems (missing teeth and gum problems). The descriptions of implications and treatments were modified following consultation with a clinical expert.

Cognitive interviews were carried out with members of staff within Brunel University London (n=7). This indicated that the teeth diagram was helpful and the WTP levels acceptable. Minor amendments were made to the survey wording following the cognitive interviews. The survey was programmed in SurveyMonkey software and tested to check ease and timing of completion (n=4).

The experimental design resulted in a total of 24 paired choice sets for the adult survey which was spread across three blocks; for the children survey 12 choices sets were generated across two blocks. This resulted in a total of eight choice questions per respondent for valuing adult oral health and six choice questions for child oral health based on the attributes and levels identified.

Survey results and analysis: The survey was administered in two rounds in November and December 2014 as it was found that the first set of responses under-represented people in the older age group. In total, 944 responses were received for the adult survey and 233 responses for the child survey. Self-reported general health and oral health of the sample was similar to that reported in ADHS 2009. Around half of the respondents to the adult survey stated that they used dental services at least once every six months, which matched the response in ADHS survey. Reported use of dental services was higher for parents who filled out the child questionnaire (60% said they used services at least once every six months).

The data were analysed using a conditional logit model in STATA v13. The direction of the model coefficients followed logically for anterior teeth, premolar teeth, gum problems and cost (i.e. were negative). For molar teeth, the direction of the coefficients was inconsistent for levels 1 and 2 (decay with and without pain). These levels were excluded and the model re-estimated. The magnitude of the coefficients for anterior teeth and gum problems follow in the expected order (most preferred to least: no decay, decay without pain, decay with pain, removal). The coefficients for two of the pre-molar dummy variables were not statistically significant.

Estimates of willingness to pay were obtained from the model of adult oral health. The results indicate a higher WTP to avoid problems with anterior teeth: people are willing to pay a mean of £56 (95% confidence limits [CL]: £16 to 95) to prevent decay with no pain, £238 (95%CL: £195 to £281) to prevent decay with pain and £333 (95%CL: £284 to £382) to prevent removal. The WTP to prevent decay with pain in a premolar tooth was £106 (95%CL: £73 to £139). For premolar teeth, the estimates for decay without pain (WTP £5.83, 95%CL -£34 to £46) and removal (WTP £7.46, 95%CL -£21 to £36), were highly uncertain and should be viewed with caution. WTP to avoid removal of a molar tooth was £37 (95%CL £9 to £65) and to avoid gum problems £125 (95%CL: £107 to £142).

A conditional logit model was fitted to the data from the survey of children's oral health. The model as a whole was statistically significant (Wald Chi^2 with 8 degrees of freedom 287.85; p<0.001). Two of the coefficients were not statistically significant and had counter-intuitive signs: decay in a baby tooth without pain and removal of a baby tooth. Therefore we are unable to conclude that a disutility is associated with these oral health problems and these variables were excluded from the final model.

The results show that respondents were willing to pay £150 (95% CI: £92 to £209) to prevent decay with pain in a baby tooth; £115 (95% CI: £42 to £187) to prevent decay without pain in a permanent tooth; £305 (95% CI: £210 to £399) to prevent decay with pain in a permanent tooth; and £244 (95% CI: £143 to £346) to prevent removal of a permanent tooth.

Economic modelling

Methods

Approach to economic evaluation: The aim of the economic modelling was to develop a mechanism to estimate the cost-effectiveness of different approaches for dental teams to convey oral health promotion messages to patients.

Economic evaluations were conducted in accordance with the methods recommended in the NICE Guidelines Manual (2014), and following the public health reference case. Results are presented in the form of a cost-consequence analysis: with estimates of oral health outcomes alongside costs and valuations in the form of QALYs and/or WTP. Costs were estimated from a public sector perspective, but charges paid by patients were also estimated. Costs and outcomes were discounted at 1.5% per year.

The population of interest was adults and children who visit the dentist, as specified in the scope. Due a lack of direct evidence of intervention effects on quality of life or well-being outcomes, modelling was based on two key indicators of oral health: dental decay and periodontal disease. Dental decay was modelled in terms of the mean numbers of teeth decayed, filled or extracted within a cohort. In children, it was necessary to distinguish decay in primary and permanent teeth (dmft or DMFT respectively), but we did not attempt to model the transition between primary and permanent teeth and made no distinction according to the location of teeth in the mouth. In adults, we distinguished anterior, premolar and molar teeth. Gum disease in adults was modelled based on the approach of Mdala et al. (2014). This required information on the proportion of periodontal sites examined that exhibited signs of gingivitis, defined as Bleeding on Probing (BOP), and the proportion of sites with Chronic Periodontitis (CP), defined as Depth of Pocket (DOP) greater than 4mm. We did not model gum disease in children.

Effectiveness evidence: The interventions that could be included in the economic analysis were limited by the availability of evidence from the effectiveness review (Kay et al. 2014) reporting outcomes that were compatible with modelling. We identified three studies that provided such evidence that were sufficiently robust (quality and applicability scores ++ or +) and found a positive mean difference between groups (even if this difference was not statistically significant). These included two studies reporting a reduction in caries incidence in children: Blinkhorn et al. (2003) for primary dentition in young children (age 1-6); and Hausen et al. (2007) for permanent dentition in older children (age 11-12). The other study provided evidence of improved gum health in older patients undergoing treatment for chronic periodontitis (Jönsson et al. 2009, 2010). Published economic evaluations based on these three studies were included in the review reported above (Blinkhorn et al. 2003; Hietasalo et al. 2009 and Jönsson et al.). However, we considered that further economic analysis based on these studies might be useful, to transfer results to a UK context, to extrapolate outcomes and to further explore uncertainty.

Model of tooth decay in children: The costs and consequences of oral health promotion advice for children were estimated following the simple decision tree approach taken for NICE guidance on community based oral health promotion PH55 by the NYEAC (Claxton et al. 2014). This approach was deemed appropriate by the committee, given uncertainty over the effectiveness evidence and lack of epidemiological data on which to base a long-term extrapolation.

The two studies were modelled separately, as they related to different populations: young children with primary dentition in Blinkhorn et al. (2003); and older children with permanent teeth in Hausen et al. (2007). The time horizon modelled was limited to the length of follow up in the associated trials: two years in the Blinkhorn study and three for Hausen.

The model starts with an eligible population with an initial prevalence of decayed, filled or missing teeth: 1.6 in children aged 5 and 0.8 in 12 year olds, based on the Children's Dental Health Survey (CDHS) 2003. Incident decay in previously sound untreated teeth was also estimated from the CDHS, assuming constant rates of decay between the ages of 5 and 8 years (0.0036 per year for primary teeth) and between 12 and 15 years (0.0092 per year for permanent teeth). The incidence of decay with intervention was then estimated by applying a relative risk multiplier, estimated from the related clinical trial (0.64 for the Blinkhorn study; and 0.22 for the Hausen study).

The numbers of dental procedures per newly decayed tooth were then estimated. The proportions of decayed teeth filled were estimated from the CDHS: 28% for primary teeth and 77% for permanent teeth. Following Claxton et al. (2014), we assumed that 13.9% of decayed teeth would be extracted, and that the proportion of extractions conducted under general anaesthetic (GA) would be 100% for 5 year olds and 50% for 12 year olds.

Finally, costs, QALYs and WTP outcomes were associated with incident decay and treatment for the intervention and control groups. The NHS cost of fillings and extractions in dental clinics was estimated assuming a band 2 procedure, incurring 3 Units of Dental Activity (UDA) at £25 per UDA (£75). The cost of extractions under GA was estimated from NHS reference costs (£1,160). Claxton et al. estimated QALY losses associated with tooth removal under general anaesthetic based on an analogy with the treatment of otitis media in young children, which the committee considered to be appropriate. Quality of life estimates for otitis media were obtained from the literature: for the base case the estimate of 0.72 from Oh et al. (1996) was used; and in sensitivity analysis 0.79 (Coco 2007) = 0.79 to 0.882 (Dakin et al. 2010). Baseline quality of life was assumed to be 0.94, and reduced quality of life related to a tooth extraction was assumed to last for 12 weeks. Claxton et al. also incorporated a QALY loss associated with GA-related mortality: assuming a 1 in 300,000 risk of death incurring a mean discounted loss of 40 QALYs per death. In addition to these estimates of QALY loss for extractions, we used parents' WTP valuations for tooth decay and removal estimated from our survey.

The effects of uncertainty over input parameters were investigated using Probabilistic Sensitivity Analysis (PSA). Deterministic sensitivity analysis was also used to test the impact of changes in key parameter values and model assumptions.

In addition to the two analyses for children based on published studies, we conducted an exploratory 'What If' analysis to estimate the possible cost-effectiveness of three levels of intervention (brief advice from a dentist in an existing consultation; a one-off session of advice delivered by an Extended Duties Dental Nurse (EDDN); and a programme of eight sessions with an EDDN, analgous to the Blinkhorn et al intervention). Costs and effects were estimated over a three year period for children aged 5 and aged 12, under a range of scenarios suggested by the PHAC. These varied key assumptions: the risk of incident tooth decay over three years; the reduction in risk associated with the interventions; the proportion of extractions performed under general anaesthetic; and the non-attendance rates for appointments with the EDDN.

Model of gum disease in adults: A model was developed to estimate the cost-effectiveness of an oral health promotion programme for adults under treatment for periodontal disease. The model structure was based on the approach of Mdala et al. (2014). They used a Markov model to predict the progression of gum disease in initially-healthy sites. The model comprised three states for gum sites: healthy (H) with DOP ≤4mm and no BOP; gingivitis (G) with DOP/LOA ≤4mm and BOP; and chronic periodontitis (CP) with DOP >4mm with or without BOP. The model allowed onset of gingivitis in previously healthy gum sites, resolution of gingivitis with sites returning to healthy, and progression to CP from previously healthy sites and from those with gingivitis. Mdala et al. assumed that once developed, CP is irreversible (it is an 'absorbing state').

Mdala et al. estimated transition probabilities between states using data from a randomised trial of treatment for chronic periodontitis, including 217 individuals in Boston USA and Gothemburg Sweden. Data on BOP and DOP were available for 1,374 gum sites in 154 people (mean age 54, range 26-84) over two years of follow up.

We aimed to extrapolate outcomes and costs from the Jönsson et al. trial (2009, 2010 and 2012) of an individually tailored education programme to promote gum health. The population in this trial was similar to that in the dataset used by Mdala et al. to estimate transition probabilities. Jönsson et al. reported that a high proportion of interproximal pockets (DOP>4mm) at baseline had closed after one year (77% under standard treatment and 75% with the individualised programme). Although this difference between groups was not significant, we adapted the Mdala model to allow transitions from the CP to H gum states during the first year after periodontal treatment, but thereafter assumed no further healing. Jönsson et al. did find a significant difference between the groups in the change in the number of sites with bleeding on probing: a reduction of 55% in the standard treatment arm, compared with 69% in the individualised programme arm (confidence intervals not reported).

Jönsson et al. (2012) estimated dental costs over one year for trial participants, using individual-level data on the number of visits to the clinic and treatment time and unit costs estimated from clinic financial data. They also collected information from patients about their travel costs, out-of-pocket expenditure, and time taken for clinic visits. As their methods of cost estimation were of a good standard, and we did not identify a better source of UK-specific data, we have converted Jönsson et al's estimates for use in our model. Costs were converted from Swedish Krona to UK pounds using OECD Purchasing Power Parity rates for 2007, and uprated for inflation using the UK Hospital and Community Health Services Index. All costs are reported in 2012/13 UK £. We did not attempt to estimate treatment costs for ongoing or newly incident sites of gingivitis or chronic periodontitis after the one-year treatment and follow-up period.

The value that patients attach to the avoidance of new sites of chronic periodontitis was estimated from the survey reported above: £125 (95% CI: £107 to £142).

The model was implemented with a one year Markov cycle, over a 10 year time horizon. In the base case, the results were estimated for a cohort of 1,000 individuals similar to the patients recruited to the Jönsson et al. trial: age 51 years with only 10% of gum sites initially healthy, 65% with gingivitis and 25% chronic periodontitis. The effect of uncertainty over model parameters was estimated using probabilistic sensitivity analysis (PSA). Deterministic analysis was also used to investigate uncertainty relating to non-sampled parameters and model assumptions.

Model of tooth decay in adults: A third model was developed to estimate the cost-effectiveness of interventions to prevent tooth decay in adults. In the event, the effectiveness review did not identify any evidence that could be used to inform this model – due to the relative rarity of incident tooth decay in adults. This model is nevertheless described here for information, although it is unlikely to be useful for development of recommendations for this guideline.

The condition of anterior, premolar and molar teeth was tracked using a Markov-type model with five tooth states: sound (S), decayed (D), filled sound (FS), filled unsound (FU) and missing (M). Following decay of a previously sound tooth (S to D), the tooth may be filled (D to FS) or extracted (D to M). Once a tooth has been filled, it may remain sound or become unsound due to failure of the filling or new caries (FS to FU). After detection, it will then undergo further restorative treatment (FU to FS) or extraction (FU to M). A tooth may be restored several times. As the model progresses, members of the cohort (and their teeth) die according to a defined mortality rate. The model was run with a three month cycle length and a 20 year time horizon.

Transition probabilities between the tooth states were calibrated to fit with data from the ADHS 1998 and 2009. Initial estimates of the decay probability by tooth type and age group were obtained by comparison of the mean proportions of teeth that were sound and untreated in consecutive ten-year age groups in the 1998 and 2009 ADHS (e.g. 16-24 years in 1998 and 25-34 years in 2009). The probability of detection of decayed and unsound teeth was governed by the frequency of dental check-ups, as reported by participants in the ADHS 2009. It was assumed that all decayed or filled unsound teeth would be identified at the next dental visit, and either restored or extracted at that time. Estimates of the filling failure rate were obtained from published estimates based on Dental Practice Board data (Burke et al. 2005). Extraction rates for decayed or filled unsound teeth were estimated as the proportion of such teeth assessed as 'unrestorable' in the ADHS 2009.

The calibration process entailed repeated random re-sampling of the above input parameters from defined probability distributions. For each set of sampled input parameters, the numbers of teeth by tooth state, age and tooth type were estimated, starting with a cohort similar to the 1998 ADHS participants and running the model for ten years. These modelled results were then compared with target values based on observations from the ADHS 2009. The 'goodness of fit' for each set of modelled results compared with the target values was estimated using a weighted chi-squared statistic. This process was repeated until a sufficient number of parameter sets with an acceptable goodness of fit (chi-squared less than 10) were obtained for PSA (2,000 iterations).

In addition to the calibrated parameters, costs and WTP estimates were sampled probabilistically. NHS costs and patient charges per filling and per extraction were estimated from NHS Dental Statistics 2013/14, assuming a mean cost per UDA of £25 (95% confidence interval of £15 to £35). WTP estimates were sampled based on the results of the valuation survey in adults.

The outputs from the adult tooth model are presented as sums of mean discounted costs and WTP accumulated over the 20-year time horizon for the three teeth categories by age of incident decay.

Results

Children's tooth model: The base case analysis based on the Blinkhorn et al. study did not indicate that the intervention was likely to be cost-effective in a population of children aged 5 at average risk of tooth decay (increase in mean dmft of 0.13 over two years). The incremental cost of intervention was estimated at £3,681 per 100 participants (95% confidence interval from PSA: -£1,303 to £12,537), the estimated number of averted dmft was very small, 3.15 per 100 children over two years of follow up (-11.72 to 17.99). This resulted in an estimated QALY gain of only 0.023 (-0.077 to 0.137) associated with tooth removal, and an Incremental Cost Effectiveness Ratio (ICER) of £163,558 per QALY. There was an additional welfare benefit due to avoidance of decay with pain and fillings, but the estimated WTP value of this benefit was small, £62 per 100 children. The results of this model were highly sensitive to uncertainty over model parameters, which might be expected as the effect on decay in the clinical study by Blinkhorn et al. was not statistically significant. The profile of costs, QALYs and WTP became favourable for a population at higher than average risk of caries: taking the risk observed in the control group in the Blinkhorn study (increase of mean dmft of 1.05 over two years) the intervention became cost-saving, but was still subject to a high degree of uncertainty.

The results for the analysis based on the Hausen et al. intervention in 12 year old children at average risk of tooth decay (0.8 new DMFT over three years) indicated that the incremental net cost to the NHS was £6,476 per 100 participants (95% confidence interval -£711 to £13,784). The intervention was estimated to avert 64.2 DMFT per 100 participants (-40 to 89), and yielded an ICER of £14,408 per QALY gained (accounting only for QALY gains related to tooth extractions). Taking a cost-benefit approach, the estimated net benefit in this average risk group was £3,924 per 100 participants (incorporating WTP estimates for decay with and without pain as well as for extractions). In a subgroup of children at high risk of tooth decay (taking the observed increase in DMFT in the Hausen study of 2.3 over three years) the intervention appeared to be robustly cost-saving: taking a cost-utility approach, the incremental net benefit at a threshold value of £20,000 per QALY was £28,677 (£8,006 to £54,156) per 100 participants; and taking a cost-benefit approach, the value of benefits (WTP) net of costs was estimated at £32,745 (£13,345 to ££52,387) per 100 participants.

The 'What If' analysis suggested that brief advice from a dentist, delivered by extending an existing consultation by five minutes *might* be cost-effective for children at higher than average risk under certain conditions and assumptions. For example, if we assume that such an intervention could achieve a hazard ratio of 0.9 over a period of three years, the estimated incremental net benefit for 100 children at twice the average risk of tooth decay would be approximately £1,000 to £1,500 (at the £30,000 per QALY threshold). To put this in context, 5 and 12 year olds at twice 'average risk' could expect one additional decayed, missing or filled tooth over a three year period without intervention (estimated from CDHS 2013 results). An intervention with a hazard ratio of 0.9 would avert about one in ten these incident dmft/DMFT. These results are based on an estimated cost for the dentist brief advice intervention of £14 per child.

We estimated that a one-off appointment with an EDDN would cost about £29. However, this figure depends on how one apportions overheads for EDDN time and for use of a room, and also on what additional costs are incurred due to missed appointments. The cost-effectiveness of brief advice from a dentist compared with an appointment with an EDDN depends on the relative costs and effectiveness of these interventions. Based on the estimated cost of £29 for a 20 minute session with an EDDN, a series of eight appointments over two years (similar to the intervention in the Blinkhorn et al. study) would cost about £230. This is very much higher than the figure used in our previous analysis (£43), which was based on costs reported by Blinkhorn et al. and uprated for inflation. Based on the higher cost, our revised estimates suggested that a preventive programme delivered by EDDNs would not be cost-effective, except maybe in children at very high risk of tooth decay (above four times average risk).

Adult gum model: Under the base case analysis, the individualised programme was estimated to be slightly more expensive than standard treatment: about £38,700 more in year one for a cohort of 1,000 patients, including both costs of treatment and costs to patients. However, effects on gum health were equivocal. The individual programme was associated with a greater proportion of gum sites with CP after ten years than standard treatment, yielding a lower willingness-to-pay (£36,228 lower in the individual programme arm than in the standard care arm). This was due to the small and non-significant difference in pocket closure observed in the trial. The resulting Incremental Net Benefit (INB) was negative (-£74,934), indicating that the additional benefits of the individualised programme of treatment do not balance its additional costs. There is a high level of uncertainty over this result: from the PSA the 95% confidence interval for INB was estimated at -£261,778 to +£119,791, and the estimated probability that the INB is positive was 22%. Furthermore, the results are somewhat sensitive to changes in assumptions about how to model outcomes. In particular, if we assume that the rate of pocket closure in year one is equal between the two arms (which is not unreasonable as the difference is not statistically significant), individualised treatment is predicted to reduce the number of gum sites with CP after ten years, and achieves a greater willingness-to-pay value than standard treatment. However, this benefit is still not sufficient to outweigh estimated costs, and the mean INB is still negative (95% CI: -£63,013 to £17,790).

The results were not sensitive to the time horizon, discount rates, initial age of the cohort, or if we assumed a cohort of smokers, with higher risk of fast progression from gingivitis to chronic periodontitis.

Adult tooth model: Over 20 years, it was estimated that on average a decayed tooth will have been filled between 1.3 and 2.4 times, depending on age at the time of initial decay. Between 15 and 26% of teeth were estimated to have been extracted over this period. Based on these results, the estimated NHS cost per decayed tooth ranged from £168 (95% confidence interval: £108 to £239) at age 16 to £286 (£183 to £414) at age 65. In addition, the estimated WTP for individuals to avoid the pathway of decay was estimated at £106 (£36 to £209) at age 16 and £139 (£4 to £356) at age 65.

Discussion

Published economic evaluations of methods for dental teams to deliver oral health advice to patients are scarce and disparate. We reviewed eleven studies reporting estimates of resource use or costs from comparative experimental or observational studies. They covered a wide age range, from infants to people in their ninth decade. The settings and interventions were also very varied, and there are concerns about the applicability of the findings to the guideline scope and UK context. In particular, some of the included studies related to interventions delivered by members of the dental team outside of clinics (by telephone, at patients' homes or in outreach settings), which might be deemed outside the scope of the guideline. Another complication relates to differential provision of preventive treatment (such as professional cleaning and fluoride varnishes) or oral hygiene products (such as fluoride tablets, toothpaste and tooth brushes) between treatment arms. This might be expected to confound the estimated effects of oral health advice. Most of the studies also suffered from very serious or potentially serious methodological flaws.

Nevertheless, some tentative conclusions might be drawn from this body of economic evidence. First, there is weak evidence that interventions to provide advice to parents in a child's first year of life in socially deprived populations can contribute to reductions in early childhood caries and net cost savings for the NHS. Evidence in older children is rather more mixed, with one UK study failing to find a significant reduction in caries incidence (Blinkhorn et al. 2003) and others in Sweden, the Netherlands and Finland reporting estimates of cost per defs or DEFS avoided from cost saving up to about €100 (Wennhall et al. 2010; Vermaire et al. 2014; and Hietasalo et al. 2009). Two studies provided some relevant economic evidence for adults. Hugoson et al. (3003 and 2007) compared three models of oral health advice for young adults, and concluded that the more intensive 'Karlstad' model was likely to be more expensive and not significantly more effective than more basic individual or group programmes. Jönsson et al (2012) reported that an individually-tailored programme of oral health advice for patients being treated for chronic periodontitis was more expensive than standard treatment but was associated with a greater proportion of patients achieving pre-defined treatment goals: yielding an estimated incremental cost per successfully treated patient of £242.

Interpretation of such cost-effectiveness ratios for dental health outcomes is difficult because of the lack of an accepted benchmark of value. It is not clear how much the NHS is able or willing to spend per decayed surface avoided, or per case of periodontal disease successfully treated. A common approach in other areas of health care is to use the QALY metric, for which an estimation of NHS opportunity cost has been established: e.g. the NICE threshold of £20,000 to £30,000 per QALY. However, although oral health specific quality of life measures have been developed (such as the OHIP), there is not yet an acceptable method for valuing these measures on a scale required for QALY calculation. This problem led us to conduct our own valuation survey. We chose to elicit values in the form of monetary willingness to pay using a DCE approach for pragmatic rather than ideological reasons – it was practical to administer a DCE within the available time and resources using an online UK general population panel.

The valuation study is one of the first studies that we are aware of to use a DCE approach to value oral health states in monetary terms using public preferences. The results indicate that people have stronger preferences to avoid problems with anterior teeth compared to pre-molar and molar teeth. Prevention of gum problems are also highly valued by respondents. With regard to children's teeth, parents highly valued the prevention of pain, and had higher preferences for avoiding problems in permanent teeth compared to baby teeth. In the model for adult oral health, it was not possible to estimate WTP for decay with or without pain for molar teeth, and the estimates obtained for decay with no pain and removal of premolar teeth were highly uncertain and should be viewed with caution. In the analysis of the children's oral health survey, it was not possible to estimate WTP values for the no decay or removal of baby teeth. The cost attribute included in the survey design appears to have significantly affected respondents' choices, with a high proportion of people opting for the least cost alternative in the choice pairs. The literature review found few similar studies to inform the design of this study. We anticipated more evidence relating to adults and therefor assigned a higher proportion of the sample to the survey of adult oral health; however the effectiveness review identified more informative evidence relating to children's oral health. In addition, there was no information in the literature to use as informative prior values for the DCE design. We anticipate that future studies could use the estimates obtained in this study as prior values in order to obtain more robust estimates.

The results of the survey were used to estimate a value for oral health benefits in *de novo* economic evaluations conducted for this guideline. We conducted three appraisals based on published effectiveness studies. The results of these analyses were mixed and highly uncertain, indicating that the cost-benefit of delivery of oral advice to patients by members of the dental team depends on the specifics of what information is provided, to whom, in which context.

Our first analysis estimated the costs and consequences of an intervention in which Primary Care Trusts seconded dental health educators to general dental practices in socio-economically deprived areas in Northwest England (Blinkhorn et al. 2003). At clinics randomised to intervention, educators provided one-to-one counselling to parents of children aged between 1 and 6 years at high risk of caries. The study showed a non-significant reduction in caries incidence with the intervention, and we estimated that the balance of costs to the NHS and benefits of avoiding tooth decay was unfavourable in a population with an average level of risk, although it did appear to be cost-effective in children at high risk of caries. Our analysis was limited in a number of ways: costs and benefits were estimated over a short time horizon; there are questions over the validity of the parental WTP valuations for primary teeth obtained from our survey, as no value was attached to decay without pain or to tooth removal; consequently, benefits had to be valued in different and non-commensurate units (QALYs for the value of avoiding extractions and parental WTP to avoid decay with pain); and there was considerable uncertainty over other key input parameters.

The second economic analysis presented in this report estimated the costs and consequences of a programme of oral health advice, preventive treatment and oral hygiene products delivered by dental hygienists to children aged 11-12 years with at least one active caries lesion, recruited from dental clinics in Finland (Hausen et al. 2007). This study did find a significant reduction in caries incidence, and the authors reported an incremental cost-effectiveness ratio of €34 per DMFS avoided (Hietasalo et al. 2009). Our analysis suggested that this intervention would be just above the £20,000 per QALY threshold (with an ICER of £21,105) and that it would be cost-beneficial (WTP net of costs £2,597 per 100 children) in a 12 year old children at average risk of tooth decay. This result was sensitive to the method of unit cost estimation, with UK estimates the ICER was over £30,000 per QALY in the average risk group. In children at high risk (mean increment of DMFT of 2.3 over three years as in the Hausen study), the intervention appeared to be cost-saving. This result was robust to uncertainty over input parameters, and to the method of valuation (cost-utility or cost-benefit analysis).

Our third economic analysis estimated the impact of adding an oral education programme to standard non-surgical treatment for periodontal disease in an adult population, based on the study by Jönsson et al. (2009, 2010). The authors reported that a greater proportion of patients met criteria for successful treatment after one year with the intervention than with standard care alone, and that from a societal perspective, the incremental cost was SEK 1,724 per additional successful case (approximately £242). This may seem a modest cost, but we note that it is higher than the WTP to avoid gum problems elicited in our survey. Broadly, our economic analysis did not support the conclusion that this intervention would be cost-beneficial: the estimated WTP for the benefits associated with a reduction in gingivitis were outweighed by the estimated costs of the intervention. This result was subject to uncertainty, and there were some important limitations in the analysis. In particular, we note that we did not estimate ongoing treatment costs for gum problems after the first year, which might be expected to offset some of the costs of the intervention. On the other hand, we attributed the WTP to avoid gum problems to each site of periodontitis, which might be expected to have exaggerated the benefits of intervention.

Finally, we report the results of an exploratory 'What If' analysis to investigate the possible cost-effectiveness of three levels of preventive intervention in 5 and 12 year old children, under a range of scenarios. This suggested that a low-cost intervention such as brief advice from a dentist, extending an existing consultation by five minutes, *might* be cost-effective in children at higher than average risk of tooth decay, *if* it could achieve a relatively modest reduction in risk. Other methods of delivering advice, such as an appointment with an EDDN *might* also be cost-effective in high risk groups, depending on the cost of the intervention and level of effectiveness that could be achieved. However, our analysis suggested that a more intensive programme of oral health advice, consisting of a series of appointments as in the Blinkhorn study, was unlikely to be cost-effective. These results should be interpreted with great caution, as they are not based on specific effectiveness evidence, and there are important uncertainties over other key model parameters, not least the cost of delivering the interventions in routine dental practice.

Chapter 1. Introduction

1.1 Scope of guideline

The Centre for Public Health (CPH) of the National Institute for Health and Care Excellence (NICE) has been requested by the Department of Health to develop guidance on oral health promotion approaches for dental teams (NICE PH60). The guidance will address how dental teams can best convey oral health promotion advice and will be informed by evidence of effectiveness and cost-effectiveness of different approaches. The scope developed by NICE outlines the approaches to be considered, the population of interest, the key questions to be addressed and outcomes that will be considered. The scope is summarised in Table 1.

Table 1: Scope for the public health guideline

Population	Adults and children who visit the dentist
Included approaches	How dental teams can effectively convey oral health promotion advice, including: • Verbal information • Practical demonstrations • Leaflets, posters and other printed information • New media
Key questions	• What are the most effective and cost-effective approaches that dental teams can use to convey oral health promotion messages to patients? • Are oral health promotion messages more likely to have an effect on patients if they are linked with wider health outcomes, such as heart and lung disease or diabetes? • What helps dental health teams to deliver oral health promotion messages? What prevents effective delivery? • What helps patients to understand and act upon oral health promotion messages? What stops them from understanding or taking action – or not following the full advice - even if they do understand the messages? • How can oral health promotion messages be delivered in a way that ensures people leave the dentist satisfied about their visit and motivated to follow the advice given?
Outcomes	• Dental health team's knowledge, ability, intentions and practice. • People's experience of visiting the dentist (e.g. satisfaction with advice). • Patients' knowledge and ability to improve and protect their oral health. • Changes in dental patients' oral health behaviours. • Oral health of people who go to the dentist (incidence and prevalence of oral cancers, tooth decay, gum disease and dental trauma). • Patients' quality of life, including social and emotional wellbeing.

NICE commissioned the Birmingham & Brunel Consortium External Assessment Centre (BBC EAC) to carry out a review of economic evidence and economic analysis to inform the development of the guideline. The terms of reference can be found at Appendix A.

A review of evidence on the effectiveness of the different approaches has been conducted in parallel by Plymouth University Peninsula Dental School, and is presented in the report by Kay et al. (2014).[3]

1.2 Aims and objectives

The aim of this research was to examine the most cost-effective approach for delivering oral health promotion messages by dental health practitioners and their team.

It consisted of three interrelated strands of work, described in the following chapters:

- A systematic review of published economic evaluations of methods for dental teams to convey oral health promotion advice (Chapter 2).
- A public preference survey to elicit willingness-to-pay (WTP) valuations for oral health outcomes for adults and children (Chapter 3).
- Economic modelling to evaluate the costs and consequences of methods for dental teams to convey oral health promotion advice (Chapter 4 and Chapter 5).

Chapter 2. Review of economic evaluations

2.1 Methods

The review was conducted in accordance with the methodology laid out in the 2014 *Developing NICE guidelines: the manual* ('NICE Guidelines Manual').[1]

2.1.1 Search strategy

A systematic search to identify relevant studies for this review was carried out using a range of databases appropriate to the topic. These are listed in Table 2.

Table 2. Economic evidence review: resources searched

Resource	Interface/url
MEDLINE	OvidSP
MEDLINE In Process	OvidSP
EMBASE	OvidSP
NHS Economic Evaluation Database (NHS EED)	Cochrane/Wiley
Health Technology Assessment Database (HTA)	Cochrane/Wiley
Cochrane Database of Systematic Reviews (CDSR)	Cochrane/Wiley
Database of Abstracts of Reviews of Effects (DARE)	Cochrane/Wiley
EconLit	EBSCO
Cost Effectiveness Analysis Registry (CEA)	Tufts Medical Center
Science Citation Index Expanded	Thomson Reuters/ISI
WHO International Clinical Trials Registry Platform (ICTRP)	http://apps.who.int/trialsearch/
ClinicalTrials.gov	https://clinicaltrials.gov/ct2/search
NIHR UK Clinical Research Network Portfolio Database	http://public.ukcrn.org.uk/search/

The search strategy was developed through discussion between the BBC EAC review team and the CPH project team. To ensure consistency with other related NICE documents, we made reference to the search strategies used in the effectiveness review for this guideline (Kay et al. 2014)[3] and the economic literature review conducted by Coffin et al. (2013) [4] for the previous NICE guidance on approaches for local authorities and their partners to improve the oral health of their communities (PH55). The aim was to make the strategy as sensitive as possible without too much detriment to precision.

In order to retrieve as many pertinent references as possible on oral health promotion approaches for the dental team, appropriate text words and index terms were selected to describe the two main concepts contained within the question ("oral health" combined with "health promotion"). The strategy was then narrowed by the addition of the terms relating to economic evaluation using a study design filter (a version of the CRD NHS EED filter which is used to locate the studies which populate the NHS EED database).[5] The filter was not applied to the subject-specific economic databases NHS EED and ECONLIT. The searches were confined to English language studies and covered the period 1994 to date; 1994 being the date of the searches for the previous systematic review on the topic by Kay and Locker (1996).[6] The draft search strategy for MEDLINE presented in the protocol was adapted to run on each of the databases listed in Table 2. The final search strategies used are listed in Appendix B.

As this approach alone would be too narrow, we employed supplementary methods including searches of the grey literature (see Appendix C for details). This comprised searches of the Open Grey database, general searches of the internet to locate government and local authority and other policy and strategy documents and searches of the following websites:

- British Dental Association http://www.bda.org/
- American Dental Association http://www.ada.org/en/
- Centre for Evidence Based Dentistry http://www.cebd.org/
- Center for Evidence Based Dentistry (ADA) http://www.ada.org/en/science-research/evidence-based-dentistry/
- Economic and Social Research Council http://www.esrc.ac.uk/
- National Oral Health Promotion Group http://nohpg.org/
- National Institute for Health and Care Excellence https://www.nice.org.uk/
- NHS Choices http://www.nhs.uk/Pages/HomePage.aspx
- NHS Evidence https://www.evidence.nhs.uk/
- NHS Health Scotland http://www.healthscotland.com/
- Health in Wales http://www.wales.nhs.uk/
- Department of Health https://www.gov.uk/government/organisations/department-of-health
- NHS England http://www.england.nhs.uk/
- The King's Fund http://www.kingsfund.org.uk/
- York Health Economics Consortium http://www.yhec.co.uk/
- Cochrane Public Health Group http://ph.cochrane.org/
- EPPI Centre(Evidence for Policy and Practice Information) http://eppi.ioe.ac.uk/cms/
- Health Education England http://hee.nhs.uk/
- WHO Health Education http://www.who.int/topics/health_education/en/

Conference proceedings and abstracts were sought using the ISI Conference Proceedings Citation Index and ZETOC (British Library) databases. Reference searching was applied to key systematic reviews of economic evaluations.[7-9] As part of a general 'call for evidence' for the guideline, experts and stakeholders were contacted to locate unpublished studies and registers of ongoing research were examined. Results from this call were reviewed for inclusion in the economic evidence review.

The search process has been documented in line with the principles outlined in the NICE Guidelines Manual (2014) [1] to ensure transparency, and the references located were managed using RefWorks Software. Audit information on the searches is provided in Appendix D.

2.1.2 Screening and selection of full papers

The records were screened by two reviewers (CM/JF) using the information available in the title and abstract (where provided). Citations with a title but no abstract were assessed for relevance based on the title only. To ensure a high degree of inter-rater reliability when assessing relevance, the two reviewers independently screened a sample of 20 studies against the inclusion criteria and discussed any relevant issues before screening the rest of the studies independently. There were no disagreements between the reviewers. Full copies of the papers selected at the screening search were requested. On receipt, the selection criteria were applied to each full paper by one reviewer (JL) and checked independently by another (CM).

Inclusion and exclusion criteria are described below.

Population

Included: Studies carried out on the general population (adults and children), with a particular interest in those groups at greater risk of poor oral health and those groups who are less able to access dental services, such as:

- Children aged 5 and under;
- Adults aged over 65;
- People on a low income;
- People who were homeless or who frequently changed the location where they lived (for example, traveller communities);
- People from some black and minority ethnic groups (for example, those of South Asian origin);
- People who chew tobacco;
- People with mobility difficulties or a learning disability and who live independently in the community;
- Children and young people who were looked after, or who are given support to live independently in the community.

Studies conducted in any Organisation for Economic Co-operation and Development (OECD) country or countries were eligible for inclusion[1], with priority given to studies from England or settings that are thought to be similar to the UK NHS.

Excluded: Studies of anyone living in residential care or other non-community dwelling populations (e.g. prisoners, hospitalised patients).

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[1] Members of the OECD in 2013 were as follows: Australia; Austria; Belgium; Canada; Chile; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; Iceland; Ireland; Israel; Italy; Japan; Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States of America

Interventions
Included: Strategies aimed to convey oral health promotion advice, such as:

- Verbal information
- Practical demonstrations
- Leaflets, posters and other printed information
- New media, webcasts, etc.

We included studies with interventions provided in any settings, including mainstream or special educational preschools/nurseries, primary or secondary schools and workplaces.

Excluded:

- Interventions that were part of a broader health promotion initiative (such as smoking cessation and drug and alcohol services) where the oral health promotion advice used was unclear.
- Interventions providing advice solely about prevention of dental trauma (such as the need to use mouth guards in sports to prevent injuries and tooth loss)
- Oral health interventions for people with orthodontic and fixed appliances

Note that the effectiveness review team specified provision of interventions outside of a dental clinic environment as an exclusion criterion.[3] Consequently, there were two evaluations that they excluded, but which we included in our review [10,11] (see section 2.2.3 below). These papers are summarised below, but could be disregarded if they are considered to be outside of the scope of this guideline.

Comparators
Included:

- no programme or no intervention
- minimal programme or intervention
- usual care

Outcomes
Included:

- Dental health team's knowledge, ability, intentions and practice.
- People's experience of visiting the dentist (e.g. satisfaction with advice).
- Patients' knowledge and ability to improve and protect their oral health.
- Changes in dental patients' oral health behaviours.
- Oral health of people who go to the dentist (incidence and prevalence of oral cancers, tooth decay, gum disease and dental trauma).
- Patients' quality of life, including social and emotional wellbeing

Oral health outcomes include changes in incidence and prevalence in:

- Dental caries;
- Decayed, missing, filled teeth (DMFT) or decayed, missing, filled surfaces (DMFS);

- Periodontal disease scores (e.g. bleeding gums, number of pockets);
- Oral cancer.

Modifiable behaviour include changes in:

- Fluoride use;
- Oral hygiene behaviours;
- Brushing/flossing;
- Dietary behaviour (sugar consumption);
- Dental practice attendance.

Excluded: Studies where the intervention and comparator outcome results are not assessed separately

Study design

Studies were eligible for inclusion if they reported full economic evaluations or both costs and health consequences of an interventions and comparator.

The following study types could be included:

- Cost-consequences analysis;
- Cost-benefit analysis;
- Cost-utility analysis;
- Cost-effectiveness;
- Cost-minimisation.

Excluded:

- Costing studies, 'burden of disease' studies and 'cost of illness' studies, which did not report data to inform a model.
- Studies that did not meet the minimum criteria for applicability and methodological quality.

2.1.3 Applicability and quality appraisal of studies

The applicability (of the study to the current English context) and quality of each included paper was assessed using the template checklist for economic studies (see Appendix I in the NICE Methods Guide (2012)[1]). One reviewer completed the checklist (JL) and this was checked by the second reviewer (CM), with differences marked up and discussed.

Applicability of economic evaluation to the public health guidance

The applicability of each study to the English public sector was judged from responses to a series of questions (1.1 to 1.8) in the Quality Appraisal Checklist for economic evaluations [1]. The questions considered aspects of applicability related to the study population, intervention, comparator, setting, perspective, benefits and costs. An overall judgment on the applicability of each economic evaluation to the current English public sector was made using the following definitions:

- *Not applicable*: The study fails to meet one or more of the applicability criteria, and this is **likely to** change the conclusions about cost-effectiveness;

- *Partially applicable*: The study fails to meet one or more of the applicability criteria, and this **could** change the conclusions about cost-effectiveness;
- *Directly applicable*: The study meets all of the applicability criteria or fails to meet one or more applicability criteria but this is unlikely to change the conclusions about cost-effectiveness.

Assessment of study quality

The overall assessment of study quality indicates whether an economic evaluation provides evidence from a methodologically robust study and hence whether its conclusions about cost-effectiveness are potentially useful to inform the Public Health Advisory Committee's (PHAC) decision-making. Studies were classified using the following definitions:

- *Very serious limitations* (-): The study fails to meet one or more quality criteria and this is highly likely to change the conclusions about cost-effectiveness. Such studies should usually be excluded from further consideration;
- *Potentially serious limitations* (+): The study fails to meet one or more quality criteria and this could change the conclusions about cost-effectiveness;
- *Minor limitations* (++): The study meets all quality criteria, or the study fails to meet one or more quality criteria but this is unlikely to change the conclusions about cost-effectiveness.

2.1.4 Data extraction

Data were extracted from each included study using cost-effectiveness evidence tables, and drawing on the template provided at Appendix K in the NICE Methods Guide (2012)[1]). The data extracted included study design, setting, population, intervention and control, cost sources, outcomes and modelling methods.

2.1.5 Data synthesis and presentation of results

The economic evaluations were too heterogeneous to support meta-analysis and are reported as a narrative. Study characteristics, applicability and methodological quality were summarised and the results are discussed below. The results were synthesised into evidence statements grouped by intervention, reflecting the balance of the evidence, its strength (quality, quantity and consistency) and applicability.

The categories used to describe the strength (quality, quantity and consistency) of evidence are:

- **No evidence** – no evidence or clear conclusions from any studies;
- **Weak evidence** – no clear or strong evidence/conclusions from high quality studies and only tentative evidence/conclusions from moderate quality studies
- or clear evidence/conclusions from low quality studies;
- **Moderate evidence** – tentative evidence/conclusions from multiple high quality studies, or clear evidence/conclusions from one high quality study or multiple medium quality studies, with minimal inconsistencies across all studies;
- **Strong evidence** – clear conclusions from multiple high quality studies that are not contradicted by other high quality or moderate quality studies;
- **Inconsistent evidence** – mixed or contradictory evidence/conclusions across studies.

2.2 Results

2.2.1 Search results

The PRISMA flow diagram is shown in Appendix E. The search yielded a total of 3,589 records, after removing duplicates. Of these, 47 papers were assessed for eligibility based on full text. Of the full text articles reviewed, 37 were excluded from our review (see Appendix F).

One study (Hietasalo et al 2009 [12]) that we excluded was included in the effectiveness review (Kay et al. 2014 [3]). Our grounds for exclusion were that the intervention group received a more intensive package of preventive treatment than the control group, such that the effect of oral health advice could not be isolated. For consistency we reviewed this paper and report on its findings below, but highlighting the possibility of confounding from differences in preventive treatment.

2.2.2 Summary of included studies

In the end eleven studies were reviewed.[2,10-23] All reported estimates of resource use and/or costs associated with oral health education interventions in the context of comparative experimental or observational studies. Descriptions of the methods and results of the included studies are provided in the Evidence Tables in Appendix G. The papers are categorised below according to the age of the study sample at baseline and intent of intervention.

Prevention of early childhood caries in infants

Three studies (Kowash et al. 2006 [14], Pukallus et al. 2013 [2] and Holst & Braune 1994 [13]) related to oral health education starting in the child's first year, with the aim of preventing caries before the age of four (see Table 3). All three studies recruited parents or carers of children who were participating in a preventive programme, and compared outcomes with no-intervention controls who were not contacted until the final outcome assessment at age 2-4. The studies were conducted in populations at high risk of caries: in socio-economically deprived areas of the UK (Kowash et al. 2006) and Australia (Pukallus et al. 2013); or a screened cohort in Sweden (Holst & Braune 1994). The intervention programmes included provision of oral health information to parents, but differed in location and mode of information delivery (by telephone, face-to-face at home or in a dental clinic), and in the intensity and frequency of contact (from 3 six-monthly phone calls, up to 9 three-monthly home visits). The study by Kowash et al. (2006) compared four active programmes: three programmes with three-monthly contact (focussing on advice on diet, oral hygiene or both), and a programme of annual advice on diet and oral hygiene. The programme evaluated by Pukallus et al. (2013) included provision of free toothpaste and brushes that were not available to the control group, potentially confounding the effects of the telephone advice. All three studies used measures of dental decay for the child (caries incidence or defs/t) as their primary outcome. Kowash et al. (2006) and Pukallus et al. (2013) calculated costs associated with the delivery of the preventive programme and dental care, and reported results in the form of a cost-effectiveness ratio (cost per defs prevented or cost per case of caries incidence prevented). The study by Holst & Braune (1994) was not an economic evaluation, and only presented estimates of the mean time up to age 4 per child (in minutes) by dentists and dental assistants.

Prevention of caries in children with primary teeth

Three studies (Wennhall et al. 2010 [10], Blinkhorn et al. 2003 [15] and Vermaire et al. 2014 [16]) related to oral health education programmes to prevent caries in children older than one year, but with predominantly primary dentition (see Table 4). These were based on a range of study types: individual (Vermaire et al. 2014) and cluster (Blinkhorn et al. 2003) randomised controlled trials; and a cohort study with retrospective control group (Wennhall et al. 2010). The studies were conducted in deprived areas in the UK (Blinkhorn et al. 2003) and Sweden (Wennhall et al. 2010), and in a large dental clinic in the Netherlands (Vermaire et al. 2014). In all cases, measures of caries incidence (defs, dmfs/t, DMFS) were used as the primary outcome. Blinkhorn et al. (2003) only estimated the costs of the health promotion visits. Wennhall et al. (2010) and Vermaire et al. (2014) also estimated costs of dental treatment. All three studies suffered from some degree of imbalance between groups in the provision of fluoride or other preventive treatments. In the Wennhall et al. (2010) study, the intervention programme included provision of free fluoride tablets and toothpaste, which were not provided for the control group. In the Blinkhorn et al. (2003) study, those in the control arm were given a single tube of toothpaste, whereas those in the intervention groups received additional products as needed. The Vermaire et al. (2014) study compared a programme of 'non-operative caries treatment and prevention' (NOCTP) with increased professional fluoride application (IPFA), and a standard dental care control. The comparison of interest for this review is NOCTP versus standard care. However, the effect of oral health advice in the NOCTP intervention may be confounded due to the increased frequency of fluoride varnish and preventive treatment.

Prevention of caries in children with permanent teeth

Hietasalo et al. (2009)[12] conducted an economic evaluation based on the RCT of an oral health promotion intervention for children aged 11-12 with at least one carious lesion (Hausen et al. 2007)[24]. The intervention was delivered by dental hygienists and included an individually-designed programme of diet and dental hygiene advice, as well as preventive treatments (fluoride and chlorhexidine varnishes) as required, and provision of free materials (toothpaste, toothbrushes and fluoride lozenges). On average, members of the experimental group had 12.4 sessions with the hygienist over 3.4 years of follow-up. The control group received 'usual care', mostly delivered by dentists. Although the control group did receive some preventive treatment, including up to two applications of fluoride varnish during the 3.4 year follow-up, this was considerably less than that received by the intervention group. This imbalance in preventive treatment between the arms makes it difficult to assess the impact of oral health promotion advice per se. The economic evaluation was a 'within-trial' study that estimated changes in DMFS and total costs of preventive and restorative dental care between baseline and end of follow-up.

Table 3. Summary of included studies: *infants*

Study	Population	Intervention(s)	Outcomes	Study design	Notes
Holst 1994 [13]	Infants (birth cohort) in southern Sweden.	– Screening for caries risk and oral health information for 'at risk' children by dental assistant in small town clinic – Usual care (other children in county)	Follow up to age 4. Caries (% with dfs=0, >=4deft, >=8defs); time spent per child by dentists and dental assistants.	Cohort with retrospective control group Resource use	No estimates of costs. The content of the intervention is not well described.
Kowash 2006 [14]	Infants (8 months) from community in deprived areas in Leeds, UK	– Oral health education at home over 3 years: A) 3-monthly, diet; B) 3-monthly, oral hygiene; C) 3-monthly diet and oral hygiene; D) annual diet and oral hygiene. – Control – no contact until follow-up	Follow up to age 3. Dental health of child (dmfs/t) and mother (DMFS/T); costs and savings for intervention and dental care (UK £, year not stated).	Cohort with concurrent control group CBA and CEA	Used simple methods and assumptions to estimate costs and savings from avoided caries. Methods for calculating benefit/cost and cost/effectiveness ratios unclear.
Pukallus 2013 [2]	Infants (6 months) in disadvantaged area of Queensland, Australia	– Telephone oral health promotion at 6, 12 & 18 months – + toothpaste and brushes posted – Usual care (no previous contact with dental service)	Follow up to age 2 (and modelling to age 6) Caries incidence; cost of intervention and dental care (2012 UK £)	Cohort with retrospective controls CEA with Markov model	Good quality economic evaluation, although effects were limited to incidence of caries. Programme included free dental hygiene products (not in control group).

Table 4. Summary of included studies: *children with primary teeth*

Study	Population	Intervention(s)	Outcomes	Study design	Notes
Blinkhorn 2003 [15]	`At-risk' children (1-6 years) in deprived areas in the Northwest, UK	– Oral health education at dental practices (up to 8 visits over 2 years) + fluoride toothpaste and brush – One visit + one tube of fluoride toothpaste	2 year follow up Dental health (dmft/s, plaque); knowledge attitudes & skills; cost of intervention (UK £)	Cluster RCT CCA	Not a full economic evaluation – only costs of health promotion visits included. More fluoride products provided free to test group
Wennhall 2010 [10]	Children (age 2) in low socio-economic multicultural urban area in southern Sweden	– Outreach education and tooth brushing training delivered over 6 sessions by dental nurse + fluoride tablets and toothpaste – Usual care control (retrospective, non-randomised cohort)	3 year follow up Caries (defs); costs of programme and savings from prevented defs (2008 SEK €)	Cohort with retrospective control group CMA	Limited outcomes and costs reported. Costing methods simple but quite well done. Free oral hygiene products provided in programme (not controls)
Vermaire 2014 [16]	Children (age 6) recruited at routine dental check-up from large dental clinic, Hertogenbosch, the Netherlands	– Non-operative caries treatment and prevention (NOCTP) delivered by dentists: assessment; oral health advice; preventive and restorative treatment as needed. – Increased professional fluoride application (IPFA): standard care plus two extra fluoride applications per year. – Standard dental care: two check-ups per year with fluoride application and treatment as needed.	3 year follow up DMFS prevented; resource use (contact time with dentist and dental auxiliaries); costs of dental care and costs to parents (travel, out of pocket, time) (2011 €)	RCT CEA	Well conducted and reported within-trial CEA. Reports cost per DMFS prevented from societal and healthcare perspective. NOCTP intervention included more frequent preventive treatment than the standard care control.

Table 5. Summary of included studies: *children with permanent teeth*

Study	Population	Intervention(s)	Outcomes	Study design	Notes
Hietasalo et al. (Hausen et al. RCT) [12,24]	Children (age 11-12) with at least one active initial caries lesion attending public dental clinics in Pori, Finland	– Individually designed patient-centred regimen delivered by dental hygienists. Included preventive treatments (fluoride and chlorhexidine varnish) and provision of materials (fluoride toothpaste, toothbrushes and fluoride lozenges), as well as oral health advice. – The control group received usual care, mostly provided by dentists. Although they received some preventive treatment (up to two applications of fluoride during follow up period), this was considerably less than that provided to the intervention group. Both groups were subject to a community-level oral health promotion campaign during the study period.	DMFS prevented (difference between arms in individual change in DMFS between baseline and end of study); resource used (dental care and treatments provided during study period); and costs (healthcare provider perspective) (2004 €)	RCT CEA	Well conducted and reported within-trial cost-effectiveness analysis. Costing methods were thorough. Reported incremental cost per DMFS avoided. There was an imbalance between the arms in the preventive treatment and materials provided.

Studies in adults

Four studies (Hugoson et al. 2003 and 2007 [17-19], Ide et al. 2001 [20], Jönsson et al. 2009, 2010 and 2012 [21-23] and Mariño et al. 2014 [11]) evaluated oral health promotion strategies in adults. These studies were very heterogeneous in terms of the setting and population and the nature of the intervention investigated (see Table 6).

The study by Hugoson et al. (2003 and 2007) was based on an RCT to evaluate oral health education programmes for young adults (mean age 20-27) recruited from general dental clinics in Sweden. The study compared three oral health education programmes (the intensive 'Karlstad' model and a more basic programme delivered individually or in groups) with a usual care control. All three active programmes included provision of fluoride toothpaste, which the control group did not receive. This may confound evaluation of the active vs control comparison. The study included a three-year follow-up period, with self-reported impacts on knowledge, attitudes and behaviour, caries and gingival health. Economic outcomes were limited to time input required from dental hygienists and from patients, assuming full attendance at scheduled health education sessions.

The Ide et al. study (2001) evaluated an oral health education programme in the workplace; in a shipyard in Japan. Groups of men in existing working teams were invited to attend a series of lunchtime education sessions, one-to-one instruction, examination and feedback. Total costs of dental care were obtained from insurance records for the year before and for three years after the intervention for participants and matched controls. The costs of delivering the preventive programme were not estimated.

Jönsson et al. (2009, 2010 and 2012) compared two educational programmes for adults with moderate to advanced periodontitis alongside a non-surgical treatment programme. One group received an Individually-Tailored Oral Health Education Programme (ITOHEP) based on cognitive behavioural and motivational interviewing techniques. The other received a Standard Treatment (ST) oral health programme. Both interventions were delivered by dental hygienists in a single clinic. The primary outcome was success in achieving pre-set individual criteria, based on bleeding, plaque and pocketing. Total costs of dental care over a twelve month period were estimated, and an incremental cost per successful case was calculated.

Finally, Marino et al. (2014) compared oral health information delivered by lay educators at social clubs with a programme delivered by a hygienist at a dental clinic for an Italian immigrant population (mean age 72) in Melbourne, Australia. The study used a non-randomised comparative study design. Outcomes were measured after delivery of the programme (four months follow up), and included a plaque index, gingival index and self-efficacy questionnaire. Costs of delivering the programmes were estimated, but no longer-term cost or oral health outcomes were reported.

Table 6. Summary of included studies: ***adults***

Study	Population	Intervention(s)	Outcomes	Design	Notes
Hugoson 2003 and 2007 [17,19]	Young adults (age 20-27) recruited from general dental clinics in Jönköping, Southern Sweden	1. Karlstad model – oral health education by dental hygienist (6 individual sessions per year for 3 years) + Fluoride toothpaste 2. Basic individual - oral health education by dental hygienist (3 individual sessions in one year) + Fluoride toothpaste 3. Basic group – education as 2 except slightly longer sessions in groups of 10 + Fluoride toothpaste 4. Usual care control	3 year follow up (in first phase of study) Knowledge, attitudes and behaviours (22 item questionnaire); caries and gingival health (exam) not presented in this paper; time (min) per patient for programmes 1-3 by dental hygienist and by patient	RCT Resource use	Results presented in this paper do not provide oral health outcomes. Economic outcomes limited to time required for interventions by hygienists and patients (in minutes). Controls not given free fluoride toothpaste
Ide 2001 [20]	Men working in shipyard in Nagasaki, Japan	1. Workplace oral health education programme comprising: orientation sessions by dentist; examination; general education and one-to-one instruction (4 10-min sessions) by hygienist; group counselling; and recall visits to hygienist. 2. No intervention	Costs of dental care for one year before and 3 years after intervention	Costing study (case-control)	Only estimated dental care costs. Did not estimate cost of preventive programme, or health outcomes.
Jönsson 2012 [23]	Adults with moderate to advanced periodontitis (mean age 51), Sweden	1. Individually-tailored oral health educational programme based on cognitive behavioural approach and motivational interviewing delivered by hygienists 2. Standard oral health educational programme delivered by hygienists	1 year follow up Periodontal outcomes (success against pre-set individual criteria; bleeding, plaque, pockets); costs (2007 SEK)	RCT CEA	Both groups received non-surgical periodontal treatment alongside the education programme. Used simple methods to estimate cost-effectiveness based on a single (quite small) study in one clinic.

Study	Population	Intervention(s)	Outcomes	Design	Notes
Mariño 2014 [11]	Older adults (mean 72 years) from Italian immigrant population, recruited from social clubs in Melbourne, Australia	1. Oral Health Information Seminars (ORHIS) by lay educators at social clubs: ten 20-min seminars; four 10-min one-to-one demonstrations; leaflets; oral hygiene products. 2. Oral health education programme by hygienist at clinic: two 20-min education sessions; four 8-min one-to-one chair side demonstrations; oral hygiene products.	4 months (?) Plaque Index; Gingival Index; self-efficacy questionnaire (reported in Mariño 2013) Costs of ORHIS and comparator programmes	Non-randomised controlled trial CMA	Assumed equal effectiveness between the ORHIS and comparator programmes, without supporting evidence. Used simple methods to estimate cost of ORHIS and comparator programme. Does not provide evidence of relative cost-effectiveness.

2.2.3 Applicability and quality of included studies

The quality checklist for economic studies was applied to the eleven studies described above (see Appendix H). The results of the applicability assessment are summarised in Table 7 below.

Ide et al. (2001) was judged to be not applicable to the UK context, as it involved a workplace intervention in a shipyard in Japan. This study was excluded from further consideration. Seven other studies were conducted in countries with a similar dental care context to the UK, but with some differences, including Sweden (Holst et al. 1994, Wennhall et al. 2010, Hugoson et al. 2003 and 2007, and Jönsson et al. 2012), Finland (Hietasalo et al. 2009), Australia (Pukallus et al. 2013 and Mariño et al. 2014) and the Netherlands (Vermaire et al. 2014).

Two studies (Vermaire et al. 2014 and Hietasalo et al. 2009) included increased frequency of professional fluoride application and other preventive treatments in the intervention arm compared with the controls. This imbalance makes it difficult to evaluate the effects of the oral health advice per se, and it is debateable whether these studies should have been excluded from the review. In four of the remaining studies (Pukallus et al. 2013, Wennhall et al. 2010, Blinkhorn et al. 2003 and Hugoson et al. 2003 and 2007), there was also some imbalance between the intervention and control arms in provision of free oral health products, including fluoride tablets, toothpaste and toothbrushes. This might also to some extent have confounded estimates of the effects of oral health advice.

Two studies that we included were excluded from the effectiveness review (Kay et al. 2014 [3]) on the grounds that the intervention was not delivered in a dental practice setting: in the Wennhall et al. (2010) study the intervention was delivered by dental nurses in a community outreach facility; and Mariño et al. (2014) compared a community-based program delivered by a lay health worker with 'chair side' oral hygiene instruction by a dental hygienist at a hospital based public dental clinic. Two other studies included in our review were also delivered in community settings. The Pukallus et al. study (2013) evaluated a telephone-delivered intervention for mothers of a birth cohort. The mothers were recruited by oral health personnel from public birthing facilities, and telephoned when their children reached 6, 12 and 18 months. Kowash et al. (2006) evaluated an early childhood caries prevention programme delivered by dental health educators (a senior paediatric surgical nurse and a senior dental hygienist) in a community outreach setting.

None of the studies performed well in terms of applicability to the NICE public health reference case. In particular, none went beyond measures of oral health to quantify effects on quality of life or well-being. However, given the limited economic evidence base for this guideline, we did not exclude other studies from further consideration on this basis.

The methodological quality of the included studies is summarised in Table 8. Overall it was judged that only one study (Pukallus et al. 2013) was of a good methodological quality, meeting current standards in the field of economic evaluation with only minor limitations. This was the only study that adopted a modelling approach, to extrapolate outcomes beyond follow up. Four studies were judged to be of a reasonable methodological standard, but with potentially serious limitations (Hietasalo et al. 2009, Wennhall et al. 2010, Jönsson 2012, and Vermaire et al. 2014). The other six studies had serious methodological limitations.

Table 7. Applicability of included studies

Study	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Blinkhorn	Yes	Yes?	Yes	No	Partly	No	No	No	Partially (+)
Holst	Yes	Yes	Partly	No	No	No	No	No	Partially (+)
Kowash	Yes	Yes?	Yes	Yes	No	No	No	No	Partially (+)
Pukallus	Yes	Yes?	Partly	Yes	No	Yes	No	No	Partially (+)
Wennhall	Yes	Yes?	Partly	No	No	Yes	No	No	Partially (+)
Vermaire	Yes	No?	Partly	Yes	No	Yes	No	Yes	Not applicable (-)
Hietasalo	Yes	No?	Partly	Yes	Partly	No	No	No	Not applicable (-)
Hugoson	Yes	Yes?	Partly	No	No	No	No	No	Partially (+)
Ide	Yes	Yes	No	Yes	No	No	No	No	Not applicable (-)
Jönsson	Yes	Yes	Partly	Yes	No	Unclear	No	Yes	Partially (+)
Mariño	Yes	Yes?	Partly	Yes	No	NA	No	No	Partially (+)

1.1 Is the study population appropriate for the topic being evaluated?
1.2 Are the interventions appropriate for the topic being evaluated?
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?
1.4 Was/were the perspective(s) clearly stated and what were they?
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?
1.6 Are all future costs and outcomes discounted appropriately?
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?
1.9 Overall judgement

Table 8. Quality of included studies

Study	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12 Overall
Blinkhorn	NA	No	No	Partly	No	No	Unclear	Unclear	No	No	Unclear	Very serious (-)
Kowash	No	No	No	No	No	Yes	Unclear	Unclear	Yes	No	Unclear	Very serious (-)
Pukallus	Yes	No	No	Partly	No	No	Yes	Yes	Yes	Yes	No	Minor (++)
Holst	NA	No	No	Yes	No	No	Yes	NA	Yes	No	Unclear	Very serious (-)
Wennhall	NA	No	No	Unclear	Partly	No	No	Yes	No	Partly	No	Potentially serious (+)
Vermaire	NA	No	No	No	No	Partly	Yes	No	Yes	Partly	Unclear	Potentially serious (+)
Hietasalo	NA	No	No	Partly	Partly	Partly	Yes	Partly	Yes	No	Unclear	Potentially serious (+)
Hugoson	NA	Partly	No	Partly	Yes	No	No	NA	No	No	Unclear	Very serious (-)
Mariño	NA	No	No	No	No	No	Unclear	Unclear	No	No	No	Very serious (-)
Jönsson	NA	No	No	Yes	Yes	Yes	Yes	No	Yes	Partly	No	Potentially serious (+)
Ide	NA	Partly	No	Yes	No	No	Yes	Yes	No	No	Unclear	Very serious (-)

2.1 Does the model structure adequately reflect the nature of the topic under evaluation?
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?
2.3 Are all important and relevant outcomes included?
2.4 Are the estimates of baseline outcomes from the best available source?
2.5 Are the estimates of relative 'treatment' effects from the best available source?
2.6 Are all important and relevant costs included?
2.7 Are the estimates of resource use from the best available source?
2.8 Are the unit costs of resources from the best available source?
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?
2.11 Is there any potential conflict of interest?
2.12 Overall assessment

2.2.4 Summary of findings in children

Oral health education to prevent caries: infants

Three studies provided information about resource use, costs or cost-effectiveness associated with the delivery of oral health advice starting in the first year of life, to prevent early childhood caries: (Holst & Braune 1994, Kowash et al. 2006 and Pukallus et al. 2013).

Holst and Braune (1994) evaluated a programme of oral health screening and provision of information for parents of children (age one at baseline) at high risk of caries, implemented by a dental assistant at a small-town dental clinic in Sweden. They reported that although dental health was initially worse in the test clinic than in controls from the rest of the County, by age four more children in the test clinic had no decayed or filled tooth surfaces: 83/102 (81%) compared with 1030/1335 (77%). However, there were no significant differences in the proportions of children with 4 or more decayed, filled or extracted teeth, or with 8 or more decayed, filled or extracted surfaces at age four. Time spent by dentists and dental assistants per child up to the age of four was lower in the test clinic than in the rest of the county: 71 min vs 90 min for dental assistants; and 27 min vs 60 min for dentists. No estimates of uncertainty were presented around these figures, and no other cost estimates were made.

Kowash et al. (2006) found a lower incidence of caries over three years in children (age 8 months at baseline) whose parents were offered home-based oral health advice, compared with controls: 2/179 (1%) versus 18/55 (33%). However it was not possible to compare outcomes between four programmes, which differed in the focus of advice (diet, oral hygiene or both) and intensity (three-monthly versus annual contact), as three of the four groups had no incident cases. The estimated costs of the education programmes were £12,891 and savings from avoided fillings and general anaesthesia were £36,386 (for the cohort of 228 children, 179 of whom completed assessment) (UK £, year not stated, undiscounted). Methods used to calculate the programme costs were not explained. The estimate of savings was based on a conservative comparison between mean dmfs in the one intervention group with incident caries (three-monthly education focussing on diet advice) in the control group: 0.29 (SD1.64) versus 1.75 (SD 5.09), a difference of 1.46. Estimates of benefit/cost and cost/effectiveness ratios were presented, but methods of calculation were poorly explained. No estimates of uncertainty were presented.

Pukallus et al. (2013) estimated that their programme of telephone oral health education delivered by a dental assistant in a socially disadvantaged area in Queensland would result in the prevention of 43 caries and a net cost saving of £69,984 up to the age of 6 per 100 infants (2012 UK £, 5% annual discounting of costs and effects). This result was robust to sensitivity analysis. The economic analysis was well conducted and reported, and used Markov modelling to extrapolate results from age 2 to 6. However, the results may be subject to confounding due to the provision of free toothbrushes and toothpaste to the intervention group, but not to the controls. The results also rest on a single study in a district in Australia, with a small non-randomised control group (n=185 in the intervention cohort, n=40 controls).

Evidence statement 1: Cost-effectiveness of oral health education to prevent early childhood caries
There is weak evidence that programmes to deliver oral health promotion messages to parents or guardians of children in the first year of life can reduce the incidence of early childhood caries and expenditure on dental care. No studies allowed comparison of different methods for provision of oral health advice, or assessment of impacts of education programmes on outcomes other than caries incidence. One good quality (++) economic evaluation (Pukallus et al. 2013) estimated the cost-effectiveness of a programme of telephone oral health education delivered by an oral health therapist at 6, 12 and 18 months, with follow up to 24 months, and extrapolation by Markov model to 6 years. It estimated that 43 caries would be prevented and £69,984 saved (2012 UK £) per 100 infants over the 6 year period. This result was robust to sensitivity analysis. However, the findings are based on a single study, with a small and non-randomised control group. It is also subject to confounding from provision of free toothpaste and toothbrushes to the intervention group, but not to the controls. One study (Kowash et al. 2006) of poor methodological quality (-) evaluated the cost-effectiveness of four, three-year programmes of education, delivered at home by oral health educators in socio-economically deprived areas of Leeds. This reported a total cost of £12,891 for delivery of the education programmes, and an estimated saving of £36,386 for avoided fillings and general anaesthesia (based on a reduction in mean dmfs of 1.46). One other study (Holst and Braune 1994) of poor methodological quality (-) evaluated a programme of oral health screening and provision of information for parents of children (age one at baseline) at high risk of caries, implemented by a dental assistant at a small-town dental clinic in Sweden. It reported an improvement in the proportion of children with no decayed or filled tooth surfaces at age 4, but noted that most of the 'at risk' children had still developed caries by age four. Time spent by dentists and dental assistants per child up to the age of four was estimated at 50 minutes per child less in the test clinic than in the rest of the county.

Oral health education to prevent caries: children age 1-6

Three studies (Blinkhorn et al. 2003, Wennhall et al. 2010 and Vermaire et al. 2014) provided estimates of cost or cost-effectiveness for oral health education programmes to prevent caries in primary teeth in children recruited between the ages of 1 and 6 years.

Blinkhorn et al. (2003) estimated the cost of a programme in which Primary Care Trusts seconded dental health educators to general dental practices in socio-economically deprived areas in Northwest England. At clinics randomised to intervention, educators provided one-to-one counselling to parents of children aged between 1 and 6 years, who were assessed by dentists to be at high risk of caries. Participants were invited to two initial sessions, with recall every four months over two years, and given advice on diet and dental hygiene, hands-on demonstration, fluoride toothpaste and brush, and leaflets. In the control practices, parents and children were seen once at baseline and given instruction on tooth brushing and a single tube of fluoride toothpaste. The authors concluded that parents in the test practices had significantly better knowledge, attitudes and behaviour after two years of follow up than parents in the control practices, but that no significant differences were found in dental health outcomes at final examination: mean dmft in deciduous molars and canines 2.65 (SD 2.56) for the test group compared with 3.22 (SD 2.85) in the controls. Because of this lack of significance, they did not conduct a full economic evaluation, and merely presented an estimate of the cost of education sessions (£40 for a two-hour session with ten parents).

Wennhall et al. (2010) estimated the cost-effectiveness of diet and dental hygiene advice delivered by a dental nurse in an outreach facility in a socio-economically deprived area in Sweden, up to 6 times between the ages of 2 and 5. Participants in the programme were given free fluoride tablets and toothpaste, which may have confounded the results. The difference in mean defs by age 5 was 3 (95% 1.66 to 4.34). The estimated cost of dental care in programme participants was €310 per child compared with €96 in the control group, and there was an additional saving of €184 due to avoided fillings (2008 Euros at 3% annual discount rate). The discounted net cost per child (€30) was sensitive to uncertainty over the estimated mean dmfs prevented (from a cost of €109 to a saving of €61 at the lower and upper 95% confidence limits of dmfs prevented).

Vermaire et al. (2014) compared costs and outcomes with standard dental care and two experimental interventions in a sample of children (age 6) recruited in a large dental clinic in the Netherlands. The experimental interventions were; 1) standard care plus Increased Professional Fluoride Application (IPFA); and 2) standard care plus Non-Operative Caries Treatment and Prevention (NOCTP) programme comprising individualised recall, assessment, oral health advice and fluoride varnish and treatment as needed. Effects on caries incidence (dmfs or DMFS), resource use and costs were estimated over three years of follow-up. Caries incidence was 0.54 in the control group, 0.42 in the IPFA group and 0.34 in the NOCTP group (statistical significance not reported). Over this same period, estimated total costs (including dental care and treatment, parental time and travel) were: €298 (279 to 317) in the control group; €476 (451 to 500) in the IPFA group; and €318 (297 to 340) in the NOCTP group (2011 Euros, discounted at 4% per year). This suggests that IPFA was dominated by NOCTP (it was more expensive and less effective). Comparison of NOCTP with control yielded an incremental cost per decayed, missing or filled surface avoided of €100 from a societal perspective, or €30 from a health care perspective (discounting costs at 4% and DMFS at 1.5% per year). Non-parametric bootstrapping showed considerable uncertainty around these results (at a willingness to pay of €50 per decayed, missing or filled surface avoided the probability that NOCTP would be cost-effective was approximately 30% from a health care perspective or 70% from a societal perspective). The results may also be subject to bias because follow-up was significantly lower in the NOCTP arm (68%) than in the control arm (85%). It is also unclear whether the reported reduction in caries incidence with NOCTP compared with standard care was attributable to the oral health advice or to additional preventive treatments in the NOCTP programme, although IPFA alone was estimated to be more expensive and less effective than NOCTP.

Evidence statement 2: Cost-effectiveness of oral health education to prevent caries in children aged 1-6

There is inconsistent and weak evidence that programmes to deliver oral health promotion messages starting between the ages of 1 and 6 years are cost-effective for the prevention of childhood caries.

One study (Blinkhorn et al. 2003) with very serious methodological limitations (-) conducted in dental practices in socio-economically deprived areas in the northwest of England aimed to estimate the effects and costs of an educational intervention for children (aged 1-6) assessed by dentists as being at risk of caries. Participants from the intervention practices had fewer caries after two years of follow up, but this difference was not statistically significant. The only cost information provided in the paper was an estimate of the cost per two-hour session of counselling for 10 children. The results of this study are therefore inconclusive.

Another study (Wennhall et al. 2010) with potentially serious limitations (+) estimated the cost-effectiveness of oral health education delivered by a dental nurse in an outreach facility in a socio-economically deprived area in Sweden, up to 6 times between the ages of 2 and 5. Mean defs after three years of follow up was significantly lower in the intervention group than in non-randomised controls: mean difference 3 (95% CI: 1.66 to 4.34). The incremental cost of the programme was estimated at €30 per child, allowing for the cost of the intervention and net of routine dental care and fillings. This finding was sensitive to uncertainty around the estimated defs prevented (from a saving of €61 to a cost of €109 per child).

Finally, a study by Vermaire et al. (2014) with potentially serious limitations (+) compared standard dental care with standard care plus additional oral health advice, individual recall intervals and increased preventive treatment for children from age 6 to 9. Over this three year period, there were fewer incident caries in the intervention group than with standard care (0.34 vs. 0.54, significance not reported). The incremental cost per decayed, missing or filled surface prevented was €30 from a health care perspective and €100 from a societal perspective. Interpretation of these results depends on societal willingness-to-pay per dmfs/DMFS avoided. There was also a high level of uncertainty over these results, and possibly bias due to lower completion of follow-up in the intervention arm.

Oral health education to prevent caries: older children with permanent dentition

One study evaluated an oral health education programme for older children with permanent dentition.

The study by **Hietasalo et al. (2009)** was a generally well-conducted 'within-trial' cost-effectiveness analysis. It evaluated a programme of oral health advice, preventive treatment (fluoride and chlorhexidine varnish) and materials (toothpaste, toothbrushes and fluoride lozenges) delivered by dental hygienists compared with standard dental care in children aged 11-12 years with at least one active caries lesion, recruited from dental clinics in Finland. The mean increment in DMFS over 3.4 years of follow up was 2.56 in the intervention group compared with 4.6 in the control group (mean difference of 2.04, 95% CI 1.26 to 2.82). It is not possible to attribute this difference to oral health advice or to additional preventive treatment and materials provided to the intervention group. Over the follow-up period, the mean cost of preventive care and treatment was €496 in the intervention group and €427 for the controls: mean difference €69 (28.25 to 110.75). The incremental cost per DMFS avoided was €34. Uncertainty over these results was estimated using non-parametric bootstrapping, and illustrated using a Cost Effectiveness Acceptability Curve (CEAC). At a societal willingness to pay per DMFS avoided of €40, there is a 65% chance that the intervention would be cost-effective.

Evidence statement 3: Cost-effectiveness of oral health education to prevent caries in older children with permanent dentition
There is weak evidence that programmes to deliver oral health promotion messages to older children with permanent dentition are cost-effective for the prevention of caries. One study (Hietasalo et al. 2009) with potentially serious limitations (+) estimated the cost-effectiveness of a preventive programme delivered by dental hygienists to children aged 11-12 years with at least one active caries lesion, recruited from dental clinics in Finland. The intervention included a package of oral health advice, preventive treatment (fluoride and chlorhexidine varnish) and provision of free materials (toothbrush, fluoride toothpaste and lozenges). This was compared with a standard care control group, who were treated predominantly by dentists and received fewer preventive treatments. The intervention was associated with an increase of €69 (95% CI: 28 to 111) in dental care and treatment costs, but a reduction of 2.04 (95% CI: 1.26 to 2.82) in incident DMFS over 3.4 years of follow up. The estimated incremental cost per DMFS avoided was €34. Interpretation of this finding depends on societal willingness-to-pay per DMFS avoided.

2.2.5 Studies in adults

Three studies (Hugoson et al. 2003 and 2007, Jönsson et al. 2012, and Mariño et al. 2014) provided estimates of costs or cost-effectiveness for methods of oral health education in adult populations.

Oral health education for young adults

Hugoson et al. (2003 and 2007) conducted a limited costing study based on a complicated RCT with long-term follow-up in young adults (mean age 20-27) recruited from two dental clinics in Sweden. The initial stage of the trial compared four groups: three models of oral health promotion delivered by a dental hygienist including the intensive 'Karlstad' model, and a more basic programme delivered either individually or in groups; and a standard care control. Effects on oral health outcomes were not reported in this paper. The authors stated that self-reported effects on knowledge and behaviour after three years of follow-up were similar with the basic programmes (individual and group) as for more intensive Karlstad model. The time required for dental hygienists to deliver the programme over three years was greatest in the Karlstad model (390 minutes), compared with 125 minutes in the basic individual intervention and 20.5 minutes in basic group intervention. Patient time spent with dental hygienist over 3 years was: Karlstad (390 min); basic individual (120min) and basic group (205min).

Evidence statement 4: Cost-effectiveness of oral health education for young adults
There is weak evidence from one study (Hugoson et al. 2003 and 2007) that the resource input required to deliver the intensive 'Karlstad' programme of oral health education (up to 18 visits over three years) is greater than for more basic programmes (up to 5 visits over three years) in young adults (age 20-27 years) recruited from two clinics in Sweden, despite similar knowledge and behavioural outcomes. There were very serious limitations with this study as an economic evaluation (-), as dental care costs and outcomes were not presented.

Oral health education for adults with periodontitis

Jönsson et al. (2012) compared two educational programmes for adults (mean age 51) with moderate to advanced periodontitis. The interventions were delivered by dental hygienists alongside a non-surgical treatment programme in a periodontics clinic in Sweden. The authors found that a greater proportion of patients randomised to an individually-tailored programme based on cognitive behavioural and motivational interviewing techniques achieved pre-set goals after one year than in the standard oral health education group: 35/57 (61.4%) versus 19/56 (33.9%) ($p=0.003$). From a dental care perspective, mean costs for the individually tailored programme were SEK 6,713 over 12 months compared with SEK 6,386 with the standard educational programme. From a societal perspective (including patient out-of-pocket expenditure and time), the total cost was SEK 10,115 for individually tailored programme compared with 9,641 for standard care (2007 SEK, discounted at 3% pa). The societal incremental cost was SEK 1,724 per additional successful case.

Evidence statement 5: Cost-effectiveness of oral health education for adults with periodontitis
There is weak evidence from one RCT (Jönsson et al. 2009, 2010 and 2012) conducted in a periodontics clinic in Sweden that an individually-tailored oral health education programme (ITOHEP) based on cognitive behavioural principles and motivational interviewing is more effective at achieving pre-set treatment goals at an additional cost, compared with a standard oral health education programme for patients with moderate to severe periodontitis undergoing non-surgical periodontal treatment. Over one year, the proportion of patients achieving pre-set treatment goals was 35/57 (61%) in the ITOHEP group compared with 19/56 (34%) in the standard care group. The additional cost of education and dental care in the ITOHEP group was 327 SEK (6713 vs 6386). From a societal perspective the addition cost for the ITOHEP group was 474 SEK (10,115 vs 9,641), yielding an incremental cost per successfully treated case of 1724 SEK (approximately £242). The study had potentially serious limitations as an economic evaluation (+), as it was based on short-term follow-up and there is no estimation of uncertainty around the cost estimates or cost-effectiveness ratio.

Oral health education for older adults

Mariño et al. (2014) estimated the cost of a culturally-tailored programme of oral health information delivered by lay educators at social clubs for Italian immigrants (mean age 72) in Melbourne, Australia. Comparison with a non-randomised control group showed no significant between-group difference in the Plaque Index, but significantly greater pre-post intervention improvement in Gingival Index and self-efficacy scores in the social club group than in the no-intervention controls. However, for this 'cost-minimisation analysis', the lay-delivered programme was compared with a (hypothetical) programme of oral hygiene instruction delivered by a dental hygienist at a public dental clinic. Not surprisingly the cost of the lay education programme ($6,965 per 100 participants) was greater than that of the assumed clinic programme ($40,185 per 100 participants) (2008 Aus $). The authors assumed that the lay intervention at the social clubs would be equally effective to the clinic-based programme, and that therefore the former would be cost-effective. However, this assumption was not supported by any empirical evidence.

Evidence statement 6: Cost-effectiveness of oral health education for older adults
There is weak evidence that a culturally-tailored programme of oral health information delivered by lay educators at social clubs for Italian immigrants (mean age 72) in Australia would cost about $70 per participant, and that it is associated with better gingival health and self-efficacy outcomes (but no difference in plaque) compared with a no-intervention control. As an economic analysis, this study has very serious limitations (-), as it did not include any estimates of dental care costs or of longer-term dental outcomes. No estimates were made of uncertainty over costs.

Chapter 3. Valuation survey

3.1 Introduction

There are particular difficulties that arise in economic evaluation of dental health interventions [25-29]. One key problem is the paucity of evidence on quality of life effects, particularly with health-related utility measures suitable for calculation of Quality Adjusted Life Years (QALYs), such as the EQ-5D or SF-6D instruments.

One attempt to overcome the lack of suitable health-related utility data has been to develop a 'mapping' algorithm in order to predict EQ-5D values from an oral health-specific measure, the Oral Health Impact Profile (OHIP) [30]. The Newcastle and York EAC (NYEAC) explored the use of this algorithm in their analysis for previous NICE guidance on oral health (Approaches for local authorities and their partners to improve the oral health of their communities, NICE PH55).[25] They expressed concerns over the coefficients, resulting estimates and large prediction error from the published OHIP mapping algorithm. In addition to these issues, we note that the population used to derive the mapping algorithm mostly report 'never' or 'hardly ever' having oral health problems and the results may therefore not be generalisable to people experiencing oral health problems (other dental outcomes such as number of decayed or missing teeth are not reported). Further, application of the algorithm is problematic. In the absence of data from the OHIP measure in the clinical evidence used to inform the economic model, NYEAC had to make assumptions regarding the 'typical' response to the OHIP questionnaire that people with oral health problems would experience. These assumptions may not reflect the distribution of responses in practice. In development of NICE oral health guidance, the Public Health Advisory Committee (PHAC) expressed concerns about the data from the application of the mapping algorithm and "some members felt that neither of these measures captured the effect of different aspects of oral health on quality of life." [31]

Given the paucity of data on quality of life associated with oral health condition and concerns over using generic measures such as EQ-5D or SF-6D, we conducted a valuation survey to value oral health outcomes using a contingent valuation approach: 'willingness-to-pay' (WTP) for the prevention of oral health problems. The WTP estimates to avoid an oral health condition may be elicited directly [26] or indirectly through a Discrete Choice Experiment (DCE) [32], which is a form of conjoint analysis. We opted for a DCE approach which allows for oral health conditions to be presented according to types and levels of problem, and values to be obtained for combinations of specific oral health characteristics. This study is described below.

3.2 Methods

DCE is a widely used and accepted stated-preference method to examine preferences of the target population. In a DCE, the respondent is presented a series of choices between two or more alternative scenarios describing oral health problems and asked which they would prefer. DCE methodology assumes that respondents have an underlying (latent) utility function. This latent utility function is revealed when respondents evaluate the alternative scenarios included in each choice set and choose the alternative which gives them the greatest relative utility. The scenarios are constructed from a set of attributes (types of outcome and cost) and levels (e.g. degrees of severity of each outcome). Choices observed in DCEs are analysed using random utility theory (i.e. an error term is included to reflect the unobservable factors in the individual's utility function). [33-36]

There are a number of techniques that can be used in eliciting preferences using the DCE approach. Recent good practice guidelines by the International Society of Pharmacoeconomic and Outcomes Research (ISPOR) taskforce has established consensus on standards to use for experimental design [37] and reporting of conjoint analysis studies.[38] The guideline includes a 10-item checklist covering 1) research question; 2) attributes and levels; 3) construction of tasks; 4) experimental design; 5) preference elicitation; 6) instrument design; 7) data-collection plan; 8) statistical analyses; 9) results and conclusions; and 10) study presentation. We present information on each of these items under the following headings representing steps in the DCE design and analysis.

1. Identification of attributes and levels (including research question to be addressed)
2. Development of the survey materials and design (construction of tasks, experimental design, preference elicitation, instrument design)
3. Piloting of survey materials (data collection plan and instrument design)
4. Administration of the survey (data collection plan)
5. Analysis of the data (statistical analysis)
6. Results and conclusions (including study presentation).

3.2.1 Identification of dimensions of outcomes to be valued

The objective of the valuation study was to obtain values for oral health states that could inform the economic model. In order to obtain values for oral health outcomes it is first necessary to identify attributes (dimensions of outcomes) associated with oral health outcomes and determine appropriate levels for those attributes. The attributes and levels identified are then combined to form the scenarios that are valued by respondents to the survey. The attributes and levels for inclusion in the survey were informed by two types of information: information on the health states expected to be included in the economic model and a focussed literature review. *A priori*, two sets of attributes and levels were developed for separate surveys: one set relating to oral health outcomes for adults and another for children.

As the valuation study was conducted in parallel to the review of effectiveness of oral health promotion messages [3], it was not possible to determine which specific oral health outcomes would have sufficient evidence for inclusion in the economic model at the outset of the study. However, based on other effectiveness reviews in oral health and based on clinical advice from the Plymouth team, we expected outcomes would include measures of Decayed, Missing and Filled Teeth (DMFT), Decayed, Missing and Filled Surfaces (DMFS), measures of gum problems and dental pain. The Decayed, Missing, Filled (DMF) index is a measure of caries experience in dental epidemiology and expressed as the total number of teeth or surfaces affected. When the index is applied to teeth specifically, it is called the DMFT index, and scores per individual can range from 0 to 28 or 32, depending on whether the third molars are included in the scoring. When written in lowercase letters, the dmf index is a variation that is applied to the primary dentition. The caries experience for a child is expressed as the total number of teeth or surfaces that are decayed (d), missing (m), or filled (f). The dmft index expresses the number of affected teeth in primary dentition, with scores ranging from 0 to 20 for children.

Therefore, the attributes and levels considered for inclusion in the valuation study needed to be compatible with these measures. In order to estimate WTP, a cost attribute was required to reflect the amount of money that people are individually prepared to pay to prevent specific oral health problems. In addition, we recognised that preferences may be affected by the delivery of dental care and/or the different types of oral health message, therefore these were also considered for possible inclusion in the design. It was also expected that the effectiveness data and economic analysis would be presented separately for adults and children.

The objective of the literature review was to obtain information on the types of attributes or descriptions of oral health problems included in published valuation studies, and to identify possible levels for those attributes. A focussed literature search was conducted to identify papers reporting primary research using WTP and DCE methods to value oral health states or oral health interventions in Medline using OvidSP. The search strategy can be found in Appendix I. The search included text words and index terms which described concepts of "oral health" combined with "willingness to pay" and "discrete choice experiment". The searches were confined to English language studies only and covered all studies to date. In addition, searches in google were conducted.

The records were screened using the information available in the title and abstract. Full copies of the papers selected at the screening search were obtained. Inclusion criteria included empirical studies reporting valuation of dental health and dental health services using contingent valuation or conjoint analyses. Review studies were excluded. A standardised data extraction template was developed to extract information on some background details to the study, valuation method, sample characteristics, attributes or scenario descriptions, levels specified (for DCE), WTP estimates obtained (if any). Data on the acceptability of the descriptions of attributes to respondents and the relative importance of attributes was considered when choosing the final set of attributes for inclusion in the survey.

In addition, two surveys were consulted - the national Adult Dental Health Survey (ADHS) and Children's Dental Health Survey (CDHS).[39,40] It was anticipated that the surveys would help inform the definitions of various oral health conditions and identify appropriate levels for specific health problems (e.g. the number of missing teeth), in addition to provide a general overview of dental health conditions in the UK.

3.2.2 Development of the survey materials and design

Survey material included an information sheet, consent form, questions on socio-demographic and health status, information on oral health problems and the DCE choice questions.

The information sheet and consent form were based on guidelines produced by Brunel Research Ethics Committee. The information sheet provided information on the purpose of the survey and details of who to contact with queries. Participants were informed that the information provided would be anonymised and that their answers would not affect their future health care. The survey included questions relating to the personal characteristics of respondents: age, gender, general health status, oral health status, use of dental services, work status, and income. A screening question asking whether respondents were parents of children aged less than 18 years was included to identify people suitable for completing the survey focussing on oral health of children.

A simple worked DCE example was provided to give respondents a clear idea of what a DCE task involved. The final set of attributes and levels resulting from Step 1 were developed into a DCE questionnaire. In addition to the DCE questions, brief information on the implications and possible treatments for the described oral health problems were included.

At the outset, it was intended that the descriptions of problems associated with different oral health problems would be based on analysis of the national dental health surveys, the ADHS and CDHS.[39,40] Data from these surveys were analysed to identify associations between the specific type of oral health problem (e.g. number of missing teeth, location of missing teeth, gum problems), and responses to the OHIP questionnaire. The intention was to then describe each type of oral health problem in terms of the most frequent OHIP items reported by respondents in the survey with those specific oral health problems.

A pair-wise choice approach was chosen for the DCE design, rather than multi-choice or best-worst scaling, in order to minimise the complexity of the task for respondents. This design results in pairs of health states and the respondent is asked to choose which he or she considers preferable. Research has shown that respondents can cope with up to twelve attributes in a single experiment [34]; however this will be affected by the number of levels and complexity of the information. We considered that substantially fewer attributes than this 'maximum' would be appropriate given the complex nature of the information presented, for example five or six attributes.

The selection of combinations of attribute-level combinations for valuation was based on a D-optimal design. This type of design is increasingly applied in DCE studies in health [36]. In selecting the final design, consideration was given to achieving attribute balance (each attribute level appearing an equal number of times), no implausible combinations of attributes and levels and no dominant alternatives (pairs of scenarios where one scenario is logically equal or better on all attributes). Guidelines specify that prior values for optimal designs should be based on previous studies, pre-test data, pilot data or logic [37]. In the absence of information on prior values for the parameters, priors indicating the expected direction of the coefficient were specified and zero priors where there was no *a priori* logical direction for the attribute levels. The analysis to identify the design was conducted using nGene software v1.1.1 [41].

3.2.3 Piloting of survey materials

Brunel University London Ethics Committee was contacted for ethical approval before piloting and administration of survey.

The survey instructions, descriptions of attributes and levels, and DCE questions were piloted in a convenience sample the general public, including parents of children. A sample size of approximately ten respondents was considered appropriate. Cognitive interviews formed a series of 'think aloud' interviews, whereby people were encouraged to verbally state their understanding of the information and questions presented to them. Particular prompting was given to check understanding of visual aids and levels of costs. Following the pilot study, minor amendments were made to the materials and wording of the DCE to improve clarity (see results section).

3.2.4 Administration of the survey

The survey was programmed into an electronic format compatible for on-line administration using SurveyMonkey software. It was administered to an on-line UK general population panel audience consisting of nearly one million members recruited to take surveys. Each time an audience member completes an eligible survey, SurveyMonkey makes a 50 pence donation to a charity of the respondent's choice as well as entering a sweepstake to win a £50 itunes voucher. SurveyMonkey is also linked to a Global Partner network which allows access to millions more respondents and maintains heterogeneity because each source attract different types of people based on different recruitment process and incentive.

In order to get a sample which reflected the national UK population, quotas were set against census data for age and gender. While all respondents were qualified to answer DCE questions relating to oral health outcomes for adults, only parents of at least one child under the age of eighteen were allowed to answer the DCE questions for children. Therefore the WTP estimates for children are elicited only from a subgroup of the general population; however asking people for their personal willingness to pay for a hypothetical child for whom they have no personal connection was considered unlikely to provide meaningful responses.

Sample size calculations are not readily available for DCE studies. A recent study simulated sample sizes for three DCE studies, and estimated the trade-off with precision [37]. They found that for all studies precision increased substantially at 150 respondents and then flattened out at 350 people, but noted some differences according to study design. At the outset the sample size was expected to depend on the final number of DCE choice sets and the attribute/levels identified in stages 1 and 2; however it was anticipated that a total sample size of 1000 people would be sufficient.

3.2.5 Analysis of the data

Data from the adult and child survey were analysed separately.

In DCE studies, respondents' results are analysed to evaluate the relative importance of the attributes for respondents' preferences and the trade-offs that individuals make between the attributes. The experimental design pre-specified a multinomial logit model, with dummy variables representing categorical variables and the cost attribute specified as a continuous variable. Alternative model specifications were considered. The analysis took into account the repeated measurement aspect of the data, whereby multiple responses are obtained from the same individual.

The estimated coefficients of the model indicate the relevant importance of the different attributes on individual preferences. In general, the higher the absolute size of the coefficient, the greater the importance of the attribute in determining overall utility (although care must be taken when interpreting the results of attributes specified according to different units of measurement). A negative sign on a coefficient indicates that as the level of the attribute increases, the utility derived decreases. It was hypothesised that all coefficients would be negative indicating decreasing preference for more severe problems. The maximum likelihood of the model was used to indicate model fit (increasing absolute likelihood indicates improved fit). No interactions were specified. A level of statistical significance of 0.05 was assumed for coefficients.

The willingness to pay is reflected by the marginal rates of substitution (MRS) between the cost parameter coefficient and the coefficients for the other attributes. Thus, the MRS of attribute Y (cost) for attribute X is the amount of attribute Y (cost) that an individual is willing to exchange for a change in attribute X.

The impact of income on average WTP was assessed by analysing data separately for different subgroups of respondents defined according to their reported income. It was hypothesised that WTP would increase as income increases.

3.3 Results

3.3.1 Review of studies eliciting utility values for oral health outcomes

A focussed literature search was carried out to identify possible attributes and levels for the DCE. The search yielded a total of 51 records. Of these, 29 were removed at the screening stage, leaving 22 papers for assessment of eligibility based on full text. The PRISMA flow diagram is shown in Appendix J.

After review of full text, 17 papers were selected for inclusion and reported 16 empirical studies. All included papers reported estimated willingness to pay associated with oral health states or interventions using DCE and WTP method. Descriptions of the methods and results of the included studies are provided in the Table 9 below. Three of the included studies reported using DCE questions [32,42,43], the rest used a direct WTP approach [26,44-56]. On review, none of the descriptions of attributes or scenarios used in the included studies were relevant to our study as they focussed on oral health treatments rather than oral health states. Only one of the seventeen included studies was conducted in the UK [48].

In order to assess the range of average WTP estimates for oral health treatments to inform our study, the reported WTP estimates from studies in the UK and similar settings such as Europe and North America were converted into current pound sterling price [42,43,47,48,54,55]. This was done by applying multiplier, generated from pay and prices index of the year the studies were conducted to inflate to current prices, and converted to pound sterling. The WTP estimates ranged from £22-£55 [42] for a visit to a dental clinic to £870-£1206 for a single tooth implant [54].

Table 9: Summary of included studies

Authors	Year	Sample	Scenario/Attributes used	Results
Al Garni, B., S. C. Pani, et al. [56]	2012	A total of 100 patients (38 male, 62 female) who had one or more missing teeth in Saudi Arabia.	Asked if they were willing to pay the median cost of a single implant in Riyadh city, which was 3000 SR (1 SR = 3.77 US$).	The majority of the patients surveyed were willing to pay the median price for an implant. They found WTP influenced by the income of the patient, the setting of the clinic and the gender; the most significant factor being the acceptability of the implant to the patient.
Balevi, B. and S. Shepperd [54]	2007	Forty school teachers in Canada	Maximum WTP for conventional crown with a post and core technique (CC), a single tooth implant (STI), a conventional dental bridge (CDB), and a partial removable denture (RPD) before they accepted losing the tooth and living with missing tooth.	WTP for restoration of a mandibular 1st molar with either the conventional crown (CC), single-tooth-implant (STI), conventional dental bridge (CDB) or removable-partial-denture (RPD) were 1,782.05 [±361.42], 1,871.79 [± 349.44], 1,605.13 [± 348.10], 1,351.28 [± 368.62] respectively ($p < 0.05$).
Bech, M., T. Kjaer, et al. [42]	2011	Online survey with 1053 responses from general public in Denmark	The DCE attributes were: business hours (8–18 & 9–15) and whether the dentist is part of a dental centre including a dental hygienist and specialists (e.g. surgery).Two attributes described the availability of two upcoming technologies adopted by some dental clinics, digital X-ray and painless anaesthesia (yes, no). The remaining two attributes were distance (1, 3, 7 & 15km) and price (200, 270, 360 & 500DKK), describing the cost of choosing one clinic relative to the other.	Overall, the results suggest that respondents are capable of managing multiple choice sets – in this case 17 choice sets – without problems
Birch, S., W. Sohn, et al. [55]	2004	A total of 611 randomly selected dentate adults in USA	Mean willingness to pay for dentin regeneration at a success rate of 95% and 75% was estimated	At a success rate of 95%, the mean WTP for dentin regeneration was $262.70 (non-insured) and $11.00 per month (insured subjects). For success rate of 75%, the corresponding values were $210.90 and $9.20 per month.

Authors	Year	Sample	Scenario/Attributes used	Results
Esfandiari, S., J. P. Lund, et al. [44]	2009	Edentulous elders (68–79 yrs) wearing maxillary dentures and either a mandibular conventional denture (n=13) or a two-implant over denture with ball attachments (n=23) who had received their prostheses 2 years previously, as part of a trial in Canada	Although you have already received new prostheses, imagine you're given a choice between two types of dentures. In order to help you make a decision, you are given the results of a study in which they were compared. The results showed denture B rated as more satisfactory than denture A for comfort, stability, chewing and general performance. ''How much more would you be willing to pay to receive prosthesis B?"	The median supplemental amount above Canadian $1200 that the implant group would pay for prosthesis B was Canadian $1000 ($100–$3,800), three times more than the conventional denture group's median of $300.
Espelid, I., J. Cairns, et al. [32]	2006	Dentists (n=42), dental assistants (n=65), and young dental patients (n=306) in Norway and Denmark	Participants were presented with several DCE scenarios comparing two restorations with three attributes - expected longevity (3, 6, 9, 20 year), the appearance (Not tooth coloured, highly visible; Tooth coloured, but visible; Tooth coloured and not visible) and the risk of an adverse reaction (One out of 10,000 persons will have an allergic reaction; no risk)	The likelihood of a dentist favouring one restoration over another was very sensitive to the difference in the expected longevity of the restorations, and much less to differences in visibility. The patients had considerable sensitivity to differences in visibility and much less to differences in duration. Danish teenagers attach less importance to visibility of the restoration and greater importance to the risk of an adverse reaction than Norwegian teenagers.

Authors	Year	Sample	Scenario/Attributes used	Results
Leung, K. C. M. and C. P. J. McGrath [45]	2010	Subjects attending a university dental hospital were recruited (n=59) in Hong Kong	The subjects were introduced to two hypothetical clinical scenarios by a trained interviewer: (a) missing one anterior tooth and (b) missing one posterior tooth (excluding third molar). They were told that the missing teeth can be replaced by several treatment options: (a) implant supported prostheses, (b) fixed (including the conventional and resin-bonded types) partial dentures, (c) removable partial dentures and (d) no replacement. Subjects were asked to imagine having the described two hypothetical clinical conditions in sequence. They were then asked which treatment option they would prefer. For subjects who chose implant-supported prostheses, they were further asked how much they were willing to pay for implant treatment to replace an anterior missing tooth using the bidding method.	There was no significant difference in the preference to replace a missing anterior tooth compared with a missing posterior tooth by means of implant (P>0.05). The mean WTP values for an implant to replace an anterior missing tooth was HK$11,282 (SD 7207) and HK$10,205 (SD 6728) for implant replacement of a posterior missing tooth. Participants had similar WTP values for the replacement of a missing anterior tooth compared with the replacement of a posterior tooth (P<0.05)
Kiiskinen, U., A. L. Suominen-Taipale, et al. [43]	2010	Follow-up sample (N=1433) of participants in the large Health Examination Survey undertaken in 2000 and a nationally representative (cross-sectional) sample (N=2874) drawn from the population register (2004) in Finland	DCE presented alternative dental services characterised by out-of-pocket cost (30, 40, 50, 60 euros for public and 120–70, 120–60, 120–50, 120–40 euros for private), direct NHI refund scheme (yes, no or not applicable), waiting time (1, 2, 3, or 4 weeks in the case of PDS and 1 or 2 weeks in the case of private dentists), travel time (10, 20, 30, and 40 min one-way), number of visits (1, 2, or 3 in the PDS and only 1 or 2 in the private care) and recall (no, yes).	Cost, Waiting time, Travel time, and Number of visits have negative coefficients, while Regular recalls and Direct refund have positive coefficients

Authors	Year	Sample	Scenario/Attributes used	Results
Matthews, D., A. Rocchi, et al. [46]	2002	Periodontal recall patients (n = 97; 'recall') and participants from the general population (n = 196; 'general') in Canada	WTP elicited the hypothetical amount of money a subject would pay to have dental gel available for maintenance cleaning, should they require anaesthetic.	The median WTP for dental gel was $Can 20.00 per visit for the general population and $Can10.00 for the recall population. The median monthly premium to have dental gel available for any plan requiring scaling and root planing (SRP) during maintenance was $Can2.00 per month for both groups.
Matthews, D. C., S. Birch, et al. [26]	1999	23 periodontal patients and 18 dental school faculty and staff in Canada	Scenarios described four treatments for moderate to advanced adult periodontal disease: surgical therapy where patients comply with maintenance schedule lose an average of one tooth every 10 or 12 years; tooth loss with non-surgical therapy for patients with advanced disease would be one tooth every 4 or 5 years; those who are untreated and not maintained will lose about one tooth per year.	Periodontal surgery was the preferred treatment for moderate to advanced periodontal disease and was more strongly preferred than other choices (i.e. higher WTP) for all income groups
Oscarson, N., L. Lindholm, et al. [47]	2007	Eighty-two individuals (19-year olds), thirty with high caries experience and 52 with no caries experience, selected randomly from a caries-free population in Sweden	Respondents were asked about their WTP monthly for participation in a caries-preventive healthcare strategy. For later comparison with the costs of averting a decayed tooth in a CBA, the preventive programme implied a hypothetical risk reduction (expected effectiveness) for a decayed tooth within the immediate following years.	The result shows a mean yearly WTP for the high- and low-risk group of 1405 SEK and 1087 SEK (7.70 SEK ¼ US$1; July 2005), respectively. When all variables were analysed, the only two that significantly influenced WTP were caries risk (i.e. group designation) and housing
Stone, S. J., G. I. McCracken, et al. [48]	2013	39 intervention and 43 control patients in a 20-week randomized controlled trial in UK were interviewed.	Participants were asked to state their maximum WTP to purchase a powered toothbrush in an open-ended valuation exercise. The valuation was preceded by the patients being given cards representing a range of prices (£1–£2000) and asked to consider whether they would pay the amount listed on each card.	All patients stated a positive maximum WTP value (range £65–£1500). Out of pocket costs for patients were generally small. The net value of treatment ranged from £97 to £1339. The mean was £172 (CI £88–£282); the median was £69 (CI £24–£124); and the inter-quartile range was £2–£194.

Authors	Year	Sample	Scenario/Attributes used	Results
Tamaki, Y., Y. Nomura, et al. [49]	2004	5,132 patients from thirty-nine private dental clinics in 15 prefectures throughout Japan participated in this study.	Desired cost for regular check-ups was estimated using open-ended valuation question	Most respondents were willing to pay less than 2,000 yen (about $ 20). The proportion of regular visitors was not large in any of the groups. As household income increased, the number of persons willing to pay less than 1,000 yen (about $ 10) decreased. In contrast, the number of persons willing to pay less than 2,000 yen (about $ 20) and the number of persons willing to pay more than 2,000 yen increased.
Tianviwat, S., V. Chongsuvivat wong, et al. [50]	2008	205 parents (or other responsible adult) of primary school children in Thailand	Questionnaire was used to measure each subject's WTP for regional hospital compared to school-based mobile clinic.	There was no evidence of significantly greater WTP for dental care provided to children as part of a school-based mobile clinic in the study sample as a whole. Significant differences were found between WTP among parents in the lowest income quintile and other income groups but the size of this difference in WTP was significantly related to setting.
Tianviwat, S., V. Chongsuvivat wong, et al. [51]	2008	206 parents (or other responsible adult) of primary school children in Thailand	Each subject's WTP was determined for sealants and fillings provided in hospital dental clinic upon presenting comparative information on caries process, treatment procedure and effectiveness was presented to subjects using a bidding game approach.	Mean WTP for sealants and fillings were not significantly different. After adjustment for parents' characteristics, the WTP for sealants and fillings remained similar. Adjusted WTP for both services among higher income group were greater than those in lower income group.

Authors	Year	Sample	Scenario/Attributes used	Results
Vermaire, J. H., N. J. A. van Exel, et al. [52]	2012	290 parents of 6-year-old children, participating in a RCT on caries preventive strategies in Netherlands	"How much are you willing to pay every month to keep your child's mouth healthy, caries-free and pain-free until his or her 18th birthday?" Parents were able to choose one out of five options.	One fifth of the parents were unwilling to spend any money to maintain good oral health in their children. On the positive side, this implies that 80% of the parents were willing to spend at least some money and almost 10% of these parents were willing to spend more than 50 euro per month on maintaining good oral health for their child.
Widstrom, E. and T. Seppala [53]	2012	Postal questionnaires on use of dental services were sent to a random sample of 1500 47-59 year olds in Finland	Two hypothetical scenarios were presented: "What would be the highest price you would be prepared to pay to have a lost filling replaced immediately, or, at the latest, the day after losing the filling?" and " How much could you pay for unexpected dental expenses at two weeks' notice, if you suddenly needed more comprehensive treatment?"	For immediate replacement of a lost filling, almost all respondents (93.2%) were willing to pay the lower price charged in the Public Dental Survey and 46.2% were willing to pay the private fee. High income and no subjective need for dental treatment were positively associated with the probability of paying a higher price.

3.3.2 Identification of attributes and levels

As the review did not identify relevant attributes related to oral health states, the attributes considered focussed on key outcomes expected to be identified in the effectiveness review: DMFT, DMFS, pain and gum problems.

Consideration was given to the number of teeth affected by problems and the location of teeth. A published study by Kay et al. examined how tooth loss affects preferences of dentition using a visual analogue scale [57]. They found that values differ according to the location of teeth with greatest disutility attached to missing incisor teeth and disutility of tooth loss decreased as the tooth in question became nearer the back of the mouth. Given the limited number of attributes and levels that could be feasibly included in the study, and the important findings of the study reported by Kay *et al*, the survey design focussed on the location of the tooth rather than number of teeth with problems.

The study by Kay *et al,* found that different values were given to individual teeth and that these differences were greatest between anterior (front), pre-molar and molar teeth. Therefore, in the study of adult oral health, affected teeth were described in terms of three groups – anterior, pre-molar and molar teeth. For children's oral health, distinction was made only between types of teeth. This generated two different attributes – baby (primary) tooth and permanent tooth. Oral health problems including decay and removal/missing teeth were identified as levels. Following consultation with a clinical expert (Professor Liz Kay, Plymouth University Peninsula Schools of Medicine and Dentistry), it was decided to refine the level indicating decay to specify whether the decay was associated with or without pain, as these would be likely to affect preferences.

An attribute related to gum problems for adults was also included to reflect the likely clinical evidence. Various specifications of this attribute were considered based on the literature and the ADHS; however in order to reduce the complexity of the task and the likely heterogeneity in reporting in clinical studies, this was defined as a dichotomous variable (with and without problems).

When considering the design of the DCE, it was originally planned to include an attribute describing the mode of delivery of the oral health message, such as verbal or printed material. However, given the number of attributes and levels required to describe the key oral health problems, we were concerned that inclusion of an additional attribute would render the design too complex and negatively impact on the cognitive burden of respondents. We hypothesised that the format of the oral health message would be less important to people than the oral health outcomes, and did not include this in the final survey.

The cost attribute was based on the range of the levels reported in the identified literature. As stated above, these ranged from £22 to £1206. It was considered important to represent an adequate range although it is not necessary to specify the full range of conceivable values in a DCE [38]. Therefore levels ranging from £10 to £800 were chosen.

The final set of attributes and levels are shown in Table 10.

Table 10: Attributes and levels used in the DCEs

DCE	Attributes	Levels
Adult Oral Health	Molar tooth	No problem; Decay without pain; Decay with pain; Tooth needs to be removed
	Pre-molar tooth	No problem; Decay without pain; Decay with pain; Tooth needs to be removed
	Front (anterior) tooth	No problem; Decay without pain; Decay with pain; Tooth needs to be removed
	Gum problems	No problems; Some gum problems
	Cost to you	£10, £50, £150, £300, £500, £800
Child Oral Health	Baby tooth	No problem; Decay without pain; Decay with pain; Tooth needs to be removed
	Permanent tooth	No problem; Decay without pain; Decay with pain; Tooth needs to be removed

3.3.3 Survey design and piloting

In order to enable the respondents to have a better understanding of the survey, an information sheet and consent form was designed for pre-testing the questionnaire as shown in Appendix K. The ADHS was consulted to obtain information on the implications of the specific oral health conditions reflected in the attributes (missing teeth by location and gum problems) on OHIP dimensions which is a 14-items questionnaire designed to measure self-reported functional limitation, discomfort and disability attributed to oral conditions. In OHIP-14 questionnaire participants were asked to respond according to frequency of impact, using a twelve-month recall period, on a 5-point Likert scale. Ordered logit regressions were carried out to assess the factors associated with OHIP. The analysis identified very few differences in OHIP responses according to the location of tooth and severity of problem (for example, one missing tooth compared to two or more); however people with missing anterior tooth reported frequent problems on OHIP items “trouble pronouncing words”, “sense of taste worsened” and “felt self-conscious”, those with missing pre-molar tooth reported frequent problems with pronouncing words, feeling self-conscious and irritable with others. And those with missing molar tooth did not have any OHIP dimensions significantly related when assessed for only one missing molar tooth. Those with gum disease reported sense of taste worsened and feeling self-conscious. A summary of the analysis of the OHIP data from the ADHS are presented in Appendix L.

Descriptions of possible treatments for the different types of oral health problem were also described. Following consultation with a clinical expert, the descriptions of the implications of each oral health problem were amended to clarify the meaning in the OHIP items and to remove those unlikely to be due to the oral health problem. The possible treatments were also amended to reflect standard UK dental practice. The oral health information sheet also included a diagram to illustrate the name of tooth in the mouth, by its location. Separate information sheets on oral health were used for adults and children (Appendix M).

A simple worked out DCE example was provided to respondents to help understand what was expected (illustrated in Appendix N). The choice questions were phrased to ask respondents to first imagine they had oral health problems. Then that they could pay for a dental service which would partly resolve the oral health problem and stop it from getting worse, but would still have the specified oral health problems at their next six-month dental visit. They were then asked to consider two dental services each resulting in different outcomes and to indicate which they were preferred. Respondents were asked to consider that they would have to pay for the initial service personally, even if they were used to receiving dental care free at the point of contact with the NHS, and informed that the cost of their next dental visit would be covered by the NHS (so that the costs of treatment were not taken into account).

On receiving ethical clearance from Research Ethics Committee, cognitive interviews were carried out with members of staff within the university (n=7). The pretesting found the teeth diagram helpful and the WTP estimates acceptable. Detailed notes were taken and based on feedback amendments were made to the information sheet and framing of the question to make the adult questionnaire more comprehensive. DCE child oral health questions were amended to make it more sensitive; few parents found it unacceptable that both choice alternatives left their child with oral health problems. The framing was amended to state that neither of the situations may be something they would ideally want but they are only two services available now and they have to make a choice. Also timing of next dental visit was not specified as six months.

The survey was set up in SurveyMonkey and tested again with two members of general public and two who had done the survey before, with focus on the time taken to complete the questionnaire. Based on the results, several questions were dropped to reduce the duration of the questionnaire to less than 15 minutes.

The experimental design resulted in a total of twenty four paired choice sets for the adult survey which was spread across three blocks; for the children survey twelve choices sets were generated across two blocks. This resulted in a total of eight choice questions per respondent for valuing adult oral health and six choice questions for child oral health based on the attributes and levels identified. An example of a DCE question is illustrated in Appendix O. The adult survey design had a D-statistic of 0.108997 and the child design a D-statistic of 0.117708. Both designs had attribute level balance and no dominant pairs.

3.3.4 Data collection and analysis

The survey was administered online to SurveyMonkey audience in the UK. It consisted of 1034 participants: 777 members of the general public completed the adult questionnaire and 257 parents completed the child questionnaire. Following review of the data, we were concerned that the responses did not sufficiently reflect the age distribution of the UK population as reported in the 2011 UK Census. The survey was re-administered to obtain additional responses in an older age group, resulting in additional 167 responses.

The self-reported general health and oral health of the sample was similar to that reported in ADHS 2009. Around half of the adult survey respondents stated using dental service at least once every six month which matched the response in ADHS survey, but was higher at 60% for parents who filled out the child questionnaire. Another difference that was noted was that a larger proportion of participants in our study used free NHS dental care and less private dental care than that reported in the 2009 ADHS survey. In terms of education, less than 5% of respondents reported they had no formal qualification compared to the 22% in the 2011 census. The proportion of respondents who stated an income below £15,500 and above £50,000 was lower than that reported by the Survey of Personal Incomes (SPI) for 2010/11 by HM Revenue and Customs tax office. However, unlike our survey which is based on self-reported income, the SPI is based on information held by the tax offices on individuals who could be liable to UK tax and different to 'self-reported' incomes.

Table 11: Characteristics of respondents

	Adult Sample (N=944)	Child Sample (N=257)	UK Population
			(Census 2011)
Gender			
Female	52.0	50.6	51.4
Male	48.0	49.4	48.6
Age			
18-24	11.3	2.3	11.9
25-34	16.3	3.5	17.1
35-44	20.2	23.4	17.8
45-54	19.1	48.3	17.5
55-64	14.1	21.0	14.9
65<	19.0	1.6	20.9
			(ADHS 2009)
Health			
Very bad	0.9	2.3	1.1
Bad	4.2	5.1	4.3
Fair	27.9	24.5	15.7
Good	48.4	47.5	43.1
Very good	18.6	20.6	35.8
Don't know	-	-	0.0
Oral Health			
Very bad	1.1	1.2	1.3
Bad	7.0	9.0	6.0
Fair	33.7	35.4	21.2
Good	43.4	38.1	47.1
Very good	14.8	16.3	24.3
Don't know	-	-	0.1
Frequency of Dental Visit			
At least once every six months	50.4	59.9	49.4
At least once every two years	5.4	3.1	4.6
At least once every year	25.3	24.1	19.5
Less frequently than every two years	6.9	2.3	8.9
Only when having trouble with your teeth	12.0	10.5	15.8
Don't know	-	-	8.9
Item not applicable	-	-	1.8
Type of Dental Service			

	Adult Sample (N=944)	Child Sample (N=257)	UK Population
NHS dental care followed by additional private dental care	2.8	2.0	0.9
NHS dental care that was free	30.2	34.2	23.4
NHS dental care that you paid for	43.0	44.0	43.7
Not sure what type of care was received	2.9	1.2	1.4
Private dental care	20.9	18.3	27.3
Some other type of care	0.3	0.4	3.3
Education			(Census 2011)
A level or equivalent (=NVQ3)	22.4	28.8	12.3
Degree level or above	39.1	31.1	27.2
GCSE/O-level/CSE	22.6	26.1	28.5
No formal qualification	4.7	3.5	22.7
Other	1.1	0.8	5.7
Rather not say	1.4	2.0	-
Vocational qualifications (=NVQ1+2)	8.9	7.8	3.6
Income			(Survey of Personal Incomes 2010/11)
Don't know	2.5	1.6	-
Rather not say	10.7	9.3	-
Under £15,500 per year	24.8	17.5	39.27
£15,500-£29,999 per year	25.6	28.8	25.84
£30,000-£49,999 per year	23.4	25.3	16.28
£50,000 and above per year	12.9	17.5	18.61

The data were analysed using a conditional logit model in STATA v13. Consideration was also given to a mixed logit model which takes into account heterogeneity in preferences between individuals [58]. Problems with anterior teeth, pre-molar teeth, molar teeth and gums, were all specified as dummy variables (no problems as the reference level). The cost attribute was specified as a continuous variable.

The direction of the model coefficients followed logically for anterior teeth, premolar teeth, gum problems and cost (i.e. were negative). For molar teeth, the direction of the coefficients was inconsistent for levels 1 and 2 (decay with and without pain). These were excluded and the model re-estimated.

The final model is presented in Table 12. The model had a log likelihood ratio of -3640.75 and was statistically significant (Chi squared 868.14, p<0.001). The Akaike Information Criterion value was 7299.50 and the Schwartz Bayesian Information Criterion was 7368.10. Details of the full model, including inconsistent coefficients, are provided in Appendix P.

The magnitude of the coefficients for anterior teeth and gum problems follow in the expected order (most preferred to least: no decay, decay without pain, decay with pain, removal). For example, the need to have an anterior tooth removed reduces utility by 0.97 compared to no problems, and decay with pain reduces utility by 0.69 compared to no problems. The coefficients of the premolar variable indicate that decay with pain has greater disutility than removal. The coefficients for two of the pre-molar dummy variables were not statistically significant and are highly uncertain.

Upon closer examination of the data, it is apparent that the cost attribute has significantly driven results. A high proportion of people consistently chose the option with the lowest cost. This may explain the imprecision in some of the estimates and lack of statistical significance of some coefficients.

Table 12: Final model for the adult survey

					95% confidence limit	
pref	Coef.	Std. Err.	z	P>z	Lower	Upper
anter1	-0.1618	0.0570	-2.84	0.005	-0.2735	-0.0500
anter2	-0.6909	0.0597	-11.57	<0.001	-0.8079	-0.5738
anter3	-0.9662	0.0658	-14.67	<0.001	-1.0952	-0.8371
premo1	-0.0169	0.0592	-0.29	0.775	-0.1329	0.0991
premo2	-0.3074	0.0455	-6.75	<0.001	-0.3966	-0.2182
premo3	-0.0216	0.0416	-0.52	0.603	-0.1031	0.0598
molar3	-0.1079	0.0416	-2.59	0.01	-0.1895	-0.0263
gum	-0.3616	0.0284	-12.73	<0.001	-0.4173	-0.3059
cost	-0.0029	0.0001	-25.72	<0.001	-0.0031	-0.0027

Notes: anter1 (decay without pain in anterior tooth); anter2 (decay with pain in anterior tooth); anter3 (requiring removal of anterior tooth); premo1 (decay without pain in premolar); premo2 (decay with pain in premolar); premo3 (requiring removal of premolar); molar3 (requiring removal of molar); gum (some gum problems).

Estimates of willingness to pay were obtained from the model by estimating the marginal rate of substitution between each variable and the coefficient for the cost attribute. The results indicate a higher WTP to avoid problems with anterior teeth (£333 to avoid a removal of an anterior tooth). The estimates for decay without pain in, and removal of, premolar teeth are highly uncertain and should be viewed with caution.

Table 13: Willingness to pay estimates from adult survey

			95% confidence limit	
Attribute	Level	Mean	Lower bound	Upper bound
Anterior teeth	No decay	(reference)		
	Decay no pain	£55.75	£16.45	£95.06
	Decay with pain	£238.13	£195.45	£280.81
	Removal	£333.01	£284.16	£381.86
Premolar teeth	No decay	(reference)		
	Decay no pain	£5.83	-£34.14	£45.80
	Decay with pain	£105.96	£73.18	£138.73
	Removal	£7.46	-£20.80	£35.71
Molar teeth	No decay/Decay	(reference)		

	Removal	£37.19	£9.10	£65.29
Gums	No problems	(reference)		
	Some problems	£124.62	£106.97	£142.28

For the analysis of the survey data relating to children's oral health, a conditional logit model reflecting repeated observations from the same individuals was fitted to the data. The model as a whole was statistically significant (Wald Chi^2 with 8 degrees of freedom 287.85; p<0.001). The Akaike Information Criterion value was 1575 and the Schwartz Bayesian Information Criterion was 1605. Various model specifications were tested as alternatives but did not improve the fit to the data.

Two of the coefficients were not statistically significant and had counter-intuitive signs: decay in a baby tooth without pain and removal of a baby tooth. Therefore we are unable to conclude that a disutility is associated with these oral health problems.

Table 14: Final model for children's oral health

					95% confidence limit	
Variable	**Coef.**	**Std. Err.**	**z**	**P>z**	Lower bound	Upper bound
Decay with pain in baby tooth	-0.4198	0.0926	-4.5300	0.0000	-0.6013	-0.2383
Decay without pain in permanent tooth	-0.3201	0.0989	-3.2400	0.0010	-0.5139	-0.1263
Decay with pain in permanent tooth	-0.8510	0.1153	-7.3800	0.0000	-1.0770	-0.6250
Permanent tooth needing extraction	-0.6821	0.1293	-5.2700	0.0000	-0.9355	-0.4286
Cost	-0.0028	0.0002	-14.1000	0.0000	-0.0032	-0.0024

Table 15 shows the estimates of willingness to pay from the children's survey. Respondents were willing to spend the most to avoid decay with pain in a permanent tooth, followed by removal of a permanent tooth.

Table 15: Willingness to pay estimates from child survey

		95% confidence limit	
Attribute/level	**Mean**	Lower bound	Upper bound
Baby tooth - decay with pain	£ 150.30	£ 91.54	£ 209.05
Permanent tooth - decay no pain	£ 114.62	£ 41.96	£ 187.28
Permanent tooth - decay with pain	£ 304.70	£ 210.04	£ 399.37
Permanent tooth - removal	£ 244.21	£ 142.79	£ 345.63

The effects of income on the willingness to pay estimates for both models are shown in Table 16 and Table 17. There is some evidence of an income effect in the adult data, although this is not consistent across all variables and income groups. Those reporting the highest incomes also indicated highest WTP values for all variables with the exception of gum problems. There not clear pattern for the survey of child oral health, and may be due to the smaller number of responses when split by income group.

A further subgroup analysis was conducted to investigate the effect of age on the WTP estimates. The results of the analysis of the survey of adult oral health are shown in Table 18. The analysis was conducted for only the survey of adult oral health as there was less variation in age for the survey of children's oral health as parents of children aged under 18 years were recruited. Several of the coefficients were not statistically significant when analysed by subgroup, which is likely to be due to the reduced number of observations in each group. The WTP estimates calculated from statistically significant coefficients are shown in bold in the table. Focussing on these estimates, there appears to be a non-significant trend of decreasing WTP by age for removal of an anterior tooth and decay with pain in a premolar tooth; but the relationship is unclear for decay with pain in a front (anterior) tooth and gum problems. The subgroup analysis is likely to be confounded by a higher proportion of people aged over 65 years reporting their income to be in lowest income bracket.

Table 16: Effect of income on willingness to pay – adult analysis (mean values, 95% confidence limits)

		Less than £15,000	£15,500-£29,999 per year	£30,000-£49,999 per year	£50,000 and above per year
Anterior teeth	Decay no pain	£50.75 -£22.72 to £ 124.22	£44.46 -£24.62 to £ 113.55	£ 7.48 -£72.92 to £87.88	£97.76 -£49.41 to £ 244.92
	Decay with pain	**£ 233.84** **£ 155.90 to £ 311.78**	**£ 214.72** **£ 140.42 to £ 289.03**	**£ 200.85** **£ 109.46 to £ 292.25**	**£ 328.98** **£ 182.87 to £ 475.10**
	Removal	**£ 277.53** **£ 191.90 to £ 363.16**	**£ 293.65** **£ 211.48 to £ 375.82**	**£ 328.71** **£ 226.17 to £ 431.25**	**£ 485.00** **£ 291.55 to £ 678.44**
Premolar teeth	Decay no pain	£39.18 -£33.95 to £ 112.30	-£4.13 -£78.67 to £70.41	- £34.55 -£ 119.33 to £50.23	£45.30 -£ 104.71 to £ 195.32
	Decay with pain	**£70.40** **£12.17 to £ 128.63**	**£85.85** **£26.01 to £ 145.70**	**£ 147.11** **£76.73 to £ 217.50**	**£ 194.24** **£58.49 to £ 329.98**
	Removal	**-£54.97** -£99.64 to **-£10.30**	-£19.18 -£70.82 to £32.45	**£66.12** **£ 3.14 to £ 129.09**	£ 109.64 -£ 5.32 to £ 224.60
Molar teeth	Removal	£18.92 -£33.01 to £70.85	£29.61 -£20.48 to £79.69	£38.79 -£23.76 to £ 101.33	£87.94 -£19.08 to £ 194.96
Gums	Some problems	**£ 125.76** **£94.16 to £ 157.36**	**£ 124.93** **£95.96 to £ 153.90**	**£ 100.95** **£61.88 to £ 140.03**	**£ 111.65** **£43.17 to £ 180.12**

Bold indicates statistically significant at $p<0.05$

Table 17: Effect of income on willingness to pay – children's analysis (mean values, 95% confidence limits in parenthesis)

	Less than £15,000	£15,500-£29,999 per year	£30,000-£49,999 per year	£50,000 and above per year
Decay without pain in baby tooth	-£43.88 (-£139.91 to £52.14)	-£60.99 (-£137.50 to £ 15.53)	-£80.99 (-£190.89 to £15.53)	**£243.46** **(£50.06 to £ 436.86)**
Decay with pain in baby tooth	**£163.63** **(£37.84 to £289.41)**	-£11.52 (-£132.45 to £109.41)	£125.53 (-£15.10 to £109.41)	**£371.96** **(£191.87 to £ 552.05)**
Baby tooth needing extraction	**-£143.15** **(-£252.57 to -£33.72)**	**-£117.92** **(-£233.52 to -£2.32)**	£16.92 (-£142.18 to -£2.32)	£122.86 (-£65.42 to £ 311.15)
Decay without pain in permanent tooth	-£4.56 (-£156.43 to £147.30)	**£186.04** **(£26.27 to £345.82)**	£122.87 (-£31.58 to £345.82)	**£190.33** **(-£4.75 to £ 385.41)**
Decay with pain in permanent tooth	**£132.53** **(£3.82 to £261.24)**	**£132.53** **(£115.33 to £495.04)**	**£392.38** **(£187.83 to £495.04)**	**£580.70** **(£321.97 to £ 839.42)**
Permanent tooth needing extraction	**£160.13** **(£18.97 to £301.28)**	**£158.41** **(-£34.03 to £350.85)**	**£294.78** **(£86.80 to £350.85)**	**£548.37** **(£267.85 to £ 828.88)**

Bold indicates statistically significant at $p<0.05$

Table 18: Effect of age on willingness to pay – adult survey

Age group (mean WTP and confidence limit)	anter1	anter2	anter3	premo1	premo2	premo3	molar3	gum
Age 18-34								
Mean	£ 93.11	**£ 255.26**	**£ 419.91**	-£ 33.57	**£ 201.04**	£ 42.71	**£ 97.67**	**£ 131.36**
Lower confidence limit	-£ 4.28	**£ 155.44**	**£ 293.58**	-£ 131.04	**£ 112.36**	-£ 32.12	**£ 28.40**	**£ 88.26**
Upper confidence limit	£ 190.51	**£ 355.08**	**£ 546.23**	£ 63.89	**£ 289.73**	£ 117.55	**£ 166.94**	**£ 174.46**
Age 35-54								
Mean	£ 23.60	**£ 224.92**	**£ 322.12**	£ 43.33	**£ 93.17**	£ 3.87	£ 39.37	**£ 136.19**
Lower confidence limit	-£ 34.08	**£ 159.50**	**£ 248.53**	-£ 19.04	**£ 44.05**	-£ 39.43	-£ 5.37	**£ 109.76**
Upper confidence limit	£ 81.28	**£ 290.34**	**£ 395.72**	£ 105.71	**£ 142.29**	£ 47.17	£ 84.12	**£ 162.63**
Age 55+								
Mean	**£ 64.45**	**£ 246.24**	**£ 297.14**	-£ 9.93	**£ 60.62**	-£ 14.60	£ 9.23	**£ 112.06**
Lower confidence limit	**£ 1.90**	**£ 177.73**	**£ 222.76**	-£ 67.89	**£ 15.43**	-£ 55.49	-£ 32.05	**£ 83.19**
Upper confidence limit	**£ 127.00**	**£ 314.75**	**£ 371.53**	£ 48.04	**£ 105.81**	£ 26.29	£ 50.51	**£ 140.93**

Chapter 4. Economic modelling

4.1 Introduction

NICE guidance on approaches for local authorities and their partners to improve the oral health of their communities (PH55) was published in October 2014.[31] The economic analysis for PH55 was developed by the NYEAC.[25] We reviewed their work to inform decisions about what types of economic modelling would be possible and useful for this current guideline.

In their preparatory work for PH55, NYEAC created a Markov model of tooth decay. This defined a 'restoration pathway' from first filling to re-filling, crown, root canal and extraction, which was used to estimate discounted costs, QALYs and Quality Adjusted Tooth Years (QATYs) per incident case of decay at different ages. These results were fed into a second Markov model to estimate the incremental costs and effects (QALYs and QATYs) of interventions for a defined cohort as a function of: the cost and relative risk reduction associated with intervention and the baseline risk of decay in the cohort. The NYEAC Tooth Decay model also incorporated the functionality to estimate impacts related to the incidence of oral cancers, although this was not used due to a lack of related effectiveness evidence. Impacts of periodontal disease or related conditions were not included in the model. Parameters for the NYEAC Tooth Decay model were derived from various sources. The baseline risk of decay was based on an analysis of data from the CDHS 2003 [59] and ADHS 2009 [60]. Filling survival was estimated from the analysis by Burke et al. of data from the Dental Practice Board.[61] The cost per decayed tooth was estimated based on expected progression of decay and NHS payments to dentists and patient charges for fillings and other restorative work and extractions. Similarly, the QALY loss per case of decay was estimated based on decay progression, age-related quality of life for the general population, and an assumed quality of life decrement for people with decayed or missing teeth.

The Public Health Advisory Committee (PHAC) for PH55 had concerns over the realism of the NYEAC tooth restoration pathway, and over the data and assumptions used to population this model.[31] So it was not used in the end to estimate cost-effectiveness for PH55. Instead, NYEAC developed two simpler analyses to inform judgments on the cost-effectiveness of community-based oral health programmes. The first used a decision tree model and data from Public Health England on the risk of poor oral health in pre-school and school children in a deprived community to estimate the cost-effectiveness of supervised tooth brushing and fluoride varnish. The second analysis used the NYEAC model to calculate a look-up table, presenting estimates of cost-effectiveness as a function of five key but uncertain parameters: intervention cost; baseline risk of dental caries; intervention effectiveness; loss in QALYs for one incident case of caries; and the cost of treating each incident case of caries.

4.2 Methods

4.2.1 The decision problem

The aim of the economic modelling was to develop a mechanism to estimate the cost-effectiveness of different approaches for dental teams to convey oral health promotion messages to patients.

The decision problem to be addressed was set out in the scope document for the guideline [62], as summarised in Table 1 (on page 15 above). The main constraints on the economic modelling related to the outcomes that were available in the effectiveness literature, and for which sufficient epidemiological and economic data were available to estimate long-term costs and oral health outcomes. These constraints are discussed below.

Population

The specified population in the scope was adults and children who visit the dentist. Analysis was therefore focussed on people reporting 'regular' or 'occasional' dental check-ups, who have generally better oral health than those reporting that they only visit the dentist 'with trouble' or not at all. [60] There are, however, big variations in oral health across the population, defined by socioeconomic group, ethnicity and region.

Although periodontal disease increases greatly with age, around 20% of 16-24 year olds have pocketing of 4mm or more somewhere in their mouth (rising to around 80% in those over 75 years of age).[60] The gum health model was therefore designed to work across a broad age range (16-75+), although the analysis below is focussed on high risk and older patients with existing periodontal disease to reflect available evidence.

Outcomes

The scope specified a range of outcomes, including changes in:

1. The dental health team's knowledge, ability, intentions and practice.
2. People's experience of visiting the dentist (e.g. satisfaction with advice).
3. Patients' knowledge and ability to improve and protect their oral health.
4. Changes in dental patients' oral health behaviours.
5. Oral health of people who go to the dentist (incidence and prevalence of oral cancers, tooth decay, gum disease and dental trauma).
6. Patients' quality of life, including social and emotional wellbeing.

The conceptual relationship between these outcomes was set out by the Plymouth team in their logic model (Figure 1 in the draft effectiveness review report).[3] This mapped a causal pathway from interventions and changes in the dental team's knowledge, abilities, intentions and practice (1 from the above list) to changes in; patients' cognitions, emotions and knowledge (2 and 3); behaviour change (4); oral health outcomes (5); to health outcomes (6).

For the purposes of the economic evaluation, our objective was to estimate the relative impact of oral health promotion interventions on costs and on the ultimate step of the outcome pathway (general health-related quality of life or well-being). However, there was no direct evidence to enable quantification of cost-effectiveness at this level. We therefore modelled the relationship between intervention and the penultimate level of oral health outcomes. This includes a range of measures specified in the scope: oral health-related quality of life; dental caries; periodontal disease;

oral cancer; and dental trauma. Again, lack of data led us to focus on two key indicators of oral health: dental decay and periodontal disease.

We chose to model dental decay in terms of the mean numbers of teeth decayed, filled or extracted within a cohort (deft or DEFT, respectively for primary or permanent dentition). This is a common method of summarising decay experience, and is compatible with the WTP estimates elicited from our valuation survey, which were defined on a 'per tooth' basis (see Table 13 and Table 15 above). Effectiveness results reported in terms of mean numbers of tooth surfaces subject to decay, filling or extraction (defs or DEFS) were converted to effects on deft/DEFT by assuming that the relative risks of incident decay (with an intervention compared with control) would be the same per tooth as per surface. However, note that this 'per tooth' approach is not compatible with some other methods of summarising effects on decay experience in the literature, such as the proportion of individuals in a cohort with greater or less than a defined threshold of sound and untreated teeth (e.g. greater than 21 sound untreated teeth).

In children, it was necessary to distinguish decay in primary and permanent teeth. Due to data limitations, particularly regarding the transition from primary to permanent dentition, we analysed changes in dmft and DMFT separately (no distinction was made between teeth by location in the mouth). We did not attempt to model gingival health in children.

The process of dental decay in adults was modelled in terms of changes in the mean numbers of anterior, premolar and molar teeth in the following categories:

- Sound and untreated (S)
- Decayed (D)
- Filled and otherwise sound (FS)
- Filled unsound, with caries and/or failed restoration (FU)
- Missing (M)

The separation of anterior, premolar and molar teeth reflects different rates of decay and restoration between these sites [63], as well as different preferences over extractions between these types of teeth [57], as discussed in section 3.3.2 above (page 53). For the purposes of this report, 'filled' is used to refer to any restoration short of extraction, including amalgam and other fillings, primary and repeat fillings, root canal work and crowns. 'Missing' includes extracted teeth, whether or not they have been replaced by an implant or bridge. (Weights are applied in the costing to reflect the frequency of different types of dental treatment on entry to the FS and M tooth states).

Characterisation of the extent and severity of gum disease is complex, as a range of summary measures are available including: depth of pocketing (DOP), loss of attachment (LOA), and bleeding on probing (BOP) at various periodontal gum sites around the mouth; and indices to summarise overall gingival health (GI), and the risk factors of calculus (CI) and plaque (PI). We developed a model to evaluate interventions to prevent gum disease in adults based on the approach of Mdala et al. (2014). [64] This required information on the proportion of periodontal sites examined that exhibit BOP and/or DOP or LOA greater than 4mm. This 'per gum site' approach is not compatible with some measures of gum health, including GI, CI and PI indices. Following the approach adopted in our valuation survey, we did not attempt to distinguish between gum sites at different locations in the mouth.

Effectiveness evidence

The interventions that could be included in the economic analysis were limited according to the availability of evidence from studies included in the effectiveness review [3] that reported outcomes compatible with our modelling approaches: tooth decay (mean dmft, dmfs, DMFT or DMFS) or gum health (mean percentage of gum sites with BOP; mean percentage of gum sites with DOP/LOA<4mm). The studies reporting these outcomes are summarised in Table 19.

Of the seven included studies concerning oral health promotion interventions based on behavioural or psychological theory, three included quantitative measures of outcome compatible with modelling. Jönsson et al. (2009, 2010 and 2012)[21-23] conducted an RCT in Sweden to test the effectiveness of an individually tailored oral health education programme compared with standard treatment for patients undergoing a course of non-surgical treatment for chronic periodontitis (mean age 51). This study was of good methodological quality (++) and external validity (++), and reported measures of pocketing and gingival health that were compatible with our approach to modelling gum disease. Two other RCTs, Clarkson et al. (2009) [65] and Little (1997) [66] reported compatible measure of gingivitis but not pocketing. One other quasi-experimental study (Fjellstrom 2010) [67] only included four participants (omitted from Table 19).

Six of the eight included studies of verbal delivery of oral health promotion included outcomes that we could model. These included four studies in children, reporting caries outcomes: two studies judged to be of good methodological quality (+) and external validity (+), Blinkhorn et al. (2003) [15] and Hausen et al. (2007) [24]; and two of lessor quality (-), Lepore et al. (2011) [68] and Weinstein et al. (2004, 2006) [69,70]. The other two studies reported on gum health in adult populations. Hugosen et al. (2003, 2007) [18,19] was of a good quality (+) and external validity (++), but only reported gingivitis outcomes, not pocketing, in a form that could be used for modelling. The study by Jönsson et al. (2006) [71] was methodologically weak (-), and was of a small size (37 patients randomised).

None of the seven included studies of written delivery of oral health advice reported outcomes that were compatible with our approach to modelling. These studies mostly reported effects on knowledge and behaviour. Lees et al. (2000) [72] compared the impact of written, video and verbal delivery of information on plaque and gingivitis in a population of orthodontic patients. However, the measure of gingivitis (the Loe and Sillness GI) could not be disaggregated to provide information on the proportion of gum sites with/without BOP.

Two studies reported relevant outcomes for other means of delivering oral health advice. Vachirarojpisan et al. (2005) [73] conducted a trial of small group discussion compared with didactic oral health education for parents or caregivers of young children (age 6-19 months). They reported incident early childhood caries (cavitated and non-cavitated lesions) over one year of follow-up (similar to a dmfs outcome, assuming few fillings or extractions in this group). However, the increment was actually higher in the intervention group (not statistically significant). The study by Sbiaraini & Evans (2008) [74] was a non-controlled (before-after) study, and only 20 patients had six-month outcome data.

Table 19. Summary of effectiveness studies reporting outcomes suitable for modelling

Studies	Quality / applicability	Population	Intervention	Outcomes compatible with modelling
Behavioural and psychological approaches				
Jonsson (2009, 2010, 2012) [21-23]	++ ++	Patients (mean age 51) being treated for chronic periodontitis, Sweden	Individually tailored oral health education programme (vs standard treatment)	Gingivitis (mean % BOP) * Pocketing (mean % DOP≥4mm)
Clarkson (2009) [65]	+ +	Adults (mean age 36) attending dentist in Scotland	Oral hygiene education based on psychological theory (vs routine care)	Gingivitis (mean % BOP)
Little (1997) [66]	- ++	Patients (age 50-70) with mild/ moderate periodontal disease	Group-based behaviour modification (vs usual care)	Gingivitis (mean % BOP)
Verbal delivery of information				
Blinkhorn (2003) [15]	+ +	Children (age 1-6) and parents attending general dental practices in Northwest England	Dental health counselling by hygienist at clinic (7 visits over 2 years) vs usual care	Caries (mean dmft at 2 years, baseline not reported)
Hausen (2007) [24]	+ +	Children (age 11-12) attending public dental clinics, Finland	Dental health counselling by hygienist (+ toothpaste & xylitol)	Caries (mean DMFS increment) *
Hugoson (2003, 2007) [18,19]	+ ++	Young adults (20-27 years) invited for free check-up at public clinics in Sweden	Dental prophylaxis and oral hygiene instruction (three models) vs control	Gingivitis (mean number of sites with GI=2 or 3, at baseline and 3 years) *
Jönsson (2006) [71]	- +	Adults (mean age 56) with poor dental hygiene treated at periodontology clinic, Sweden	Oral health promotion by dental hygienist (vs control)	Gingivitis (mean % BOP) Pocketing (mean number of pockets ≥4mm)
Lepore (2011) [68]	- -	Children (age 1-6), US	Oral hygiene and diet information by dentist	Caries (dmft) Gingivitis (not stated)
Weinstein (2004, 2006) [69,70]	- +	Parents of young children (age 6-18 months) from South Asian Punjabi speaking population, Canada	Motivational interviewing, video and pamphlet (vs pamphlet and video alone)	Caries (dmfs)

Studies	Quality / applicability	Population	Intervention	Outcomes compatible with modelling
Means other than leaflet and verbal advice				
Vachirar-ojpisan (2005) [73]	+ +	Carers of children (age 6-19 months) attending health centres in Thailand	Small group discussion (vs a didactic dental health education programme)	Caries (cavitated and non-cavitated carious lesions)
Sbaraini & Evans (2008) [74]	- +	Patients attending clinic	Assessment + demonstration by dentist + 5000ppm toothpaste	Caries (DMFT) Gingivitis (GI)
Receiver characteristics				
Poole (2010) [75]	- +	Scleroderma patients	Oral health education video, hand and facial exercises	Caries (DMFT) Gingivitis (mean sites with BOP) Pocketing (mean sites with DOP≥4mm)
Meurman (2001) [76]	- +	Mutans streptococci (MS) positive children (age 18 months)	Oral health promotion and Xylitol lozenges (vs usual care)	Caries prevalence (dmft>0 at 5 years)

BOP – bleeding on probing; DOP – depth of pocket; dmft/s decayed, missing or filled teeth/surfaces, primary teeth; DMFT/S decayed, missing or filled teeth/surfaces, permanent teeth; GI – gingival index of Silness and Loe.

** Statistically significant difference between intervention and control group reported (p<0.05)*

No studies reported outcomes that could be modelled for interventions defined by particular ‘sender’ characteristics, but two studies did for interventions based on particular ‘receiver’ characteristics. Poole et al. (2010) [75] conducted a non-controlled (before-after) study of structured oral hygiene instruction and facial and hand exercise to improve oral health for people with scleroderma. Although the number of sites with BOP declined over the six month follow-up, the number of pockets ≥ 4mm and number of caries increased. In the absence of a control group it is difficult to interpret these results. Finally, the study by Meurman and colleagues (2009) [76] evaluated an oral health promotion intervention and Xylitol lozenges for young children (age 18 months) in Finland, compared with a usual care control. Although caries outcomes were measured in this study, results were only presented as the proportion of children with dmft>0 at the age of five. Mean dmft scores per child were not reported.

In summary, we identified three studies that provided sufficiently robust (quality and applicability scores ++ or +) quantitative evidence of effectiveness (intervention vs control group comparison positive, but not necessarily statistically significant) for outcomes that were suitable for modelling (caries, gingivitis and pocketing). These included two studies supporting some reduction in caries incidence in children: Blinkhorn et al. (2003) for primary dentition in young children (age 1-6); and Hausen et al. (2007) for permanent dentition in older children (age 11-12). The other study provided evidence of improved gum health in older patients undergoing treatment for chronic periodontitis in (Jönsson et al. 2009, 2010, 2012).

Two models were developed to estimate costs and the value of health outcomes based on these studies: one for tooth decay in children and one for gum disease in adults. These models are described below. A third model was developed to evaluate effects on dental decay in adults. However, given the lack of evidence for this outcome, this model is of limited use for this guideline. Nevertheless, we describe the adult tooth model below, and present a look-up table of results for information.

Framework for economic analyses

The analyses were conducted according to the principles and methods set out in the NICE public health methods guide.[1] Some differences from the standard public health reference case were adopted (see Table 20 below).

Table 20. Reference case for economic analysis

Element of assessment	Public Health reference case	Variations for this analysis
Decision problem	The scope developed by NICE	
Comparator	Interventions routinely used in the public sector, including those regarded as best practice	
Perspective on costs	Public sector, including the NHS and PSS, or local government Societal perspective (where appropriate)	Two cost perspectives are presented: NHS with and without patient charges.
Perspective on outcomes	All health effects on individuals. For local government guidance, non-health benefits may also be included	Health effects associated with oral health (decay and gum disease). There were insufficient data to model impacts on other related diseases (e.g. oral cancer and cardiovascular disease).
Type of economic evaluation	CCA, CBA, CUA – to ensure comparability with other parts of NICE	Results are presented in the form of a CCA, CBA (using WTP estimates from the valuation survey); and CUA using estimated QALY effects of fillings and extractions.
Synthesis of evidence on outcomes	Based on a systematic review	As reported by Plymouth team.
Measure of health effects	QALYs	Simple estimates presented.
Measure of non-health benefits	Where appropriate, to be decided on a case-by-case basis in conjunction with the CPH technical team	No. We considered including preferences over methods of oral health advice in the valuation survey, but this was not feasible.
Source of data for measurement of health-related quality of life (HRQL)	Reported directly by patients or carers	No direct data available. Simple estimates of QALY loss presented.
Source of preference data for valuation of changes in HRQL	Representative sample of the public	Public sample for valuation survey.
Discount rate	An annual rate of 1.5% on both costs and health effects (sensitivity analyses should include discount rates used by other parts of NICE)	
Equity weighting	An additional QALY has the same weight, regardless of the characteristics of the individuals who gain the health benefit	

DOP: Depth of pocket; BOP Bleeding on Probing;

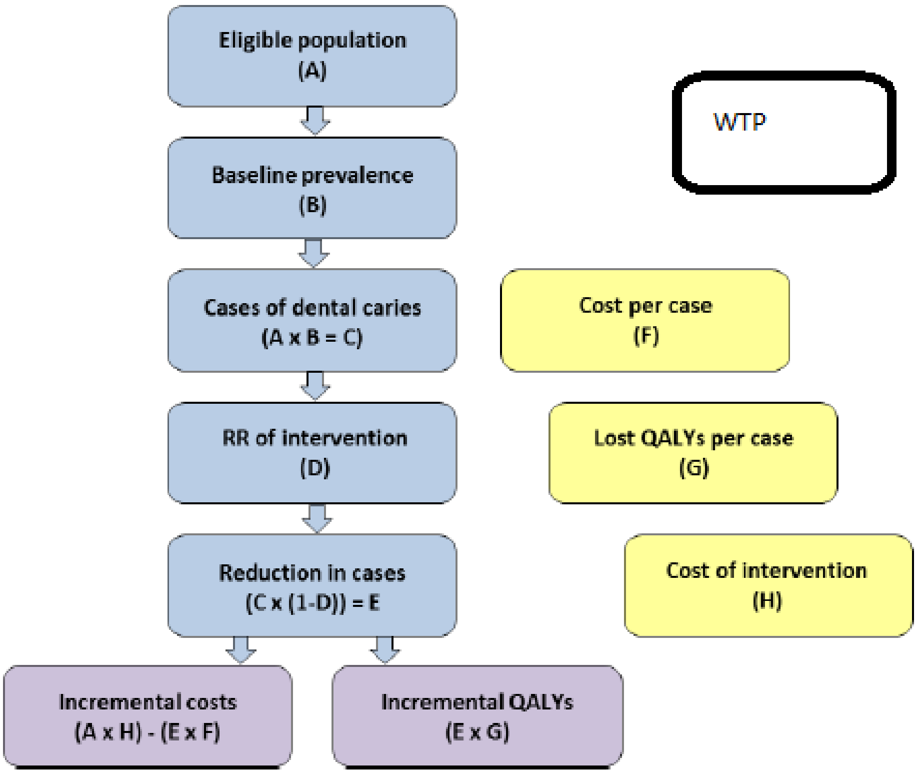
4.2.2 Children's model

Model structure

Our analysis of the costs and consequences of oral health promotion advice for children followed the decision tree approach taken by the NYEAC for PH55.[25] For that guideline, the committee concluded that this simple approach was appropriate, given the large uncertainties over the effectiveness evidence and the lack of epidemiological data on which to base a long-term extrapolation of costs and outcomes.

Key parameters of the NYEAC model were: baseline risks of dental caries (dmft/s or DMFT/S); relative risk reduction of dental caries with interventions; QALY loss from tooth decay and removal; and costs of intervention, fillings and extractions. We added estimates of willingness to pay to avoid decay, pain and dental procedures in children from the valuation study (see Table 15 above). The diagram below (Figure 1) is adapted from the NYEAC report, and illustrates our inclusion of willingness to pay estimates for dental caries.

Figure 1. Children's model structure, adapted from Claxton et al. 2014 [25]



Results are presented using a Cost Consequence Analysis (CCA) or 'balance sheet' approach. This summarises effects on oral health outcomes, costs to the NHS, and valuations of benefits to children and families (QALYs and WTP). Results are presented per 100 children participating in the preventive programmes. We also present summary cost-utility results in the form of Incremental Cost Effectiveness Ratios (ICERs) (cost per QALY), and Incremental Net Benefits (INBs), calculated at threshold values of £20,000 and £30,000 per QALY gained. In addition (where relevant), we present cost-benefit results by subtracting total costs from total WTP. Note, however, that WTP and QALY estimates are not commensurate, so we do not combine these methods of valuation in a single statistic.

The Children's Model was used to estimate oral health outcomes, costs, QALYs and WTP for an intervention compared with control over a defined follow-up period, based on the results of two published trials: Blinkhorn et al. (2003)[15] and Hausen et al (2007)[24]. These studies were chosen as exemplars for the evidence relating to verbal delivery of oral health advice in children with primary dentition and permanent dentition respectively. The analyses were conducted separately for the two studies. The time horizon for each analysis was based on the follow-up period for the related study: no attempt was made to extrapolate results over a longer time period. This approach is analogous to the 'within-trial' approach to economic evaluation. Table 21 and Table 22 below give the parameters used to estimate results of the cost-consequences analysis.

Table 21. Blinkhorn analysis: Parameters and values for sensitivity analysis

Parameter	Base case	PSA distribution (alpha, beta)	Source
Baseline risks and probabilities			
Number of dmft - 5 years	1.6	Gamma (211.6, 0.008)	CDHS 2003
Number of dmft - 8 years	1.8	Gamma (661.2, 0.003)	CDHS 2003
Filled teeth - 5 years	0.2	Gamma (100, 0.002)	CDHS 2003
Filled teeth - 8 years	0.5	Gamma (51, 0.01)	CDHS 2003
Number of GA performed per death	300,000	Gamma (34.6, 8677)	Assumption
Proportion of extractions under GA	100%	-	Assumption
% children with caries who have extraction	13.9%	Beta (25.5, 157.56)	NYEAC
QALY loss if death	40.4	Beta (see source)	Ara & Brazier
Effectiveness			
Control baseline	2.17	Gamma (116, 0.019)	Blinkhorn study
Control Endpoint	3.22	Gamma (171, 0.019)	Blinkhorn study
Intervention baseline	1.97	Gamma (111, 0.018)	Blinkhorn study
Intervention Endpoint	2.65	Gamma (147, 0.018)	Blinkhorn study
Costs			
Cost per UDA	25	Gamma (25, 1)	NHS
Cost of hospital tooth extraction	£1,160	-	PSSRU
Cost per session (10 parents)	£53.49	Gamma (2, 31.061)	Blinkhorn study
Valuation			
Baby tooth - decay with pain	£150.30	Gamma (25, 5.979)	Valuation study

Table 22. Hausen analysis: Parameters and base case values for sensitivity analysis

Parameter	Base case	PSA distribution (alpha, beta)	Source
Baseline risks and probabilities			
Number of DMFT -12 years	0.8	Gamma (400, 0.002)	CDHS 2003
Number of DMFT - 15 years	1.6	Gamma (316, 0.005)	CDHS 2003
Filled teeth - 12 years	0.5	Gamma (277.8, 0.02)	CDHS 2003
Filled teeth - 15 years	1.2	Gamma (225, 0.005)	CDHS 2003
Number of GA performed per death	300,000	Gamma (34.6, 8677)	Assumption
Proportion of extractions under GA	50%	-	Assumption
% children with caries who have extraction	13.9%	Beta (25.5, 157.56)	NYEAC
QALY loss if death	40.4	Beta (see source)	Ara & Brazier
% filled teeth with pain	50%	-	Assumption
Effectiveness			
Control baseline	2.3	Gamma (116, 0.014)	Hausen study
Control endpoint	4.6	Gamma (218, 0.021)	Hausen study
Intervention baseline	2.1	Gamma (188, 0.011)	Hausen study
Intervention endpoint	2.56	Gamma (105, 0.025)	Hausen study
Costs			
Cost per UDA	25	Gamma (25, 1)	NHS
Cost of hospital tooth extraction	£1,160		PSSRU
Intervention (£ per participant per year)	£50.89	Gamma (25, 2.035)	Hausen study
Valuation			
Decay no pain	£114.62	Gamma (10, 11.99)	Valuation study
Decay with pain	£304.70	Gamma (40, 7.656)	Valuation study
Removal	£244.21	Gamma (22, 10.964)	Valuation study

Effectiveness data

Rates of decay without intervention were estimated for 2 years and 3 years respectively for the Blinkhorn and Hausen studies. For the Blinkhorn study model, a 2 year baseline rate of decay was estimated from dmft prevalence obtained from the CDHS 2003[39] at ages 5 and 8 years, assuming a constant risk of decay during this time. A similar approach was used to calculate baseline risk in the Hausen study, based on DMFT prevalence at ages 12 and 15. The relative risks of decay in previously sound untreated teeth (with the intervention compared with usual care) were estimated from the Blinkhorn and Hausen studies. The estimated relative risks were applied to the baseline rates of new decay to estimate change in dmft/DMFT in the experimental groups. The dmft/DMFT averted was then calculated as the difference in change in dmft/DMFT between the control and experiment al groups.

The numbers of newly decayed teeth that were filled and extracted during the follow up period were then estimated. The percentage of newly decayed teeth that were filled was estimated from the CDHS 2003: the figure for 8 year olds (28%) was used for the Blinkhorn analysis and that for 15 year olds (77%) for the Hausen analysis. Following the NYEAC analysis, we assumed that 13.9% of newly decayed teeth would be extracted. Sensitivity analysis was performed to test the robustness of these assumptions.

Cost of intervention and dental treatment

In the Blinkhorn study, parents in the control group were only seen at the beginning of the study and did not accrue any significant costs. Parents in the test group received counselling, tooth brushing demonstrations, the analysis of 24-hour diet records and dental health educational leaflets in groups of 10 parents per session. Parents also received tooth paste and small brushes for their children. The study began with two sessions and then a session every four months for a period of two years. The authors determined that each session cost £39.37 pounds at 2002/3 prices, or £53.49 in 3013/14 prices (applying an uplift of 36% for inflation, based on the Hospital and Community health Services (HCHS) index).This resulted in an overall estimate of £42.56 per child over the study period, when a discount rate of 1.5% was applied.

In the Hausen study, there were four major sources of expenditure, namely preventive procedures, restorative procedures, local anaesthesia and endodontic procedures. They estimated the cost of preventive procedures by multiplying the mean number of 20 minute sessions per child recorded over the study period by a unit cost per 20 minute session delivered by dentists or dental hygienists (€33.56 and €23.35, respectively).[12] We adapted these calculations by applying estimates of unit costs in current UK practice. A unit cost for dentists was estimated by the British Dental Association (BDA) in their 'Heathrow Timings Inquiry' at £47 per hour (at 1999 prices).[77] No estimate was identified for the cost per hour for dental hygienists in the UK. We therefore used the relative cost per hour for dental hygienists compared with dentists estimated by Hietasalo et al (69.6% = €23.35/(€33.56) to adjust the BDA cost for dentists. This yielded an estimate of £32.70 per hour for dental hygienists in 1999 prices. Unit costs were then uprated for inflation using the HCHS price index (54% increase between 1998/99 and 2013/14).[78] The mean cost of preventive procedures for each child was estimated at £199.34 in the test group and £26.33 in the control group for the study: a mean difference of £150 per childover the period of 3.4 years when a discount rate of 1.5% was applied. A sensitivity analysis was performed to test the impact of cost differences between both groups.

NHS dental treatments are classified as band 1, band 2 or band 3.

- Band 1 – Includes examination, diagnosis, advice, scale and polish, application of fluoride vanish and fissure sealant.
- Band 2 – Covers all interventions in band 1 and additional interventions such as filling, refilling, root canal, extraction.
- Band 3 – Includes all treatments in bands 1 and 2 as well as crown, replacement (e.g. dentures, bridges).

The cost of a band of treatment is determined by the number of Units of Dental Activity (UDA) associated with the band (1 UDA for band 1, 3 for band 2 and 12 for band 3) and the payment per UDA. The payment per UDA varies around the country, but is usually in the range £15 to £25.[25] We assumed that fillings and extractions conducted in general practices would be classified as band 2, incurring 3 UDAs at a cost of £25 per UDA. The cost of extractions conducted under general anaesthetic was taken to be £1,160, based on the NHS Reference cost for this procedure. Since children below the age of 18 are exempt from patient charges, no patient charges were included in the model.

Health state values

Following the NYEAC approach [25], QALY losses were attributed to extractions but not to fillings or decayed teeth per se, due to a lack of data. The assumptions used to estimate QALY loss associated with decay were agreed by the PHAC for PH55. Firstly, we used the NYEAC estimates of QALY loss from the mortality risk associated with general anaesthesia, which is necessary for extractions in young children (assumed 100% in the analysis for 1-6 year olds) and for some older children (assumed to be 50% for 11-12 year olds). The NYEAC assumed a mortality rate associated with extraction under general anaesthesia of one in 300,000 (0.00013). Each death was then associated with an estimated loss of 40 QALYs. This figure was calculated from general population life tables and utilities (EQ-5D scores from the Health Survey for England)[79].

The second element of QALY loss due to extractions relates to pain and anxiety for the child. Again, we adopted assumptions used by NYEAC in their previous analysis. [25] In children, mapping estimates were considered inappropriate and it was decided that, utility estimates for Otitis Media (OM) would be used as a proxy for the quality of life impact of tooth extraction. The base case OM utility estimate of 0.72 was obtained from Oh et al. (1996)[80], and sensitivity analysis was done using values reported by Coco (2007)[81] and Dakin et al. (2010)[82].

Finally, we added willingness to pay from our valuation analysis (Table 13). These figures were used to infer a value for avoidance of decay with pain in young children, not otherwise captured by the QALY estimates for extraction. In older children three estimates of willingness to pay were used: WTP to avoid decay without pain, decay with pain and extraction. We assumed that 50% of filled teeth would have been associated with pain.

Probabilistic sensitivity analysis

In addition to one-way sensitivity analyses and scenario analyses, stochastic analyses were carried out in both models to account for uncertainty over model inputs. Table 21 and Table 22 detail the base case values of parameters and their distributions for the PSA. We were interested in determining how the uncertainty in the many input parameters affected oral health outcomes, costs, QALYs, and WTP estimates. We applied gamma distributions to prevalence of dmft/DMFT at ages 5, 8, 12 and 15 from the CDHS 2003, using reported standard errors from the survey. Uncertainty over the effectiveness estimates (relative risks of decay per initially sound untreated tooth) were estimated by fitting gamma distributions to the mean dmft/DMFT for the intervention and control groups at baseline and end of studies. Means and standard errors for these distributions were taken from the reported values in the Blinkhorn and Hausen studies. Gamma distributions were also used to reflect uncertainty over the WTP estimates from the valuation survey, using means and standard errors reported in Table 15 above. For cost data, duration of disutility and probability of death with general anaesthesia, no standard errors or confidence intervals were available and we had to make plausible estimates.

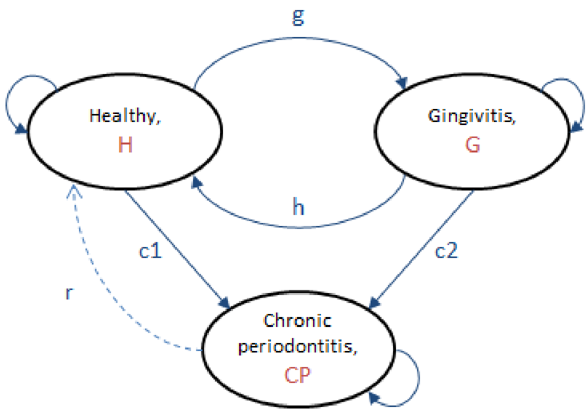
Stable estimates from the PSA were obtained after 5000 iterations. The outputs from the PSA simulations were ICERs, incremental net benefits from a cost-utility perspective (valuing QALY gains at the NICE thresholds of £20,000 and £30,000), and incremental net benefit from a cost-benefit perspective (based on WTP and cost estimates). In addition, we estimated the 95% confidence intervals for these outputs and plotted scatter diagrams of cost and effect.

4.2.3 Adult gum model

Model structure

We used a model to estimate the cost-effectiveness of oral health promotion programmes for adults with periodontal disease. The model structure was a three-state Markov model developed by Mdala et al.[64] to predict the progression of gum disease in initially-healthy sites in adults after treatment for chronic periodontitis (CP) (as illustrated in Figure 2 below).

Figure 2. Adult gum model



Mdala et al. presented two versions of their model, defining CP on the basis of either DOP or LOA:

- Healthy sites (H) : DOP/LOA ≤4mm and no BOP
- Gingivitis (G): DOP/LOA ≤4mm and BOP
- Chronic Periodontitis (CP): DOP/LOA >4mm with or without BOP

The model allowed onset of gingivitis in previously healthy gum sites (transition probability g), and also resolution of gingivitis, with the site returning to healthy (probability h). Progression to CP could occur from previously healthy sites, 'fast progression' (probability c1) and from those with gingivitis, 'slow progression' (probability c2). Mdala et al. assumed that once developed, CP is irreversible (it is an 'absorbing state').

We adapted this model to evaluate the effectiveness of an individually tailored education programme to promote gum health based on the Jönsson et al. (2009, 2010, 2012) [21-23] study. The trial included patients undergoing a non-surgical treatment programme for CP. Jönsson et al. reported that some gum sites with CP healed (DOP reduced to less htan 4mm) over 12 months of follow-up, during which patients received periodontal treatment. We therefore adapted the model to allow transitions from the CP to H gum states during the first year (probability r), but thereafter assumed no further healing (as in Mdala et al).

Jönsson et al. (2012) published a cost-effectiveness analysis based on their trial, which reported an incremental cost of €191 per case of treatment success (approximately £242).[23] This figure may seem modest, but it is higher than the estimated willingness to pay to avoid gum problems from our valuation study, £125 (95% CI: £107 to £142), suggesting that the intensive individually-tailored programme might not produce benefits of sufficient value to justify its cost. However, the Jönsson et al. cost-effectiveness analysis used a short time horizon of only one year, and so did not incorporate value attached to gum health improvements persisting after this time. We therefore aimed to extrapolate outcomes and costs from the Jönsson et al. trial to investigate its possible costs and benefits over a longer time period. The model was implemented with a one year Markov cycle, over a 10 year time horizon. In the base case, the results were estimated for a cohort of 1,000 individuals similar to the patients recruited to the Jönsson et al. trial: age 51 years with only 10% of gum sites initially healthy, 65% with gingivitis (BOP) and 25% chronic periodontitis (DOP>4mm).

Baseline risks

Mdala et al. estimated transition probabilities for their three-state Markov model of periodontal disease using data from initially healthy mesiobuccal sites over two years of follow up.[64] The study used data from a randomised trial of treatment for chronic periodontitis, including 217 individuals in Boston USA and Gothemburg Sweden.[83,84] Data for the LOA version of the model were available for 1,124 sites in 162 individuals (mean age 52, range 26-84), and for the DOP version from 1,374 sites in 154 people (mean age 54, range 26-84).

We used transition probabilities from the DOP version of the Mdala model, which provided consistency with outcomes reported by Jönsson et al. (2009, 2010, 2012).[21-23] Transition probabilities were sampled as Beta distributions for the PSA, using the means and confidence intervals reported in Table 23 below. The annual probability of new-onset gingivitis in previously healthy sites in this high-risk population was 12%, although there was a high annual probability of recovery (72% in the LOA model and 80% in the DOP model). Fast progression of sites from healthy to CP was 5% based on a measure of LOA, and 1% based on DOP. Annual progression from gingivitis to CP was 7% based on LOA, and 3% based on DOP. Mdala et al. noted that the estimates of the incidence of CP based on LOA may be an over-estimate, since attachment loss can be from non-inflammatory causes. Conversely, they argued that estimates based on DOP may be an under-estimate, as this measure does not allow for gingival recession, which is common from middle age.

Table 23. Annual transition probabilities for mesiobuccal sites, Mdala et al.[64]

		Mean (95% confidence interval)			
State transitions		*Loss of attachment*		*Depth of pocket*	
Healthy to gingivitis (H to G)	g	0.12	(0.11, 0.13)	0.12	(0.11, 0.13)
Gingivitis to healthy (G to H)	c1	0.72	(0.68, 0.77)	0.80	(0.77, 0.83)
Healthy to chronic periodontitis (H to CP)	h	0.05	(0.04, 0.06)	0.01	(0.01, 0.02)
Gingivitis to chronic periodontitis (G to CP)	c2	0.07	(0.04, 0.10)	0.03	(0.01, 0.05)

Mdala et al. also used multivariate analysis to estimate hazard ratios for a number of baseline risk factors for periodontitis: gingival redness, smoking, gender, age and severity (number of teeth with LOA/DOP > 4mm) – Table 24. This found that gingival redness and male gender were related to an increased the risk of gingivitis. However, it is perhaps surprising that age was negatively associated with the onset of gingivitis. Mdala et al. argued that this may be explained by a ‘frailty effect’ in this selected group of people with existing periodontitis, as sites prone to develop periodontal disease tend to do so at a younger age. Sites in people with extensive periodontal disease at baseline were more likely to progress to CP. Smoking was also associated with an increase in ‘fast progression’ of CP.

For sensitivity analysis, the hazard ratios for age and smoking were used to adjust the incidence of gingivitis (g) and 'fast progression' from healthy to CP (c1) respectively. The hazard ratios were sampled from lognormal distributions for the PSA analysis, based on the reported means and confidence intervals in Table 24.

Table 24. Hazard ratios for transitions from multivariate analysis, Mdala et al. [64]

Covar-iates	Mean (95% confidence interval)							
	H to G (g)		*G to H (h)*		*H to CP (c1)*		*G to CP (c2)*	
Loss of attachment model								
Redness	2.15	(1.56, 2.98)*	0.96	(0.64, 1.45)	0.48	(0.14, 1.70)	3.11	(0.53, 18.34)
Smoking	0.72	(0.53, 1.00)	0.71	(0.48, 1.05)	2.11	(1.19, 3.76)*	1.02	(1.02, 3.97)
Male	1.51	(1.10, 2.08)*	1.22	(0.81, 1.84)	1.18	(0.67, 2.08)	3.10	(0.84, 11.40)
Age	0.97	(0.96. 0.99)*	0.98	(0.97, 1.00)	1.00	(0.97, 1.03)	0.94	(0.87, 1.00)
Severity	1.00	(0.97, 1.02)	1.00	(0.97, 1.04)	1.07	(1.02, 1.12)*	1.15	(1.06, 1.26)*
Depth of pocket model								
Redness	2.13	(1.53, 2.97)*	1.13	(0.76, 1.68)	3.43	(1.12, 10.52)	1.57	(0.38, 6.51)
Smoking	0.89	(0.66, 1.22)	1.02	(0.71, 1.45)	2.20	(1.66, 7.37)*	0.48	(0.05, 5.02)
Male	1.39	(1.01, 1.91)*	1.00	(0.68, 1.48)	0.77	(0.25, 2.39)	7.43	(0.35, 15.63)
Age	0.98	(0.96, 0.99)*	1.00	(0.98, 1.01)	1.00	(0.94, 1.06)	0.88	(0.77, 1.02)
Severity	0.96	(0.96, 1.000	0.96	(0.92, 1.01)	1.11	(1.00, 1.25)*	1.12	(1.01, 1.28)*

** Statistically significant coefficient (p<0.05)*

Effectiveness data

Jönsson et al. compared an individually-tailored oral health education programme (ITOHEP) with standard therapy (ST). Their series of papers presented estimates of gum health status over a one-year follow-up period, based on clinical examination of depth of pocket (DOP) and bleeding on probing (BOP) at six surfaces of each tooth – outcomes compatible with the Mdala et al. model structure - as well as plaque and gingival health indices and an overall assessment of 'whole mouth' treatment success based on pre-defined criteria. The populations in the Mdala and Jönsson analyses were similar, both being based on individuals of a similar age (mean age 53 and 51 respectively) under treatment for chronic periodontitis.

Results from the one-year follow-up of participants in the Jönsson et al. RCT are summarised in Table 25. There was no significant between-group difference in the percentage of interproximal pockets (>4mm) at baseline that were closed after one year. However, there was a significant difference between the groups in the reduction in the number of sites with bleeding on probing: a reduction of 55% in the standard treatment arm, compared with 69% in the individualised programme arm (confidence interval not reported).

Table 25. One year results of Jönsson et al. trial used in gum model

	Standard treatment (ST)	Individual therapy (ITOHEP)
Participants at baseline	57	53
Percentage of interproximal pockets (DOP>4mm): mean (sd)		
Baseline	27.7% (20.7%)	24.8% (17.2%)
One year	6.7% (8.4%)	6.7% (6.9%)
Proportion of pockets closed	77% (17%)	75% (21%)
Percentage of interproximal sites with bleeding on probing: mean (sd)		
Baseline	75% (18%)	70% (20%)
One year	29% (14%)	19% (13%)
Percentage reduction	54.5%*	69.0%*

** Standard deviations not reported*

We used Beta distributions to model the uncertainty around the proportion of pockets closed over the year of follow up in the two arms (transition probability r) using the reported means and standard deviations for the two arms. Pocket closure was assumed to only occur in the first year after treatment initiation.

The absolute rates of site recovery from gingivitis (h) in both arms of the trial were lower than the estimate from Mdala et al. (80% one-year recovery, Table 23). The relative reduction in BOP with the individualised programme compared with standard treatment was therefore modelled using a hazard ratio (mean 1.5) to adjust the baseline risk from the Mdala study. This relative effect was only applied during the first year – assuming no residual benefit in gingivitis recovery rates after that time. Uncertainty over the hazard ratio for gingival recovery was modelled by taking independent random samples from beta distributions for the four proportions reported with standard deviations in Table 25 (the baseline and one-year proportions for the two treatment groups).

It was assumed that there were no differences between the arms in other transition probabilities: incidence of gingivitis (g) and progression to CP (c1 an c2).

Cost of intervention

Jönsson et al. (2012) estimated dental treatment costs over one year for participants in the RCT using individual-level data on the total mean treatment time (in minutes) and the number of visits to the clinic: see Table 26.[23] These data were used, together with unit costs (Table 27), to estimate costs for the two trial arms. Unit costs for dental hygienist and dentist time were estimated from clinic financial data, with allocation of overheads (including a dental assistant nurse for the dentist cost. Jönsson et al. also collected information from patients about their travel costs, out-of-pocket expenditure, and time taken for clinic visits.

As their methods of cost estimation were of a good standard, and we did not identify a better source of UK-specific data, we have converted Jönsson et al's estimates for use in our model. In the base case, we assumed that all treatment was delivered by a dental hygienist (as did Jönsson et al). Costs were converted from Swedish Krona to UK pounds using OECD Purchasing Power Parity rates for 2007, and uprated for inflation using the UK Hospital and Community Health Services Index. All cost results are reported in 2012/13 UK £. Resource use parameters were sampled from Gamma distributions for the PSA. Unit costs were treated deterministically.

Table 26. Resource use for individuals in Jönsson et al. trial [23]

	Standard treatment (ST)	*Individual therapy (ITOHEP)*
Participants at baseline	57	53
Number of visits: mean (sd)	8.37 (1.10)	8.71 (0.99)
Treatment time in minutes: mean (sd)	412.13 (90.84)	433.27 (67.31)
Patient time per visit: mean (sd not reported)	102.64	103.14

Table 27. Unit costs for resource items in Jönsson et al. trial [23]

		2007 Swedish Krona (Euros)	**2012/2013 UK £***
Dental hygienist	(per minute)	SEK 15.49 (€1.72)	£1.27
Dentist	(per minute)	SEK 36.04 (€4.00)	£2.94
Transport and out of pocket	(per visit)	SEK 32.86 (€3.64)	£2.68
Patient time	(per minute)	SEK 3.47 (€0.38)	£0.28

** Converted using 2007 GDP Purchasing Power Parity (SEK 13.77 per £) and Hospital and Community Health Services inflation index 2007/8 to 20012/13 (1.12 multiplier)*

We did not attempt to estimate treatment costs for ongoing or newly incident sites of gingivitis or chronic periodontitis after the one-year treatment and follow-up period, although individuals experiencing ongoing or recurrent gum disease are likely to re-attend for further treatment. These costs could be added to the model if appropriate data or assumptions are available.

Health state values

The value that patients attach to the avoidance of new sites of chronic periodontitis was estimated from the survey reported above: £125 (95% CI: £107 to £142). This parameter was sampled from a Gamma distribution for the PSA, and attached as a benefit for pockets closed in the first year and as a penalty for each new site of CP during the ten year time horizon.

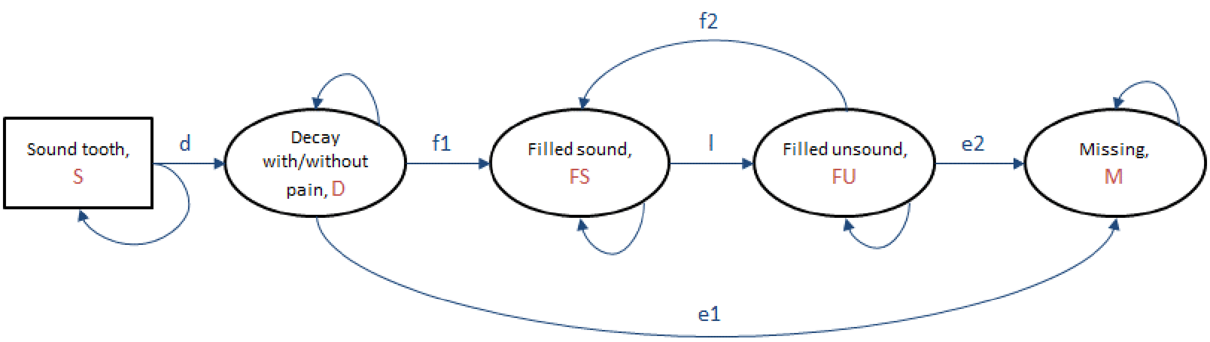
4.2.5 Adult tooth model

Model structure

Following the NYEAC approach[25], we estimated costs and effects per incident case of tooth decay by age using a Markov model to reflect possible series of fillings, other restorative work and extractions. The output of this 'decay pathway' was a lookup table of dental treatments, costs (to the NHS and to patients) and WTP valuations per newly decayed tooth by age at the time of onset, discounted and summed over a defined time horizon (20 years). These results could be fed into a second Markov model, to quantify the effects of an oral health promotion intervention on the incidence of decay, and hence treatment costs and WTP incurred (versus a 'usual care' comparator). However, no evidence of effectiveness in reducing the incidence of tooth decay in adults has been identified. The results of the first-stage decay pathway model are therefore presented below for information.

The decay pathway model is illustrated in Figure 3. NYEAC [85] described a sequence of increasingly radical attempts at restoration (filling, bigger filling, crown, root canal, extraction). We used a simpler approach, and did not differentiate between types of fillings or other restorations. Following decay of a previously sound tooth (S to D, probability d), a filling may be administered (D to FS, probability f1) or the tooth may be extracted immediately (D to M, probability e1). Once a tooth has been filled, it may remain sound or become unsound either due to failure of the filling or repeated decay in the same tooth (FS to FU, probability l), and then require further restorative treatment (FU to FS, probability f2) or extraction (FU to M, probability e2). A tooth may undergo several attempts at restoration in this model. In addition to the five tooth states (S, D, FS, FU and M) members of the cohort (and their teeth) may die according to a defined mortality rate.

Figure 3. Decay and treatment pathway for anterior, premolar and molar teeth



The pathway was replicated for the three categories of teeth: anterior, premolar and molar teeth. Data from the ADHS of 1998 [63] and 2006 [60] justify the approach of separately modelling different teeth types, as anterior teeth have significantly different rates of decay and extraction compared with premolars and molars. In addition, there is evidence that the retention of anterior teeth is valued more highly than the other teeth.[57]

A three month cycle length was deemed to be a plausible reflection of the maximum speed of transition between states of the decay pathway model (it is assumed to be impossible to make more than one transition in this time). We used a 20 year time horizon for the Adult Tooth Model. The outputs from the decay pathway model were cumulative sums of costs and WTP discounted over the given time horizon for the three teeth categories by age of incident decay.

Baseline risks and calibration

The rate of progression of teeth through the model is governed by six three-month probabilities (d, f1, e1, l, f2 and e2). These probabilities were allowed to vary between the three tooth types (anterior, premolar and molar) and by the age of the modelled cohort (in five age groups: 16-24, 25-34, 35-44, 45-54, 65+). In addition, members of the cohort can die within the modelled time horizon. Mortality rates by age were taken from national life tables (England, 2011-13).[86]

Transition probabilities between the tooth states were fitted using prevalence data from the ADHS 1998 and 2009 (see Appendix Q for the Stata 'do file' programmes for this analysis).[60,63] Steele et al. used a synthetic cohort approach to estimate the progression of tooth decay and loss from the five cross-sectional national surveys of adults' dental health conducted at ten-year intervals between 1968 and 2009.[87] They adjusted for cohort effects by tracking 10-year age groups across the consecutive decennial surveys. For example, the 16-24 year old age group in 1968 were compared with the 25-34 year group in 1978, the 35-44 year group in 1988 and so on. This analysis demonstrated strong cohort effects, with large reductions in decayed and missing teeth in each age group over this fifty year period. However, estimates of incidence obtained by this method do not account for the uncertainty that arises because the individuals examined at each survey are not the same people, but different samples from the population. Thus differences in DMFT between neighbouring age groups in consecutive surveys may be due to sampling error rather than true differences in the incidence of decay.

Calibration is a method that can be used in such cases to adjust uncertain input parameters (e.g. incidence rates estimated from cross-sectional data) to achieve a better fit between predicted model outputs (e.g. point prevalence of tooth states) and real-world observations.[88] This approach is often used in models of cancer screening, where early rates of cancer incidence and progression are unknowable or uncertain due to a lack of longitudinal data.[89-91] Calibration can also be used to introduce correlations between sets of sampled input parameters for use in probabilistic sensitivity analysis (PSA), to more appropriately reflect uncertainty over the results. Vanni et al. have described the process of calibration using a seven-step approach. [88]

I. Parameters to include in the calibration process

The parameters to be calibrated were the three-month transition probabilities between tooth states (d,f1,e1,l,f2,e2) for each tooth type and age group. Starting values for each of these parameters were sampled probabilistically.

- An initial estimate of the decay probability (d) by tooth type and age group was obtained by comparison of the mean proportion of teeth that were sound and untreated in consecutive ten-year age groups in the 1998 and 2009 ADHS (e.g. 16-24 years in 1998 and 25-34 years in 2009). Uncertainty was introduced into these initial incidence estimates by independent random sampling of the proportion of sound untreated teeth in both years (from independent Beta distributions).

Estimates of the filling failure probability (l) were sampled from reported median failure times by age, calculated from Dental Practice Board data.[61] Again, Beta distributions were used to sample failure probability.

- The probability of detection of decayed (D) and filled but unsound (FU) teeth was governed by estimates of the probability of a dental check-up per cycle (v), which varied by age group. This was sampled using a Dirichlet distribution based on the frequency distribution of self-reported time since last dental visit in the ADHS 2009. It was assumed that all decayed or filled unsound teeth would be identified at the next dental visit, and either restored or extracted at that time.

- The proportion of decayed or filled unsound teeth that were extracted once detected (r), was estimated as the proportion of decayed and filled unsound teeth identified in the ADHS 2009 examination that were assessed as 'unrestorable'. This information was not recorded separately for unfilled/ filled teeth, and so a single proportion was used to infer the transition probabilities from D to M and from FU to M. However, to allow variation between these two transitions, two independent values of r were sampled from the same Beta distribution. The mean proportion of decayed or filled unsound teeth that were unrestorable estimated from the ADHS 2009 data differed between anterior, premolar and molar teeth, but was similar between people of different ages.

II. Selection of calibration targets

The aim of the calibration process was to obtain modelled estimates of the proportion of anterior, premolar and molar teeth in each tooth state (S, D, FS, FU, M) for each age group (16-24, 25-34, …, 64+) close to the observed values from the ADHS 2009 data. The model was initiated using tooth state prevalence from the 1998 ADHS, and run for ten years. The modelled distributions for each age cohort in 1998 were then compared with the targets for the next age cohort in 2009 (e.g. ten-year modelled results for 16-24 year olds in 1998 were compared with target outcomes for 25-34 year olds in 2009).

III. Goodness-of-Fit (GOF) measures

The measure of how well the model outputs fitted the calibration targets was taken to be a weighted sum of chi-squared values. There were a total of 90 targets (5 x 3 x 6 for each of 5 tooth states, 3 tooth types and 6 age bands). For each target (i=1,2,…90), a chi-squared value (χ_i^2) was calculated by taking the difference between the target mean μ_i and the modelled outcome y_i, dividing by the standard error of the target σ_i, and taking the square:

$$\chi_i^2 = \left(\frac{(\mu_i - y_i)}{\sigma_i}\right)^2$$

A weighted sum of these chi-squared values was calculated as the summary measure of GOF.

$$\chi^2 = \sum_{i=1}^{90} w_i \left(\frac{(\mu_i - y_i)}{\sigma_i}\right)^2 \Big/ \sum_{i=1}^{90} w_i$$

The lower this value, the better the 'fit' of the modelled results to the target outcomes. The weights w_i were set to place greater emphasis on fitting more robust data: a weight of 100 was used for the proportions of sound, filled sound and missing teeth; and 50 each for decayed or filled unsound (since the latter are less frequent than the longer lasting states (S, FS and M), and therefore less likely to be accurately measured in the survey).

IV. Parameter search strategies

A simple random search method was used. Values for each of the original input parameters (d, v, r, l) were randomly sampled from the probability distributions defined in step 1 above, and used to calculate a set of transition probabilities $\vartheta_j = \{d, f1, e1, l, f2, e2\}$ for each tooth type and age strata, j= 1,2,…,108 (6 x 3 x 6). Each set of probabilities was used to generate one set of outcomes y_i (i=1,2,…,90), and GOF summary χ^2.

V. Convergence (or acceptance) criteria

The criterion for an acceptably-calibrated parameter set was defined by a maximum χ^2 value. In the final this value was set to 10. This was defined empirically, as a number low enough to ensure a reasonably close fit, but sufficiently high to make model run-time feasible.

VI. Stopping rule

The above process was repeated until sufficient acceptably-calibrated parameter sets were obtained to return stable estimates from the PSA (2,000 iterations).

VII. Integrating the results of the calibration and the economic parameters

The output from the calibration model comprised a table, with each row containing one calibrated set of sampled transition probabilities. One set of values for the non-calibrated probabilistic parameters was sampled alongside each set of calibrated parameters:

- WTP values to avoid fillings and extractions in anterior, premolar and molar teeth were sampled from independent gamma distributions based on the means and confidence intervals reported in Table 13.
- Data used to estimate NHS costs and patient charges per filling and per extraction are summarised in Table 28. The NHS cost per UDA was sampled from a gamma distribution, assuming a mean of £25 and 95% confidence interval of £15 to £35. The proportions of fillings and extractions coded as band 1, 2 and 3 were estimated from NHS Dental Statistics 2013/14. The proportion of patients paying charges for NHS dental treatment was also estimated from this source.

Table 28. Costs of NHS dental treatment

	Band 1	Band 2	Band 3
UDA per treatment	1	3	12
Mean NHS cost	£25	£75	£300
Patient charge	£18.50	£50.50	£219.00
Percentage paying charges	78.06%	64.99%	45.12%
Proportion of fillings	0.13%	81.90%	17.97%
Proportion of extractions	0.24%	68.17%	31.59%

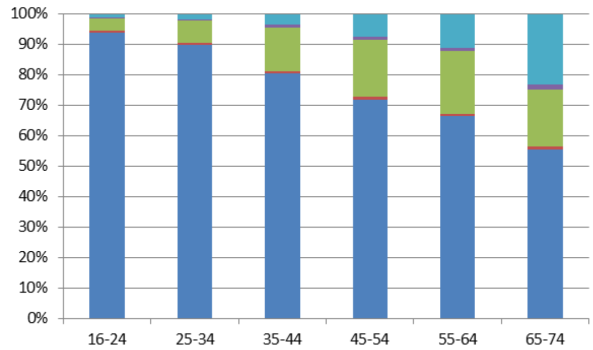
4.2.5.1.1 Results of the calibration process

The means and standard errors for the calibrated parameters are shown in Appendix R. The fit of the final model to the ADHS 2009 targets is illustrated in Table 29. The three graphs on the left hand side show the proportions of anterior, premolar and molar teeth by health state by age cohort observed in the ADHS 2009. The graphs on the right hand side show the corresponding modelled outputs from the calibrated model (means from 2,000 calibrated parameter sets). Note that the age groups shown on these graphs correspond to the initial age of the cohorts at the start of the model run, while the targets and modelled outputs relate to their outcomes after ten years. It can be seen that the calibration process achieved a good overall fit to the target outcomes.

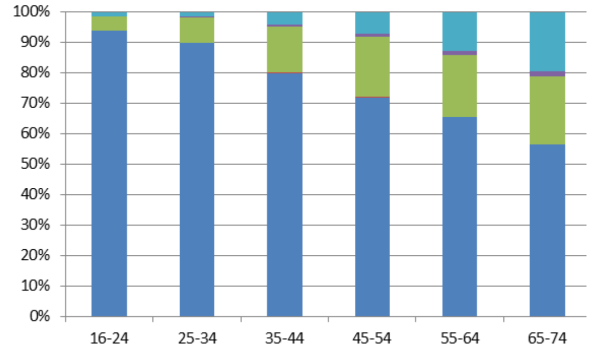
Table 29: Calibration targets and outputs from adult tooth model

Anterior teeth

Targets for calibration (ADHS 2009)

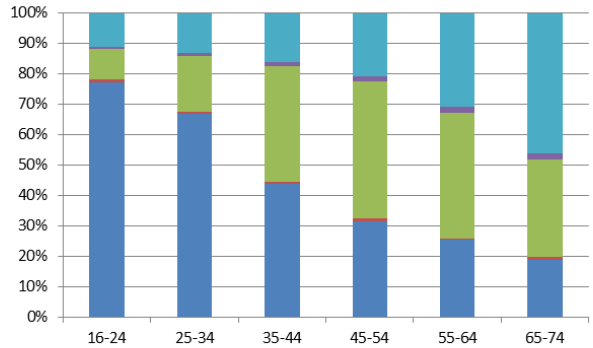


Outputs from calibrated model (mean of PSA iterations)

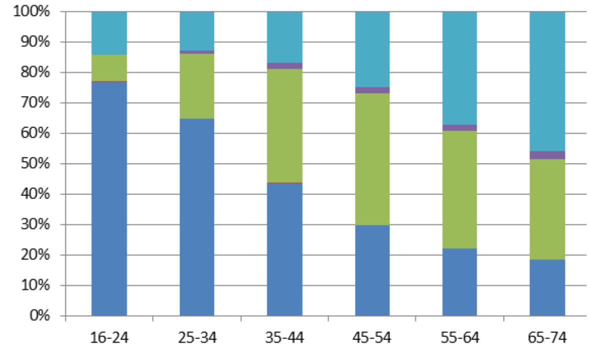


Premolar teeth

Targets for calibration (ADHS 2009)

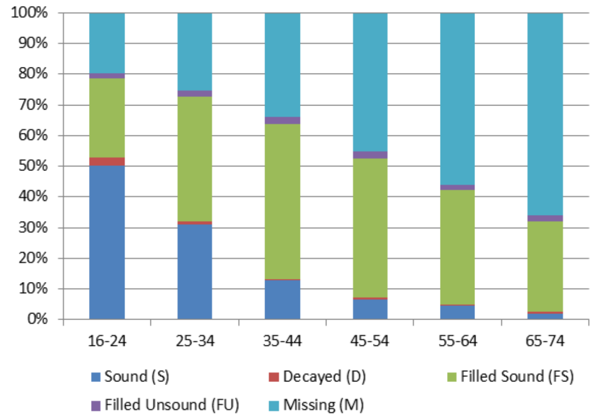


Outputs from calibrated model (mean of PSA iterations)

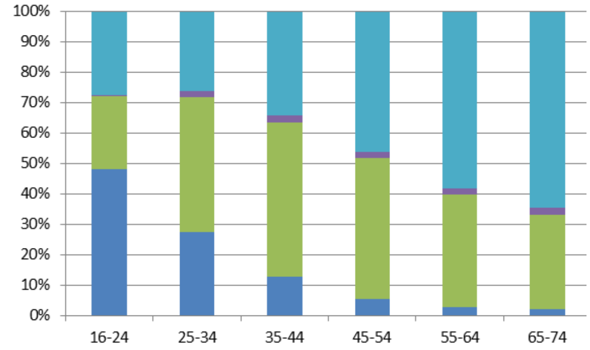


Molar teeth

Targets for calibration (ADHS 2009)



Outputs from calibrated model (mean of PSA iterations)



4.3 Results

4.3.1 Children's model

Table 30 to Table 33 detail base case and probabilistic cost-consequence summaries for young and older groups of children in average and higher risk subgroups. Results are presented per hundred children participating in the preventive intervention.

The results of the economic analysis based on the Blinkhorn intervention in children aged 5 years at average risk (increase in mean dmft of 0.13 over two years) are shown in Table 30. The number of dmft averted due to the intervention per hundred children participating was estimated at 3.15 (mean PSA results). However, this figure was subject to a very high level of uncertainty: with an estimated 95% confidence interval of -11.72 to 17.99. The estimated reductions in fillings and extractions were small, and the associated cost savings for the NHS did not compensate for the estimated cost of the preventive intervention. The net increase in costs was estimated at £3,681 (-£1,303 to £12,537) per 100 children. QALY gains attributed to avoided extractions were estimated at 0.023 (-0.077 to 0.137), and additional WTP benefits for avoidance of decay with pain at £62 (-£218 to £381). Overall the estimated incremental cost per QALY was £163,558, which was highly uncertain (from the intervention being dominant to a very high ICER of over £2m). This suggests that the intervention is not cost-effective in this average-risk group of 5 year olds, according to usual NICE thresholds, however this finding is highly uncertain: there is a 20% probability that the ICER falls below £20,000 per QALY. If we consider a higher risk group, as included in the control arm of the Blinkhorn study (with a mean increment in dmft of 1.05 over two years), the intervention appears to be cost-saving, but still subject to high uncertainty (see Table 31). The mean estimated INB at £20,000 per QALY is £7,438 (-£18,939 to £35,841) per 100 children: 71% estimated probability that the intervention is cost-effective at this threshold.

The results for the analysis based on the Hausen study in 12 year olds at average risk (increase in mean DMFT of 0.8 over 3 years) are summarised in Table 32. This shows a total DMFT averted of 64.15 (40 to 89) and an estimated cost saving for the NHS of £6,476 (-£711 to £13,784) over 3 years per 100 children participating. The estimated ICER is £14,408 per QALY gained (dominated to £55,168), and the estimated probability that the intervention is cost-effective is 65% at a threshold of £20,000 per QALY or 84% at a £30,000 per QALY threshold. Using a cost-benefit approach, WTP net of costs is estimated at £3,924 (-£5,832 to £15,346) per 100 children: 75% estimated probability that the intervention is cost-beneficial. These results are even more favourable if we consider a subgroup of 12 year old children at higher than average risk (increase in DMFT of 2.3 over 3 years), which is the mean risk observed in the control group for the Hausen study (see Table 33). This analysis gave an estimated INB at £20,000 per QALY of £28,677 (£8,006 to £54,156) per 100 children, and WTP net of costs of £32,745 (£13,345 to £52,387). All of the 2,000 PSA iterations ran suggested that the intervention was cost-effective at usual NICE thresholds.

In addition to the PSA results reported above, we conducted a series of deterministic sensitivity analyses across plausible ranges of model input parameters (see Appendix Q). The results of the analysis based on the Blinkhorn et al. study were sensitive to a number of parameters. Firstly, the baseline risk of decay in the population of interest (as discussed above). The Blinkhorn-based model was also sensitive to the proportion of decayed teeth that are extracted. In the base case this was assumed to be 14%, but when this figure was increased to 60% the ICER fell to around £20,000 per QALY. Not surprisingly, the model was sensitive to changes in the cost and effectiveness of the intervention, although large improvements were required to bring the ICER into the acceptable range.

The results of the analysis based on the Hausen et al. study were also sensitive to the baseline risk in the population of interest: in a subgroup with lower than average risk (below 0.7 increase in mean DMFT over 3 years) the ICER rose to above £20,000 per QALY. The results were also somewhat sensitive to assumptions about the percentage of decayed teeth filled, the percentage of decayed teeth extracted and to the percentage of extracted teeth removed under general anaesthetic. The ICER was also sensitive to assumptions about the QALY loss associated with tooth removal. Finally, as might be expected, the results were sensitive to increases in the incremental cost of intervention and to reductions in its effectiveness (the hazard ratio).

Table 30: Cost consequences of Blinkhorn intervention in 5 year old children at average risk **(**change in mean dmft of 0.13 over 2 years): Results per 100 children

		Deterministic results			Probabilistic results			
		Control	*Intervention*	*Increment*	*Mean*	*Lower limit*	*Upper limit*	*P(INB>0)*
dmft	Δdmft	13.358	8.472	-4.89	-3.15	-17.99	11.72	
	Δfilled	1.670	1.059	-0.61	-0.40	-2.48	1.55	
	Δextracted	1.858	1.178	-0.68	-0.44	-2.54	1.63	
Costs	Intervention	£0	£4,256	£4,256	£4,217	£397	£12,694	
	Fillings	£124	£79	-£45	-£30	-£198	£114	
	Extractions (no GA)	£0	£0	£0	£0	£0	£0	
	Extractions (under GA)	£2,139	£1,357	-£782	-£507	-£2,929	£1,875	
	Total	**£2,264**	**£5,692**	**£3,428**	**£3,681**	**-£1,303**	**£12,537**	
QALY loss	Extraction (OM)	0.094	0.059	0.0342	0.0224	-0.0766	0.1370	
	Extraction (GA)	0.000	0.000	0.0001	0.0001	-0.0002	0.0004	
	Total	**0.094**	**0.060**	**0.0343**	**0.0225**	**-0.0768**	**0.1374**	
WTP	Decay with pain	-£249	-£158	£91	£62	-£218	£381	
ICER	Cost per QALY			**£99,826**	**£163,558**	**Dominant**	**£2,353,655**	
INB	At £20,000 per QALY			**-£2,741**	**-£3,231**	**-£13,025**	**£3,539**	**20%**
	At £30,000 per QALY			**-£2,398**	**-£3,006**	**-£13,245**	**£4,668**	**24%**

Table 31: Cost consequences of Blinkhorn intervention in 5 year old children at high risk (change in mean dmft of 1.05 over 2 years): Results per 100 children

		Deterministic results			Probabilistic results			
		Control	*Intervention*	*Increment*	*Mean*	*Lower limit*	*Upper limit*	*P(INB>0)*
dmft	Δdmft	105.000	67.246	-37.75	-38.00	-119.90	43.62	
	Δfilled	13.125	8.406	-4.72	-4.78	-15.60	5.56	
	Δextracted	14.606	9.354	-5.25	-5.27	-17.86	6.07	
Costs	Intervention	£0	£4,256	£4,256	£4,311	£395	£12,521	
	Fillings	£977	£626	-£351	-£356	-£1,235	£406	
	Extractions (no GA)	£0	£0	£0	£0	£0	£0	
	Extractions (under GA)	£16,819	£10,771	-£6,048	-£6,075	-£20,571	£6,992	
	Total	**£17,796**	**£15,653**	**-£2,144**	**-£2,120**	**-£17,861**	**£13,788**	
QALY loss	Extraction (OM)	0.736	0.471	0.2647	0.2652	-0.3018	0.9603	
	Extraction (GA)	0.002	0.001	0.0007	0.0007	-0.0008	0.0025	
	Total	**0.738**	**0.473**	**0.2654**	**0.2659**	**-0.3027**	**0.9627**	
WTP	Decay with pain	-£1,958	-£1,254	£704	£714	-£840	£2,449	
ICER	Cost per QALY			**Dominant**	**Dominant**	**Dominant**	**£141,951**	
INB	At £20,000 per QALY			**£7,452**	**£7,438**	**-£18,939**	**£35,841**	**71%**
	At £30,000 per QALY			**£10,106**	**£10,097**	**-£21,586**	**£45,759**	**73%**

Table 32: Cost consequences of Hausen intervention in 12 year old children at average risk (change in DMFT of 0.8 over 3 years): Results per 100 children

		Deterministic results			Probabilistic results			
		Control	*Intervention*	*Increment*	*Mean*	*Lower limit*	*Upper limit*	*P(NB>0)*
DMFT	ΔDMFT	80.000	15.516	-64.48	-64.15	-88.72	-40.00	
	Δfilled	50.000	9.697	-40.30	-40.24	-58.31	-24.08	
	Δextracted	11.128	2.158	-8.97	-8.96	-14.31	-4.74	
Costs	Intervention	£0	£15,041	£15,041	£15,016	£9,622	£21,394	
	Fillings	£3,695	£717	-£2,979	-£2,976	-£4,986	-£1,530	
	Extractions (no GA)	£411	£80	-£331	-£331	-£598	-£154	
	Extractions (under GA)	£6,497	£1,260	-£5,237	-£5,233	-£8,338	-£2,787	
	Total	**£10,603**	**£17,097**	**£6,494**	**£6,476**	**-£711**	**£13,784**	
QALY loss	Extraction (OM)	0.557	0.108	0.4487	0.4489	0.1877	0.8257	
	Extraction (GA)	0.001	0.000	0.0006	0.0006	0.0003	0.0010	
	Total	**0.557**	**0.108**	**0.4493**	**0.4495**	**0.1881**	**0.8263**	
WTP	Decay no pain	-£2,824	-£548	£2,276	£2,234	£944	£4,356	
	Decay with pain	-£7,506	-£1,456	£6,050	£6,011	£3,177	£9,770	
	Removal	-£2,678	-£519	£2,159	£2,155	£968	£3,892	
	Total	**-£13,008**	**-£2,523**	**£10,485**	**£10,400**	**£5,777**	**£16,154**	
ICER	Cost per QALY			**£14,454**	**£14,408**	**dominated**	**£55,168**	
INB	At £20,000 per QALY			**£2,492**	**£2,514**	**-£7,705**	**£14,527**	**65%**
	At £30,000 per QALY			**£6,985**	**£7,008**	**-£5,481**	**£22,693**	**84%**
	Cost benefit (WTP - cost)			**£3,991**	**£3,924**	**-£5,832**	**£15,346**	**75%**

Table 33: Cost consequences of Hausen intervention in 12 year old children at high risk (change in DMFT of 2.3 over 3 years): Results per 100 children

		Deterministic results			Probabilistic results			
		Control	*Intervention*	*Increment*	*Mean*	*Lower limit*	*Upper limit*	*P(NB>0)*
DMFT	ΔDMFT	203.964	40.337	-163.63	-162.00	-203.96	-105.61	
	Δfilled	127.478	25.210	-102.27	-101.53	-136.01	-63.97	
	Δextracted	28.371	5.611	-22.76	-22.45	-33.92	-12.68	
Costs	Intervention	£0	£15,041	£15,041	£14,986	£9,739	£21,248	
	Fillings	£9,423	£1,863	-£7,560	-£7,455	-£11,668	-£4,019	
	Extractions (no GA)	£1,049	£207	-£841	-£826	-£1,418	-£390	
	Extractions (under GA)	£16,567	£3,276	-£13,291	-£13,111	-£19,803	-£7,389	
	Total	**£27,038**	**£20,387**	**-£6,651**	**-£6,406**	**-£17,769**	**£4,367**	
QALY loss	Extraction (OM)	1.420	0.281	1.1389	1.1121	0.5168	2.0244	
	Extraction (GA)	0.002	0.000	0.0014	0.0014	0.0007	0.0025	
	Total	**1.421**	**0.281**	**1.1403**	**1.1135**	**0.5175**	**2.0258**	
WTP	Decay no pain	-£7,200	-£1,424	£5,777	£5,756	£2,370	£10,600	
	Decay with pain	-£19,140	-£3,785	£15,356	£15,156	£8,591	£22,399	
	Removal	-£6,828	-£1,350	£5,478	£5,426	£2,560	£9,460	
	Total	**-£33,169**	**-£6,558**	**£26,611**	**£26,339**	**£15,963**	**£37,715**	
ICER	Cost per QALY			**Dominant**	**Dominant**	**Dominated**	**£6,145**	
INB	At £20,000 per QALY			**£29,457**	**£28,677**	**£8,006**	**£54,156**	**100%**
	At £30,000 per QALY			**£40,860**	**£39,812**	**£13,430**	**£74,191**	**100%**
	Cost benefit (WTP - cost)			**£33,262**	**£32,745**	**£13,345**	**£52,387**	**100%**

4.3.2 Adult gum model

Figure 4 illustrates the modelled gum health outcomes (deterministic model results) for the two active periodontal treatment strategies (standard treatment, and the individualised programme) in the Jönsson et al. (2009, 2010, 2012) [21-23] study, compared with a 'natural history' post-treatment baseline (based on the Mdala et al. cohort analysis). It can be seen that a large initial improvement in gum health is predicted in all three groups, including the modelled 'post treatment' control group. The estimated improvement by the second year is larger in the two active treatment groups (standard and individualised therapy from the Jönsson et al. trial), due to the recovery of a high proportion of CP sites in year one (both groups), and the additional reduction in the proportion of sites with gingivitis (in the individual treatment cohort). After ten years, the two active treatment groups are estimated to retain better overall gum health, with a higher proportion of healthy sites and fewer CP sites than the comparator. However, it can be seen that there is very little difference in the estimated outcomes between the standard and individualised treatment groups after ten years.

The comparative results for the standard and individualised programmes of treatment are summarised in Table 34. These suggest that the conclusion about the relative costs and benefits of these interventions is not at all clear-cut. The individualised programme is estimated to be slightly more expensive than standard treatment: about £38,700 more in year one for a cohort of 1,000 patients, including both costs of treatment and costs to patients. However, effects on incidence of chronic periodontitis are equivocal. Although the individualised programme was estimated to achieve a greater reduction in gingivitis in the first year, and this reduction would be associated with a reduced risk of progression to CP over time, standard treatment was associated with a small but non-significant advantage in the observed rate of pocket closure in year one (77% compared with 75% for the individual programme). The net result is that the individual programme is associated with a greater proportion of gum sites with CP after ten years than standard treatment, which yields a lower willingness-to-pay value (£36,228 lower in the individual programme arm than in the standard care arm). The Incremental Net Benefit (INB) is therefore also negative (-£74,934), indicating that the additional benefits of the individualised programme of treatment do not balance its additional costs.

There is a high level of uncertainty over this result however: from the PSA the 95% confidence interval for INB was estimated at -£261,778 to +£119,791, and the estimated probability that the INB is positive was 22%. Furthermore, the results are somewhat sensitive to changes in assumptions about how to model outcomes. In particular, if we assume that the rate of pocket closure in year one is equal between the two arms (which is not unreasonable as the difference is not statistically significant), individualised treatment is predicted to reduce the number of gum sites with CP after ten years, and achieves a greater willingness-to-pay value than standard treatment (see Table 35). However, this benefit is still not sufficient to outweigh estimated costs, and the mean INB is still negative (95% CI: -£63,013 to £17,790).

Figure 4. Modelled gum health outcomes

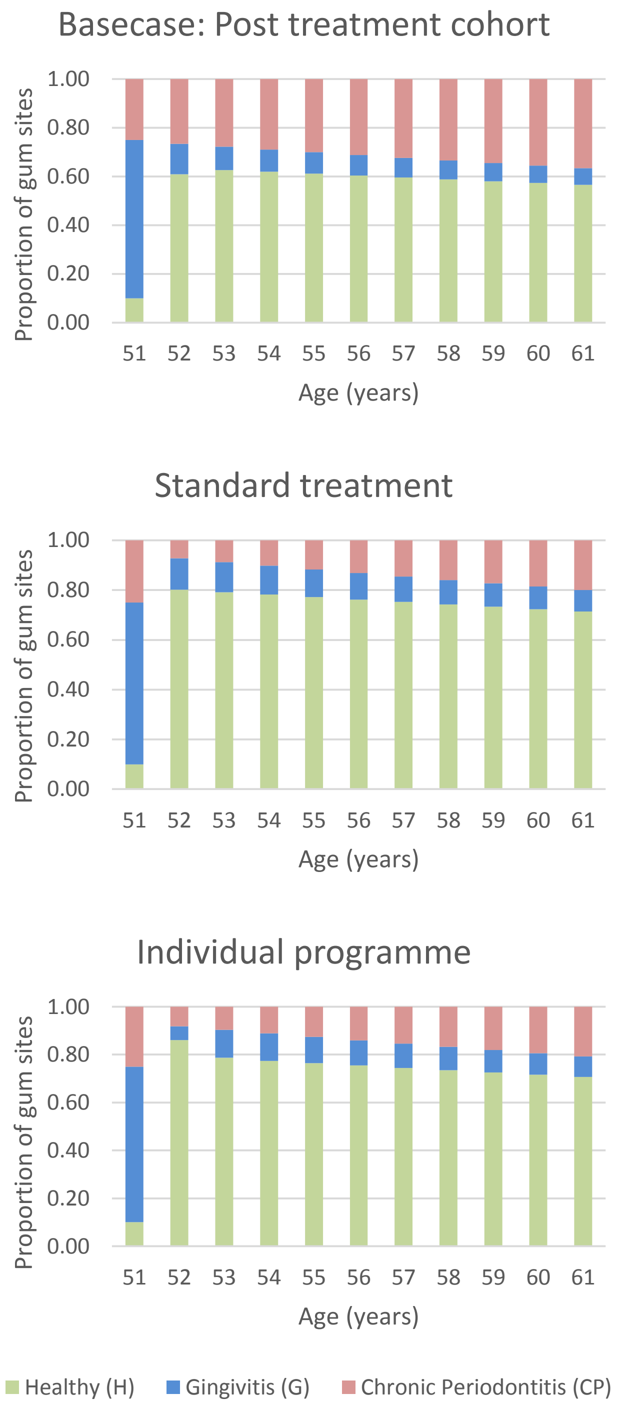


Table 34. Standard vs. individualised periodontal treatment: base case analysis (per 1,000)

	Standard	Individual	Increment
Final % of gum sites			
Healthy (H)	0.7391	0.7363	-0.0027
Gingivitis (G)	0.0951	0.0948	-0.0004
Chronic periodontitis (CP)	0.1658	0.1689	0.0031
Costs of intervention			
Dental care (year 1)	£521,531	£548,201	£26,670
Patient cost (year 1)	£265,949	£277,984	£12,035
Total	£787,480	£826,185	£38,705
Willingness to pay			
To avoid G	£0	£0	£0
To avoid CP	£981,204	£944,975	-£36,228
Total	£981,204	£944,975	-£36,228
Net benefit	£193,724	£118,790	-£74,934

Table 35. Standard vs. individualised periodontal treatment: assume equal pocket closure in year one (per 1,000)

	Standard	Individual	Increment
Final % of gum sites			
Healthy (H)	0.7395	0.7407	0.0012
Gingivitis (G)	0.0952	0.0954	0.0002
Chronic periodontitis (CP)	0.1653	0.1639	-0.0013
Costs of intervention			
Dental care (year 1)	£521,246	£547,970	£26,724
Patient cost (year 1)	£265,943	£277,988	£12,044
Total	£787,190	£825,958	£38,768
Willingness to pay			
To avoid G	£0	£0	£0
To avoid CP	£987,684	£1,002,637	£14,953
Total	£987,684	£1,002,637	£14,953
Net benefit	£200,495	£176,679	-£23,815

The basecase results were not sensitive to the time horizon (20 rather than 10 years), discount rates (3.5%/3.5% or 3.5%/1.5%) the initial age of the cohort (age 40 or 60, rather than 51 as in the base case), or if we assumed a cohort of smokers, with higher risk of fast progression from gingivitis to chronic periodontitis.

4.3.3 Adult tooth model

The treatment consequences of onset of decay in one previously sound untreated tooth are presented in Table 36. Over 20 years, it is estimated that on average a decayed tooth will have been filled between 1.3 and 2.4 times, depending on age at initial decay. Between 15 and 26% of teeth are estimated to have been extracted over this period.

Table 36. Results of adult tooth model: fillings and extractions

Age	Fillings			Extractions		
	Mean	*LL*	*UL*	*Mean*	*LL*	*UL*
16	1.32	1.15	1.51	0.18	0.12	0.26
25	1.74	1.46	1.98	0.15	0.08	0.27
35	1.80	1.58	2.03	0.25	0.20	0.31
45	2.14	1.81	2.40	0.17	0.10	0.28
55	2.44	2.05	2.74	0.19	0.12	0.31
65	2.36	1.98	2.78	0.26	0.18	0.35
75	1.93	1.65	2.24	0.22	0.14	0.30

LL/UL lower/upper limit of 95% confidence interval

Estimated costs to the NHS and patient charges and willingness to pay to have avoided these treatments are shown in Table 37. These figures are suggestive of the amount that could be paid for a prevention programme. From an NHS perspective, a programme is likely to be cost-saving if it costs less than around £165 to £283 per case of incident decay prevented (allowing for the cost of the programme and number needed to treat to avoid one case of decay).

Table 37. Results of adult tooth model: costs and willingness-to-pay

Age	NHS cost (£)			Charges (£)			WTP (£)		
	Mean	*LL*	*UL*	*Mean*	*LL*	*UL*	*Mean*	*LL*	*UL*
16	165	105	238	20	15	27	108	39	205
25	200	127	290	78	70	86	243	47	388
35	222	143	320	86	78	94	61	13	153
45	244	159	348	95	85	104	313	97	476
55	279	180	392	107	95	117	355	58	535
65	283	178	408	109	94	125	145	4	356
75	237	151	340	92	81	103	121	3	294

Chapter 5. 'What if' analysis [NEW]

5.1 Introduction

Following discussion at the PHAC meeting on 6 March 2015, we conducted further 'What if' analysis to investigate the possible cost-effectiveness of preventive interventions for children. This analysis was not based on specific effectiveness evidence, but explored a range of assumptions about the costs and effects of three levels of intervention: '*dentist advice*', comprising one-off brief advice from a dentist within an existing consultation; '*preventive session*', consisting of oral health advice delivered by an Extended Duties Dental Nurse (EDDN) at a single separate appointment; and '*preventive programme*', consisting of a series of sessions delivered over a period of two years by an EDDN. The latter is analogous to the intervention in the Blinkhorn *et al* study [15] that we modelled in the previous chapter. We varied assumptions about the effectiveness of each intervention at reducing the risk of decay over a three-year follow-up period, down to a minimum hazard ratio of 0.6, which is similar to that observed by Blinkhorn *et al*. When interpreting the results presented below, it is important to remember that the less intensive interventions (the 'dentist advice' and 'preventive session') are unlikely to be as effective as the 'preventive programme'.

5.2 Methods

The 'What If' analysis was conducted using the Children's Model; see section 4.2.2 above (page 72).

5.2.1 Baseline risks of decay

Results were estimated for children at age 5 and at age 12, with each group followed for three years. We estimated baseline rates of decay using information about the average prevalence of decay for children in England from the CDHS 2013.[92] The report presented a number of different definitions of decay. For our analysis we used the CDHS definition of ***obvious decay***:

> '…established disease which has spread through the outer layer of tooth enamel to significantly involve the inner lay of dentine beneath. This includes lesions where the decay can be visualised through the enamel as well as lesions where it has advanced to form a frank cavity.' (p14).

The definition includes teeth with obvious decay experience at the time of examination, as well as those that had been previously filled or extracted because of such decay. Thus we use the terms dmft and DMFT below to refer to the numbers of primary and permanent teeth respectively meeting the CDHS definition of obvious decay experience.

Mean dmft/DMFT at ages 5, 8, 12 and 15 from the 2013 survey, and for comparison from the 2003 survey, are shown in Table 38. This reflects the overall reduction in rates of tooth decay for children over the decade. Despite this average improvement, the 2013 CDHS highlighted poor dental health in sections of the population, with geographical variations and a larger proportion of children who were eligible for school meals having severe or extensive tooth decay compared with children not eligible for school meals.

Table 38. Prevalence of tooth decay and estimated incidence

	Primary teeth		Permanent teeth	
	Age 5	Age 8	Age 12	Age 15
Number of teeth with obvious decay experience				
England 2003: mean (standard error) [a]	1.5 (0.12)	1.7 (0.08)	1.0 (0.05)	1.8 (0.11)
England 2013: mean (standard error) [b]	0.9 (0.08)	1.4 (0.08)	0.8 (0.06)	1.3 (0.11)
Estimated incidence of decay, 2013				
Mean number of teeth	20		28	
Initial number of sound untreated teeth	19.1		27.2	
3-year incidence of decay	0.5		0.5	
Hazard per sound untreated tooth	0.0088		0.0062	

Mean number of teeth with obvious decay experience, England 2003 (Tables, CDHS 2003).[93]

Mean number of teeth with obvious decay experience, England 2013 (Tables 2A3 and 2A9, CDHS 2013).[92]

We used the 2013 CDHS data to estimate the incidence of decay in primary teeth (Δdmft) between the ages of 5 and 8, and the incidence of decay in permanent teeth (ΔDMFT) between the ages of 12 and 15. This method of inferring incidence from results by age from cross-sectional data may be unreliable, as it does not account for cohort effects: e.g. the five year-olds who participated in the survey in 2013 may well have different levels of decay when they reach age eight compared with the eight year-olds who participated in the 2013 survey. In this case, since there was only a three-year gap between the ages compared, one would not expect large cohort effects unless the rate of change in children's dental health had been very rapid. There is, however, still uncertainty over the incidence estimated by this method due to the comparison of two independent samples, rather than longitudinal follow-up of individuals.

It can be seen that in 2013 the mean number of primary teeth with obvious decay experience was 0.5 higher at age 8 than at age 5. By comparison, in 2003 the difference in decay between the ages of 5 and 8 was only 0.2. This may seem surprising given the overall improvement in children's dental health between 2003 and 2013, but may be explained by a *bigger improvement* over this decade at age 5 than at age 8. However, this apparent anomaly could also be a chance finding, due to sample variation around the mean estimates at age 5 and at age 8. In the older age group, the mean number of permanent teeth with obvious decay experience in 2013 was 0.5 higher at age 15 than at age 12, down from a difference of 0.8 in 2003. Again, this may be a chance finding.

For the model, we calculated the hazard per sound untreated tooth, assuming this to be constant across the three-year periods : 0.0088 from age 5 to 8, and 0.0062 from ate 12 to 15. These figures were calculated assuming 20 primary teeth at age 5 and 28 permanent teeth at age 12. This results in a difference in the numbers of sound untreated teeth at the beginning of the modelled period, and explains why the calculated hazard was lower at age 5 than at age 12, despite the fact that both groups were estimated to incur the same mean number of newly decayed teeth (0.5) over three years.

The base-case analysis assumed an average level of risk for the children offered the interventions. We also conducted sub-group analysis, to investigate the cost-effectiveness of offering the interventions to children at higher than average risk: assuming baseline increase in dmft/DMFT over three years of twice, three times, and four times the average.

5.2.2 Interventions

Costs, oral health outcomes, and associated QALY gains were estimated for three interventions:

1. **Dentist Advice** – five minutes of oral health advice delivered by the dentist extending an existing consultation for routine check-up or treatment.
2. **Preventive Session** – one 20 minute appointment with an EDDN.
3. **Preventive Programme** – five 20 minute appointments with an EDDN in year one, and three 20 minute appointment in year two.

5.2.3 Cost of the interventions

The cost of the Dentist Advice intervention was calculated based on the unit cost for 'providing-performer' dentists provided in the latest PSSRU report by Curtis (2014).[94] This gives an estimated cost per hour of patient contact of £173, accounting for overheads. This figure is reasonably close to an estimate provided by a member of PHAC, based on the 'Guild rate' of £75 per hour for dentists and £75 per hour for overheads. Thus the cost for the five minute brief advice intervention was estimated at about £14.

Table 39. Costs for providing-performer dentist (2013/14) [95]

	Annual cost
Net remuneration for dentists: [a]	£115,200
Employee expenses [b]	£32,425
Office, premises and other expenses	£75,405
Total cost per year	**£223,030**
Cost per hour of patient contact [c]	**£173**
Cost per patient for brief dentist advice (5 minutes)	**£14**

a. *Mean taxable income of self-employed primary care providing performer dentist in 2012/13*
b. *Including: 0.75 FTE of a hygienist/dental nurse at Agenda for Change (AFC) Band 4; 0.21 FTE of a practice manager at AFC Band 7; and 0.54 FTE of a receptionist (AFC Band 2)*
c. *Assumes 43.4 weeks per year, 41 hours per week and 73.2% of time spent with patients*

We also estimated costs for the two EDDN delivered interventions based on cost information provided in the PSSRU report. This assumed that dental nurses and hygienists would be paid at Agenda for Change (AFC) band 4, £20,144 per year. We assumed the same overhead (for arranging the appointment and use of the room) as for the dentist, but excluding the cost of dental nurse/ hygienist. This yielded an estimate of £29 for the one-off Preventive Session and £230 for the Preventive Programme of eight appointments over two years (discounted at 1.5% in year 2).

For comparison, we note that the PSSRU estimated the cost per hour of patient contact for GPs to be £175 (excluding direct care staff costs and training costs); and the cost per hour of patient contact for a primary care nurse (AFC band 5) to be £44.[94] NOTE TO COMMITTEE: This might suggest that we have rather overestimated the overheads for an EDDN?

Table 40. Costs for EDDN

	Annual cost
Annual salary (Agenda for Change band 4)	£20,144
Employee expenses (excluding costs for nurse/hygienist) [a]	£17,317
Overheads (for use of room, excluding employee expenses)	£75,405
Total cost per year	**£112,866**
Cost per hour of patient contact [b]	**£87**
Cost per patient for preventive session (20 minutes)	**£29**
Cost per patient for preventive programme (eight 20 minute appointments) [c]	**£230**
Cost per patient for preventive programme assuming 50% non-attendance	**£345**

*a. £32,425 minus 0.57 * £20,144*

b. Assumes 43.4 weeks per year, 41 hours per week and 73.2% of time spent with patients,

c. Costs for three sessions delivered in year 2 are discounted at 1.5% per year

These estimates do not allow for additional costs that might be incurred due to non-attendance at scheduled appointments with EDDNs. For example, if patients were to only attend 50% of appointments in the Preventive Programme, if patients who did not attend would be offered and attend a second appointment, *and* if the EDDN could not make productive use of time when patients do not turn up, the cost of the preventive programme would be effectively inflated by 50% (£345 per patient).

In the base case analysis, we assumed 100% attendance (or equivalently, that the EDDN could make productive use of time for missed appointments, or that patients did not receive a replacement for any missed appointments

5.2.4 Effectiveness of the interventions

The effectiveness of the interventions was modelled using a Hazard Ratio (HR) parameter: the ratio of the hazard with intervention compared with that without intervention. A HR of 1 indicates no effect, and a lower value indicates more effective intervention.

The Blinkhorn et al. study reported an increase in dmft of 0.68 for the intervention group compared with 1.05 in the control group over two years of follow up (a difference that was not statistically significant).[15] This equates to a hazard ratio of about 0.6, which we treated as a maximum plausible effect size for the intensive Preventive Programme intervention (similar to the Blinkhorn intervention). There is no direct evidence of the effectiveness of the two less intensive interventions that we modelled, though one might reasonably expect them to be quite a bit less effective than the Preventive Programme (corresponding to higher hazard ratios).

We present results below assuming a range of hazard ratios from 0.6 to 0.9.

5.2.5 Other parameters

Other model parameters are shown in Table 41. Most of these parameters are the same as for the Children's model presented in the previous chapter (see Table 21 and Table 22). There are two exceptions. Firstly, the proportion of decayed teeth that are filled was updated, based on the reported ratio of mean number of teeth filled over the mean number of teeth with obvious decay experience at age 5 and 12 from the 2013 CDHS.

The other exception was the assumed proportion of tooth extractions that are performed under general anaesthetic (GA). In the previous chapter we assumed that 100% of extractions in five year olds would be under GA, and 50% of extractions in twelve year olds. The PHAC noted that they felt that this did not reflect current routine practice, and suggested base-case figures of 20% and 5% respectively. In sensitivity analysis, we used figures of 50% and 20%.

Table 41. Other parameters used in 'What If' model

Parameter	Age 5	Age 12
% of decayed teeth that are filled	11%	38%
% of decayed teeth that are extracted	13.91%	13.91%
% of extractions under general anaesthetic (GA)	20%	5%
% of filled teeth with pain	50%	10%
Cost per filling/ extraction not under GA (£)	£75	£75
Cost per extraction under GA (£)	£1,160	£1,160
QALY loss from pain/anxiety associated with extraction	0.0508	0.0508
QALY loss from GA related mortality per extraction	0.0000067	0.0000063
WTP to avoid decay with no pain (£)	£150	£115
WTP to avoid decay with pain (£)	-	£305
WTP to avoid extraction (£)	-	£244

5.2.6 Sensitivity analysis

In summary, we conducted a range of sensitivity analyses, varying four key parameters over which there was felt to be the greatest uncertainty:

- The baseline risks of decay: between 0.5 and 2 increase in dmft/DMFT over 3 years
- Intervention effectiveness: assuming a hazard ratio of between 0.9 and 0.6
- Proportions of extractions under GA: 20%/50% for 5 year olds; 5% /10% for 12 year olds
- Non-attendance at EDDN delivered sessions: from 0% to 50%

The model was run probabilistically, to incorporate uncertainty relating to input parameters other than: the hazard ratio, proportion of extractions under GA and non-attendance rates.

5.3 Results

5.3.1 Effects on tooth decay

Figure 5 and Figure 6 illustrate the impacts of the range of assumptions about intervention effects (HR from 0.9 to 0.6) the baseline risk of decay (increase in dmft/DMFT over three years from 0.5 to 2) for the two age groups. The two graphs at the top show how dmft/DMFT would be expected to change over time for children at average risk (three year increase in dmft/DMFT of 0.5 without intervention). The lower three graphs show change in dmft/DMFT for children at twice, three and four times average risk. For example, with no intervention (HR=1) dmft would be expected to increase from 0.9 at age 5 to 1.4 at age 8. But with an effective intervention (HR=0.6), dmft at age 8 would be 1.2. Thus a total of 0.2 dmft would be averted per child treated with this intervention. Less effective interventions (HR= 0.9, 0.8 or 0.7), would avert somewhat fewer than 0.2 dmft per child treated. It can also be seen that for an intervention of a given level of effectiveness, the expected number of dmft/DMFT averted is greater for children with a higher baseline risk of decay.

Figure 5. Illustration of effects of assumptions about baseline risk and treatment effects: 5 to 8 year olds

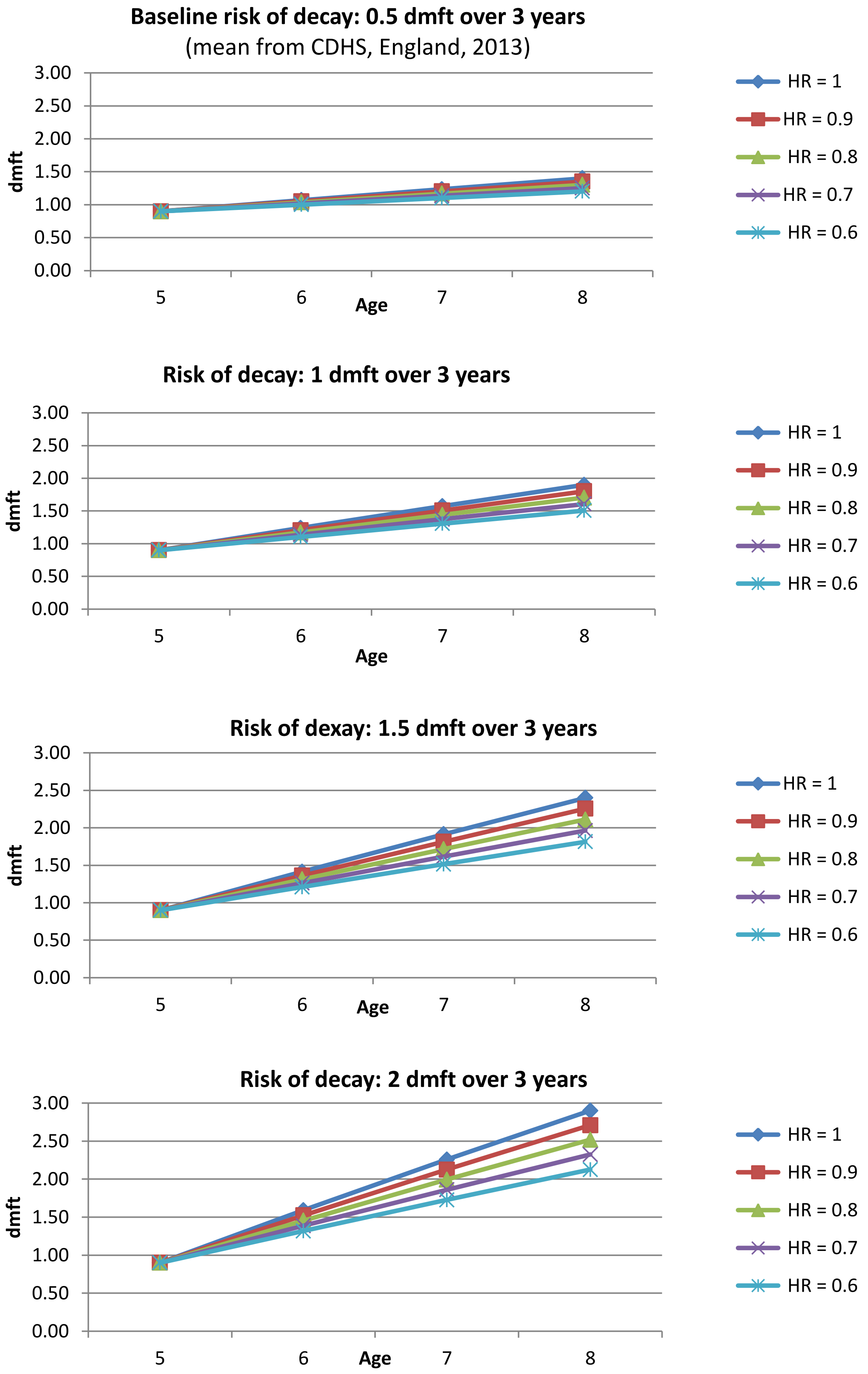
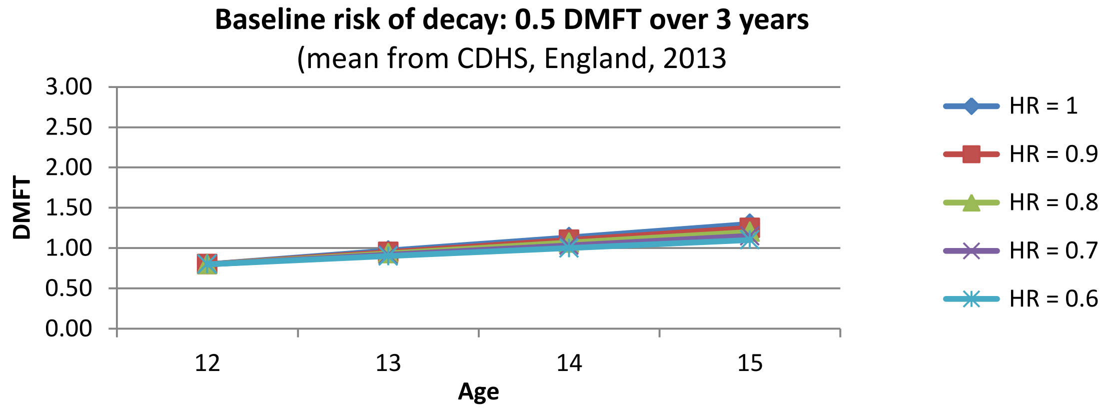
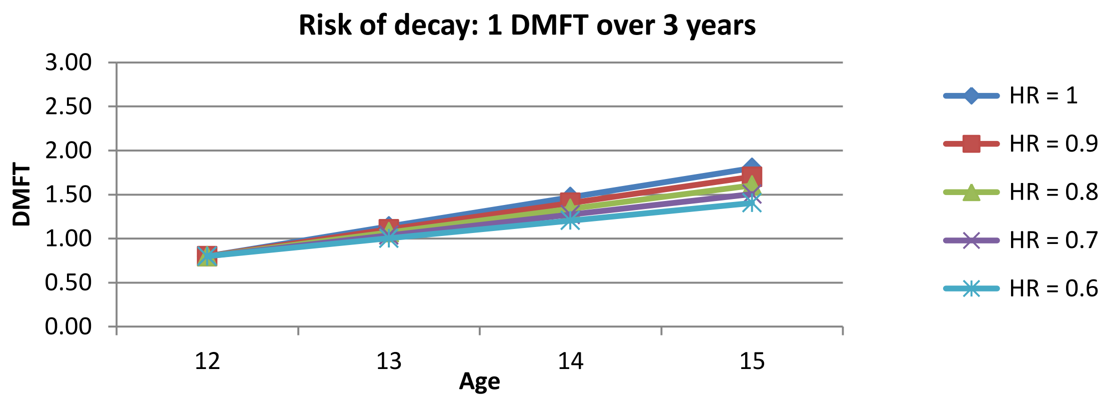
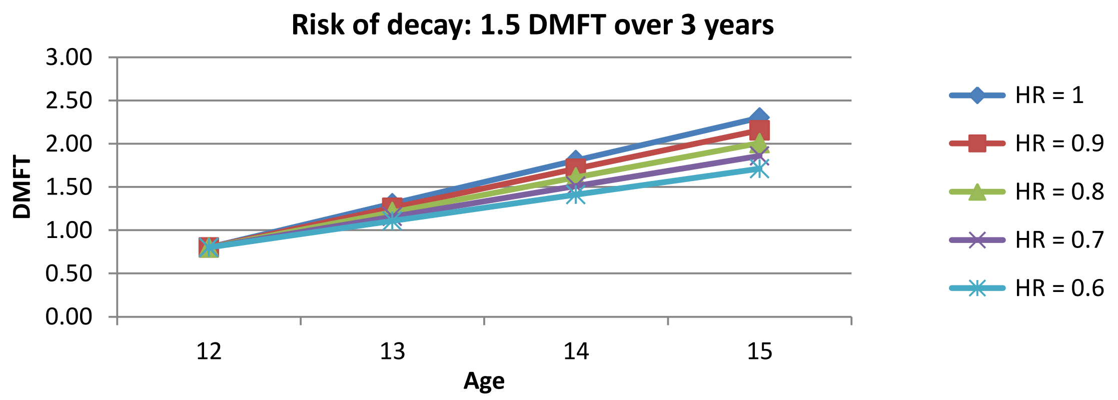
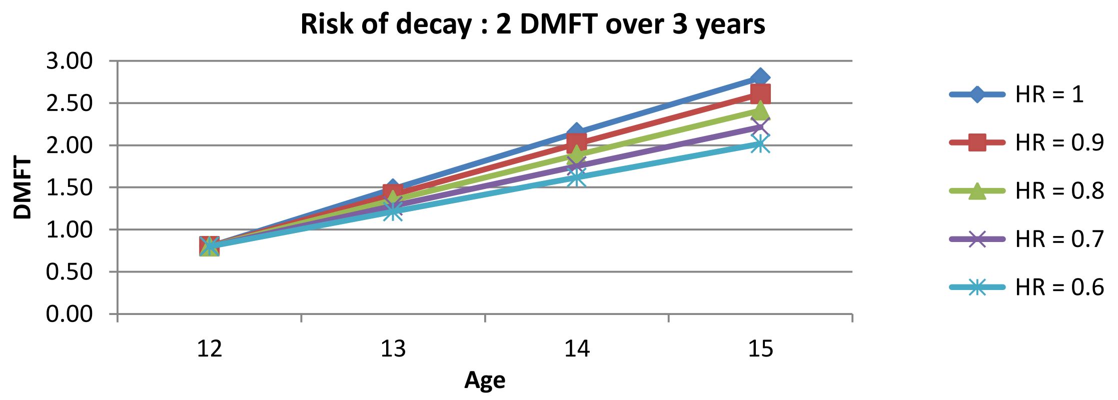


Figure 6. Illustration of effects of assumptions about baseline risk and treatment effects: 12 to 15 year olds









5.3.2 Cost effectiveness of brief advice from a dentist

The cost-effectiveness of the dentist brief advice intervention is summarised in Table 42. The results are given in the form of the Incremental Net Benefit (INB) per 100 children, calculated at the £30,000 per QALY threshold. A positive INB indicates that the intervention is cost-effective at the defined threshold, while a negative number indicates that it is not cost-effective.

It is important to remember that there is no evidence to estimate the likely effectiveness of this intervention. As it involves only a minimal input of time for delivery of oral health advice, one might not expect the magnitude of any effect to be large. If this effect were to be, for example, reflected by a HR of 0.9 (a relative reduction of 0.1 in the hazard of decay), this intervention would be of borderline cost-effectiveness for children at average risk (expected increment of 0.5 in the number of teeth with obvious decay experience over three years): the model estimates a small positive INB in the 5 year old group, if one assumes that 50% of extractions are performed under general anaesthetic, otherwise the estimated INB in this average risk group is negative. However, for children at two or more times the average risk of tooth decay the estimated INB is positive at an HR of 0.9 or lower, indicating that the intervention would be cost effective.

Table 42. INB per 100 children at £30,000 per QALY threshold: Dentist Advice

Intervention effectiveness (Hazard ratio)	Baseline risk: expected change in dmft/DMFT over 3 years			
	0.5 *'average risk'*	1 *'twice average'*	1.5 'three times'	2 'four times'
5 year olds				
20% extractions under GA				
0.900	-£176	£1,091	£2,320	£3,388
0.800	£1,133	£3,625	£6,020	£8,549
0.700	£2,396	£6,245	£9,677	£13,438
0.600	£3,644	£8,823	£13,864	£18,596
50% extractions under GA				
0.900	£70	£1,551	£2,966	£4,342
0.800	£1,586	£4,417	£7,360	£10,309
0.700	£3,121	£7,593	£12,041	£16,072
0.600	£4,538	£10,489	£16,310	£21,782
12 year olds				
5% extractions under GA				
0.900	-£161	£1,112	£2,281	£3,472
0.800	£1,090	£3,617	£6,066	£8,310
0.700	£2,367	£6,060	£9,772	£13,393
0.600	£3,559	£8,735	£13,508	£18,638
10% extractions under GA				
0.900	-£125	£1,138	£2,386	£3,588
0.800	£1,182	£3,690	£6,262	£8,786
0.700	£2,505	£6,312	£10,063	£14,038
0.600	£3,790	£9,022	£13,908	£19,051

5.3.3 Cost effectiveness of one-off preventive session

The results for the one-off session of oral health advice delivered by an EDDN are shown in Table 43. The estimated INBs are rather lower than for the brief dentist advice, due to the rather higher estimated cost of this intervention (£29 compared with £14). Again, it should be emphasised that there is no evidence to support the effectiveness of this intervention. If it were to achieve a modest 10% reduction in risk (HR=0.9), it appears that the intervention might be cost-effectiveness for children at roughly three or more times the average risk of tooth decay over the next three years.

Table 43. INB per 100 children at £30,000 per QALY threshold: Preventive Session

Intervention effectiveness (Hazard ratio)	Baseline risk: expected change in dmft/DMFT over 3 years			
	0.5 *'average risk'*	1 *'twice average'*	1.5 'three times'	2 'four times'
5 year olds				
20% extractions under GA				
0.900	-£1,611	-£336	£834	£1,992
0.800	-£342	£2,188	£4,699	£6,985
0.700	£853	£4,677	£8,425	£12,020
0.600	£2,213	£7,188	£12,078	£17,022
50% extractions under GA				
0.900	-£1,396	£32	£1,500	£2,889
0.800	£107	£3,061	£5,852	£8,721
0.700	£1,594	£6,093	£10,461	£14,712
0.600	£3,200	£9,087	£14,938	£21,011
12 year olds				
5% extractions under GA				
0.900	-£1,639	-£334	£826	£2,051
0.800	-£351	£2,121	£4,484	£7,125
0.700	£949	£4,639	£8,299	£12,078
0.600	£2,178	£7,291	£12,119	£17,069
10% extractions under GA				
0.900	-£1,590	-£315	£968	£2,200
0.800	-£331	£2,321	£4,828	£7,337
0.700	£1,021	£4,841	£8,416	£12,549
0.600	£2,336	£7,539	£12,705	£17,520

5.3.4 Cost effectiveness of a preventive programme

Estimated INBs for the more intensive preventive programme are shown in Table 44. This intervention consists of eight 20-minute appointments with an EDDN over two years, which is similar to the intervention in the Blinkhorn et al. study.[15] Evidence underlying this intervention is weak, however, as the Blinkhorn study did not find a significant reduction in tooth decay for children in the intervention group compared with controls (HR=0.63, not significant).

The results of our 'What If' analysis suggest that even if the preventive programme were to achieve a 40% reduction in the risk of tooth decay (HR=0.6), it would be unlikely to be cost-effective except for children at very high risk. Note that the results reported in Table 44 assume that there are no additional costs incurred by missed appointments. This may be reasonable if EDDNs can make productive use of time when patients miss appointments, or that patients are not offered a repeat appointment if they miss one. However, if additional costs are incurred, this would reduce the estimated INBs, and make the intervention even less likely to be cost-effective.

Table 44. INB per 100 children at £30,000 per QALY threshold: Preventive Programme

Intervention effectiveness (Hazard ratio)	Baseline risk: expected change in dmft/DMFT over 3 years			
	0.5 *'average risk'*	1 *'twice average'*	1.5 'three times'	2 'four times'
5 year olds				
20% extractions under GA				
0.900	-£21,724	-£20,464	-£19,213	-£18,118
0.800	-£20,422	-£17,974	-£15,580	-£13,137
0.700	-£19,153	-£15,234	-£11,646	-£8,000
0.600	-£17,797	-£12,882	-£7,956	-£2,972
50% extractions under GA				
0.900	-£21,461	-£19,991	-£18,580	-£17,295
0.800	-£19,918	-£17,035	-£14,229	-£11,270
0.700	-£18,453	-£14,027	-£9,649	-£5,571
0.600	-£17,013	-£11,032	-£5,144	£238
12 year olds				
5% extractions under GA				
0.900	-£21,736	-£20,489	-£19,254	-£18,069
0.800	-£20,454	-£17,992	-£15,523	-£13,062
0.700	-£19,200	-£15,363	-£11,583	-£8,131
0.600	-£17,934	-£12,913	-£7,877	-£2,837
10% extractions under GA				
0.900	-£21,686	-£20,375	-£19,199	-£17,942
0.800	-£20,404	-£17,763	-£15,367	-£12,944
0.700	-£19,074	-£15,254	-£11,500	-£7,709
0.600	-£17,724	-£12,658	-£7,499	-£2,752

These results conflict with those from the analysis reported in Chapter 4, which suggested that the intervention was likely to be cost-effective for the children at high risk (increment of dmft of 1.05 over 2 years as in the study control group, approximately an increment of 1.5 over three years). There are two reasons for this difference. Firstly, the cost of the intervention used in this current analysis (£230) is very much higher than that in our earlier analysis (£43), which was based on costs reported by Blinkhorn et al. and uprated for inflation. Secondly, in our earlier analysis we assumed that 100% of extractions would be conducted under general anaesthetic, compared with 20% or 50% in this current analysis. A higher percentage of extractions under general anaesthetic increases the expected monetary savings for the NHS from preventing tooth decay, and also incurs a small gain in QALYs due to the avoidance of anaesthetic-related mortality.

Chapter 6. Discussion

6.1 Review of economic evaluations

6.1.1 Summary of findings

Eleven studies reporting some estimate of resource use or costs were identified. One of these studies was excluded at the appraisal stage, as it was not considered applicable to a UK dental practice context.[20]

Three of the remaining studies evaluated programmes to deliver oral health promotion messages to carers of children, starting in the first year of life. One good quality economic evaluation (Pukallus et al 2013) [2] based on a non-randomised study in a socially disadvantaged area in Australia estimated that oral health advice delivered by an oral health therapist over the telephone when the child was aged 6, 12 and 18 months would save approximately £70,000 (2012 UK £) and prevent 43 caries per 100 infants over 6 years of follow up. Two other studies provided some supportive evidence of reductions in caries and associated cost savings for interventions in this age group: Kowash et al (2006) evaluated a three-year programme of education delivered at home by oral health educators in a deprived area of Leeds; and Holst and Braune (1994) evaluated a programme of oral health information for high-risk children in a small-town clinic in Sweden.

Evidence for the cost-effectiveness of preventive programmes for children above the age of one was more equivocal. One study evaluated an intervention for children aged 1-6 at high risk of caries in deprived areas in the Northwest of England (Blinkhorn et al 2003). Although participants in the intervention practices had fewer caries after two years of follow up, there was no statistically significant difference from control practices. Minimal cost information was provided in this paper. Another study (Wennhall et al 2010) evaluating oral health education delivered by a dental nurse in an outreach facility in a deprived area of Sweden did find a statistically significant reduction in caries incidence at a modest additional cost (€30 per child), compared with a non-randomised control group. Vermaire et al (2014) evaluated the cost-effectiveness of a 'non-operative' caries treatment and prevention programme in children aged 6, recruited in a large dental clinic in the Netherlands. This study estimated an incremental cost per decayed, missing or filled surface prevented of €30 from a healthcare perspective, and €100 from a societal perspective. However, there was a high degree of uncertainty over these results. Another study in older children, aged 11-12 with at least one active caries lesion recruited from dental clinics in Finland (Hietasalo e tal 2009) estimated the cost-effectiveness of a preventive programme delivered by dental hygienists. They estimated an incremental cost per DMFS avoided of €34. This intervention included a package of oral health advice, preventive treatment and free materials.

Only three of the identified economic studies related to interventions for adults. Hugoson et al (2003 and 2007) evaluated three different programmes of oral health promotion for young adults recruited in dental clinics in Sweden. All three programmes were associated with significant improvements in plaque and gingival indices, compared with control. However, the intensive 'Karlstad' programme (up to 18 visits over 3 years) was not significantly better than more basic individual or group based programmes. Although costs for the interventions were not reported, the time input from dental hygienists and patients was greater for the Karlstad programme. Jönsson et al (2009, 2010 and 2012) evaluated an individually-tailored programme of oral health education based on cognitive behavioural principals and motivational interviewing delivered by dental hygienists to adults undergoing a programme of non-surgical treatment for chronic periodontitis. The reported that treatment was more successful in the intervention group compared with standard care, but rather more expensive. The incremental cost per successfully treated case was approximately £242. Finally, a culturally-tailored programme of oral health information delivered by lay educators at social clubs for older immigrants in Australia was reported to achieve better gingival health compared with usual care at a hospital periodontal clinic, at an additional cost.

6.1.2 Uncertainties

Published economic evaluations of methods for dental teams to deliver oral health advice to patients are scarce and disparate. We reviewed eleven studies reporting estimates of resource use or costs from comparative experimental or observational studies. They covered a wide age range, from infants to people in their ninth decade. The settings and interventions were also very varied, and there are concerns about the applicability of the findings to the guideline scope and UK context. In particular, some of the included studies related to interventions delivered by members of the dental team outside of clinics (by telephone, at patients' homes or in outreach settings), which might be deemed outside the scope of the guideline. Another complication relates to differential provision of preventive treatment (such as professional cleaning and fluoride varnishes) or oral hygiene products (such as fluoride tablets, toothpaste and tooth brushes) between treatment arms. This might be expected to confound the estimated effects of oral health advice. Most of the studies also suffered from very serious or potentially serious methodological flaws.

6.1.3 Study limitations

Interpretation of reported cost-effectiveness ratios for dental health outcomes is difficult because of the lack of an accepted benchmark of value. It is not clear how much the NHS is able or willing to spend per decayed surface avoided, or per case of periodontal disease successfully treated. A common approach in other areas of health care is to use the QALY metric, for which an estimation of NHS opportunity cost has been established: e.g. the NICE threshold of £20,000 to £30,000 per QALY. However, although oral health specific quality of life measures have been developed (such as the OHIP), there is not yet an acceptable method for valuing these measures on a scale required for QALY calculation. This problem led us to conduct our own valuation survey.

6.2 Valuation survey

6.2.1 Summary of findings

This is one of the first studies that we are aware of to use a DCE approach to value oral health states in monetary terms using public preferences. The results indicate that people have stronger preferences to avoid problems with anterior teeth compared to pre-molar and molar teeth. Prevention of gum problems are also highly valued by respondents. With regard to children's teeth, parents highly valued the prevention of pain, and had higher preferences for avoiding problems in permanent teeth compared to baby teeth.

6.2.2 Uncertainties

Some of the coefficients of parameters included in the models were not statistically significant and some had non-intuitive signs. In the model for adult oral health, it was not possible to estimate WTP for decay with or without pain for molar teeth, and the estimates obtained for decay with no pain and removal of premolar teeth were highly uncertain and should be viewed with caution. In the analysis of the children's oral health survey, it was not possible to estimate WTP values for the no decay or removal of baby teeth.

The cost attribute included in the survey design appears to have significantly affected respondents' choices, with a high proportion of people opting for the least cost alternative in the choice pairs. Ideally, there would be greater variation between respondents choosing each option in each scenario. This has been referred to as the 'magic P value' where the ideal split is approximately a probability of choosing the option in each pair of 0.25/0.75 [37]. The levels of the cost attribute in this study were based on the review of the literature and did not reflect the full range of average values reported. Based on the results of this study, it may be more appropriate to use a smaller (lower) range of levels for the cost attribute in future studies.

6.2.3 Study limitations

The survey was administered to an online panel of respondents. This enabled us to obtain a large sample size (n=1201 for adult and child survey samples combined). The sample was recruited so as to reflect the national UK population by age and gender. It is, however, possible that the panel of respondents may not be representative of the general UK population in other ways. For example, by definition the sample only consisted of those who have access to internet and have joined a program to take survey. Comparisons of characteristics of the sample with statistics for the UK general population found that people were on average more highly educated in our sample compared to national data and on average in poorer health, which is comparable with similar surveys using online panels. While the sample in online surveys may not be representative of the general population, the same can be said of people participating in any type of survey. Given the online administration of the survey, we are not able to obtain qualitative feedback on the comprehension of, and engagement with, the survey questions. It is possible that some respondents struggled to understand the choice questions or the information presented; however pre-testing was conducted which suggested that the survey materials were comprehensible to those interviewed.

The income distribution and payment of dental care (i.e. people attending free NHS dental care and those attending private dental care) was slightly different in our sample compared to the general population. Compared to the general UK population, a larger proportion of our sample reported receiving NHS dental care that was free and a smaller proportion reported receiving private dental care. Subgroup analysis was not carried out as the analysis is intended to represent all potential NHS patients. Also, the definition of NHS care in dental services may not be entirely clear for respondents. Patients may pay some NHS charges for care, but may also pay for some private charges within the same course of treatment. Therefore it is difficult to distinguish accurately between people who receive private and NHS care. We have, however, presented the impact on WTP estimates based on their income as it is directly linked to affordability.

The survey was designed to elicit values for the duration of the oral health problem, until treated and beyond where treatment is not available. For example, where a tooth is decayed, respondents were informed that they could be treated with a filling at their next appointment. Some implications of the oral health states were described in the information tables provided to respondents based on an analysis of data from the OHIP instrument as reported in the ADHS. It is possible that in answering the survey questions, respondents focus primarily on the immediate effects of the oral health problem. The impacts of oral health problems can be diverse and long-term; for example the removal of teeth may have an impact on the integrity of other teeth in the mouth in the long term, whereas respondents may only focus on the immediate impact of the removed teeth. It is frequently a challenge in stated preference surveys to balance the provision of all relevant information to respondents whilst keeping the choice task easy to comprehend and not posing too great a burden on respondents. It is not possible for us to establish if respondents ignored potential long term impacts of the oral health states; however if they did, the estimates presented here would be likely to be underestimated.

This study estimated WTP to avoid oral health problems. This approach is not new to health care, but is more commonly applied in other areas of public sector economics (e.g. transport and environment). One established issue of the WTP approach is that the resulting estimates are highly correlated with ability to pay, so that those on lower incomes tend to provide lower values, even if they 'value' prevention of the health state highly. There are methods of attempting to control for this, for example by asking respondents to consider a hypothetical income over a given period and asking how much of that they would be prepared to spend. We did not employ that method in our study as we considered it would make the task too complex when incorporated into the DCE survey. In addition, the survey included people with a spread of income levels and therefore the average of responses can be seen to approximate to an average value for the population.

Health outcomes are more commonly measured using QALYs within economic evaluations for NICE. QALYs require estimates of utility associated with health outcomes for their calculation using methods such as the standard gamble or, more commonly, the time-trade off. We consider that it could be possible to estimate utility values for oral health states based on these general approaches; however the resources and time required in undertaking this would be substantial and beyond those available for this study. Further research in this area would be worthwhile.

The literature review found few similar studies to inform the design of this study. These studies focussed on characteristics of oral health treatment rather than oral health states; nevertheless we used the estimates of WTP for oral health treatments from included studies to inform cost levels. The selection and levels of the oral health attributes were defined to reflect on outcomes expected to be included in the effectiveness review and economic model. The valuation survey was conducted in parallel to the effectiveness review and development of economic model. We anticipated more evidence relating to adults and therefor assigned a higher proportion of the sample to the survey of adult oral health; however the effectiveness review identified more informative evidence relating to children's oral health. Similarly the valuation study gave more focus to valuing different types of, and problems relating to, teeth. A gum attribute was included in the survey of adult oral health; however this was simply specified as a dichotomous variable of 'no' or 'some' problems. Future surveys could examine differences in valuations for different types, and severities, of gum problems. For example, this could include gingivitis and chronic periodontitis. There may be challenges in simply communicating the types and impacts of gum problems, and further research would be beneficial.

Finally, there was no information in the literature to use as informative prior values for the DCE design. We anticipate that future studies could use the estimates obtained in this study as prior values in order to obtain a more efficient design and more robust estimates.

6.3 Modelling

6.3.1 Summary of findings

The results of the survey were used to estimate a value for oral health benefits in *de novo* economic evaluations conducted for this guideline. We report three appraisals based on published effectiveness studies. The results of these analyses were mixed and highly uncertain, indicating that the cost-benefit of delivery of oral advice to patients by members of the dental team depends on the specifics of what information is provided, to whom, in which context.

Our first analysis estimated the costs and consequences of an intervention in which Primary Care Trusts seconded dental health educators to general dental practices in socio-economically deprived areas in Northwest England (Blinkhorn et al. 2003). At clinics randomised to intervention, educators provided one-to-one counselling to parents of children aged between 1 and 6 years at high risk of caries. The reduction in caries incidence with the intervention was not statistically significant, and we estimated that it was unlikely to be cost-effective in a population at average risk of caries: with an ICER of £163,558 per QALY and only small additional benefits of avoiding decay with pain, estimated at only £62 per 100 children. However, the model was sensitive to a number of parameters. In particular, the analysis suggested that the intervention would be cost-saving in a population at high risk of caries (as observed in the Blinkhorn study).

The second economic analysis estimated the costs and consequences of a programme of oral health advice, preventive treatment and oral hygiene products delivered by dental hygienists in children aged 11-12 years with at least one active caries lesion, recruited from dental clinics in Finland (Hausen et al. 2007). This study did find a significant reduction in caries incidence, and the authors reported an incremental cost-effectiveness ratio of €34 per DMFS avoided (Hietasalo et al. 2009). Our analysis suggested that this intervention would be cost-effective in a population of 12 year old children at average risk of tooth decay in a UK context: with an estimated ICER of £14,408 per QALY and a benefit net of costs of £3,924 per 100 children, accounting for parental WTP to avoid decay with and without pain as well as tooth extractions. The intervention was estimated to be cost-saving in a population at high risk of caries (2.3 new DMFT over three years, as observed in the Hausen study); a result that was robust to sensitivity analysis and to the method of analysis (cost-utility or cost-benefit analysis).

Our third economic analysis estimated the impact of adding an oral education programme to standard non-surgical treatment for periodontal disease in an adult population, based on the study by Jönsson et al. (2009, 2010). The authors reported that a greater proportion of patients met criteria for successful treatment after one year with the intervention than with standard care alone, and that from a societal perspective, the incremental cost was SEK 1,724 per additional successful case (approximately £242). This may seem a modest cost, but we note that it is higher than the WTP to avoid gum problems elicited in our survey. Broadly, our economic analysis did not support the conclusion that this intervention would be cost-beneficial: the estimated WTP for the benefits associated with a reduction in gingivitis were outweighed by the estimated costs of the intervention.

In addition to the above economic evaluations, we developed a model to estimate the costs and benefits of interventions to reduce incidence of dental decay in adults. In the absence of effectiveness evidence, we reported estimates of the cost and WTP associated with incident decay at different ages. These results may be seen as indicative of the maximum that the NHS or local authorities should pay for programmes to prevent tooth decay in adults.

Finally, following the second PHAC meeting on 6 March, we conducted a 'What If' analysis to investigate the possible cost-effectiveness of three levels of preventive intervention for children: brief advice from a dentist, a one-off appointment with an Extended Duties Dental Nurse (EDDN), and a series of eight EDDN appointments over two years (similar to the Blinkhorn et al (2003) intervention).[15] Costs of the interventions (£14, £29 and £230 respectively for Dentist Advice, Preventive Session and Preventive Programme) were calculated using estimates of unit costs for dentists recently published by the PSSRU.[94] The analysis was conducted for hypothetical cohorts of 5 and 12 year old children, each followed for a three year period, using data from the newly published 2013 Children's Dental Health Survey to estimate the average incidence of decay.[92] The limited time horizon means that these analyses are likely to have underestimated the benefits of avoiding tooth decay for children and their parents and the associated cost savings for the NHS. We explored a range of scenarios, varying four key parameters over which there was most uncertainty: the risk of tooth decay in the targeted population, the effectiveness of the interventions at reducing this risk, the proportion of tooth extractions performed under general anaesthetic, and the non-attendance rate for appointments with the EDDN in the preventive programme. The analysis was not based on any specific effectiveness evidence, and so should be viewed as only illustrative. The highest level of effectiveness tested (hazard ratio of decay per sound untreated tooth of 0.6) was similar to that observed in the Blinkhorn et al study. It is unlikely that the less intensive interventions could achieve this level of effectiveness.

The results of the 'What If' analysis suggested that brief advice from a dentist extending an existing consultation by five minutes might be cost-effective for children at above-average risk of tooth decay (two or more times average risk), *if* one believes that it could reduce risk by a modest amount (say 10% risk reduction over three years). The results of the analysis for the one-off EDDN appointment are similar, but there is greater uncertainty over the cost of this intervention (based on how overheads are assigned for EDDNs). The relative cost-effectiveness of brief advice from a dentist compared with a one-off session with an EDDN depends on the relative costs of these interventions, and whether one approach is likely to be more or less effective than the other. The results were less favourable for the more intensive preventive programme, due to its higher cost, even assuming that it were to achieve a large reduction in relative risk. Here too, though, there is uncertainty over the cost of this intervention in practice.

6.3.2 Uncertainties

There was considerable uncertainty over the results of all of the economic models developed for this guideline.

The children's model suffered from uncertainty over several key input parameters, notably the baseline rates of decay and treatment in the relevant populations, and the consequences of decay for children's quality of life and parental willingness-to-pay to avoid tooth decay, pain and the risks of extraction for their children. Under sensitivity analysis, the results of the Blinkhorn and Hausen analyses presented in Chapter 4 were far from clear-cut. However, in high risk populations the interventions did appear to be cost-saving, and the results were robust. In the Hausen analysis, there was additional uncertainty over the applicability of the unit cost estimates from Finland to costs in

UK dental practice. It should be noted that the intervention also included additional preventive treatment and free oral hygiene products not provided to the standard care control group. The observed effects cannot therefore be exclusively attributed to the delivery of advice.

There are additional uncertainties over the results for children due to updating and reconsideration of some of the parameters used in the Blinkhorn and Hausen analyses in Chapter 4. For the 'What If' analysis presented in Chapter 5, we updated estimates of baseline risks of tooth decay, based on newly published results from the Children's Dental Health Survey 2013.[92] This indicated a general improvement in children's oral health, although wide variations persist and some sections of the population are still at very high risk of tooth decay. This might be expected to reduce the relative cost-effectiveness of preventive interventions for children at average risk, but targeted interventions for children at high risk, if effective, might well be cost-effective. Secondly, in framing the updated analysis the PHAC indicated that in routine practice they would expect a lower proportion of extractions to be performed under general anaesthetic than we had previously assumed. This would have the effect of making the interventions appear to be less cost-effective, as monetary savings from avoiding extractions would be lower. Thirdly, we re-estimated the cost of a preventive programme using new unit cost estimates from the PSSRU.[94] This suggested a very much higher estimate for the cost of a preventive programme than that based on up-rating estimates from Blinkhorn et al. However, there is still a lot of uncertainty over the true costs of delivering such a programme in practice.

The adult gum model was also subject to considerable parameter uncertainty, as demonstrated by the wide confidence interval for the estimated incremental net benefit, which spanned zero.

6.3.3 Study limitations

These analyses were also subject to some important limitations. Firstly, the outcomes that could be captured were limited: including only prevention of tooth decay in children, and progression of gum disease in adults with pre-existing periodontal disease. Intermediate outcomes observed in the literature, such as improvements in patients knowledge and behaviour, might reasonably be expected to be linked to better oral health outcomes and hence to improved quality of life and well-being. However, we were not able to model these relationships and many studies did not report oral health or generic health outcomes, or they did so but did not find significant effects, possibly due to inadequate study power. The effectiveness evidence that we could utilise in economic modelling was therefore limited. Furthermore, other important outcomes linked to oral health, such as prevention of oral cancer and cardiac disease, were not evaluated, due to lack of data.

The children's model had a number of serious limitations: costs and benefits were only estimated over a short time horizon (2-3 years); there are questions over the validity of the parental WTP valuations for primary teeth obtained from our survey, as no value was attached to decay without pain or to tooth removal; consequently, benefits had to be valued in different and non-commensurate units (QALYs for the value of avoiding extractions and parental WTP to avoid decay with pain), making interpretation of results difficult.

The adult gum model suffered from structural uncertainty about how to model progression of gum disease, and how to attach costs and WTP values to the results. The analysis combined results from two key sources: the Mdala et al. (2014) estimates of transition probabilities and the Jönsson et al. (2009) estimates of treatment effects. Although the patient populations and outcome definitions in these studies were similar, the results might not be wholly compatible. In particular, while Mdala et al. assumed that chronic periodontitis was irreversible, Jönsson et al reported that a large proportion of gum pockets meeting one of the Mdala et al. definitions of CP (DOP>4mm) had closed by the end of follow up. There might also be a question over the transferability of both sources to a UK context. We considered using data from the ADHS to calibrate the transition probabilities in the gum model. Changes in the methods of assessment for gum health between the 1998 and 2009 surveys make this complicated. Another limitation of the adult gum model is that we did not attempt to estimate ongoing treatment costs for gum problems after the first year, which might have been expected to offset some of the costs of the intervention. On the other hand, we attributed the WTP to avoid gum problems to each site of periodontitis, which might be expected to have exaggerated the benefits of intervention. Further research could be conducted to test and improve the gum model.

Finally, we note that the adult tooth model was subject to some serious limitations. Most notably, due to the estimation of rates of incidence and treatment for tooth decay from cross-sectional data. We attempted to integrate uncertainty arising from the linking of two independent patient samples, and used calibration to limit deviation of modelled results from observed results. However, it is unclear to what extent we have been successful in mitigating the risks of this approach.

Chapter 7. Conclusions

The report has presented the results of three interrelated strands of work, designed to provide information about the balance of costs and benefits of alternative methods for dental health teams to convey oral health advice to patients.

The review highlighted that existing economic evidence in this field is sparse and of generally poor quality. Nevertheless, some tentative conclusions might be drawn. First, there is some weak but consistent evidence that interventions to provide advice to parents in a child's first year of life in socially deprived populations can achieve reductions in early childhood caries and save money. Evidence in older children was more mixed, with one UK study failing to find a significant reduction in caries, but three others reporting that interventions could be cost saving or achieve reductions in caries at a moderate cost, up to about €100 per defs/DEFS. Evidence in adults was scarcer, but findings from two Swedish studies might be informative. First, an intensive oral health promotion programme for young adults (the 'Karlstad' model) was more expensive but not significantly more effective than more basic individual or group programmes. Second, a programme of oral health advice for older adults being treated for chronic periodontitis achieved a higher success rate, but at an increased cost (approximately £242 per successfully treated patient).

The difficulty in interpreting such oral-health specific cost-effectiveness ratios, led us to conduct our own valuation survey. We used a DCE approach to elicit monetary valuations of individuals' willingness to pay to avoid adverse oral health outcomes. The survey was conducted with a sample of over 1,000 adults from a UK online panel. The distribution by gender and age was representative of the general population, but the sample had lower than average incomes and levels of educational attainment. The survey results indicated that adults had stronger preferences to avoid problems in their anterior teeth and in gums than in pre-molar and molar teeth. With regard to children's teeth, parents valued the prevention of pain highly, and placed a greater value on avoiding problems in permanent teeth than in baby teeth. The WTP estimates should be treated with caution, as some estimates were subject to uncertainty and there were some inconsistent or unexpected results; notably that parents appeared to place no value on avoiding decay in children's primary teeth, unless this was accompanied by pain; and that adults did not value avoidance of decay with or without pain in molar teeth. Nevertheless, the results are indicative of the magnitude of values attached by members of the public to maintaining their own and their children's oral health.

The WTP results from the valuation survey can be used to evaluate oral health promotion interventions: to put it crudely, if the money value of benefits is greater than the cost of the intervention net of any savings in treatment costs, then the intervention may be said to be cost-beneficial. This cost-benefit approach is unusual for NICE, and the committee will need to consider whether and how the NHS or other public bodies should pay to obtain benefits valued in terms of individual willingness to pay (rather than the communally valued estimates of health gain, as in the QALY).

In this report we have presented three new economic evaluations for oral health promotion interventions based on published studies. The results of the two analyses for children were presented in the form of a cost-consequence analysis, with estimates of incremental costs, oral health effects, QALYs and WTP. The results of the Blinkhorn et al. study indicated that although the intervention was associated with only a relatively modest increase in cost, it yielded only very small increments in both QALYs and WTP in children at average risk of caries, and is therefore unlikely to be cost-effective in this group. However, this result was sensitive to the baseline risk of the population, and for children at high risk (as in the Blinkhorn study) the model suggested that the intervention would be cost-saving. In contrast, the analysis based on the Hausen et al. study evaluating a more intensive programme of preventive treatment and advice for older children, suggested that although the intervention was more expensive, it yielded greater benefits. In this case, the intervention appeared to be cost-effectiveness for 12 year old children at average risk, and cost-saving for a high risk population (as in the Hausen study). The latter result was robust to sensitivity analysis and method of economic evaluation (cost-utility and cost-benefit approaches).

The cost-benefit analysis of the Jönsson et al. intervention for adults under treatment for periodontal disease, using our elicited value that adults attach to having healthy gums, did not suggest that the intervention was likely to be cost-beneficial. This result was subject to uncertainty, and we note various limitations with the analysis.

Finally, we conducted an exploratory 'What If' analysis to investigate the possible cost-effectiveness of three levels of preventive interventions for children, under a range of scenarios suggested by the PHAC. These analyses were not linked to effectiveness evidence, and so should be treated with caution. They did suggest however, that low-cost interventions (such as a five minute extension of an existing consultation) might be cost-effective for children at higher than average risk of tooth decay, if they could shown to reduce the risk of tooth decay by a relatively modest amount.

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Appendix A: Terms of reference

The guideline on oral health promotion approaches for dental teams is part of a suite of guidance on oral health being developed by the NICE Centre for Public Health (CPH). The guideline will address the effectiveness and cost-effectiveness of approaches for delivering oral health promotion messages by dental health teams.(1) The guideline will consider how dental teams can effectively deliver the oral health advice recommended in the Department of Health and British Association for the Study of Community Dentistry toolkit.(2)

The Birmingham and Brunel Collaboration External Assessment Centre (BBC EAC) has been commissioned by NICE to produce economic analysis to inform this guidance comprising: an economic evidence review; an economic model; and a valuation exercise. A review of effectiveness evidence has been commissioned separately from Plymouth University. The BBC EAC analysis will build on the economic analysis and model developed by the Newcastle and York External Assessment Centre (3) for previous oral health guidance RX058 (Economic analysis of oral health improvement programmes and interventions). As requested, we will acknowledge any aspects of the analysis that are based on Newcastle and York EAC work, but remove their logos or other identifiers and avoid any implication that NYEAC has endorsed the revised model.

The terms of reference for the BBC EAC analyses are set out in the Product Initiation Document dated 14.08.14. These are summarised below.

Objectives	To provide information on: 1. What are the most effective and cost-effective approaches that dental teams can use to convey oral health promotion messages to patients? 2. Are oral health promotion messages more likely to have an effect on patients if they are linked with wider health outcomes, such as heart and lung disease or diabetes?
Population	Adults and children
Interventions	Methods for dental teams to deliver oral health advice, including: verbal information; practical demonstrations; leaflets posters and other printed information; and new media. The effectiveness review will also consider the extent to which outcomes vary with: the characteristics of the population; the status of the person delivering the activity; the frequency, intensity, length and duration of an activity; and the medium through which it takes place.
Outcomes	Changes in: a) dental health team's knowledge, ability, intentions and practice; b) people's experience of visiting the dentist; c) patients' knowledge and ability to improve and protect their oral health; d) dental patients' oral health behaviours; e) oral health of people who go to the dentist: incidence and prevalence of oral cancers, tooth decay, gum disease and dental trauma; f) dental patients' quality of life, including social and emotional wellbeing.

Appendix B: Economic evidence review – search strategies

Database: Ovid MEDLINE(Ovid) 1946 to August Week 4 2014

Search Strategy:

4. health education, Dental/ (5811)
5. ((dental or oral) adj3 (health or hygiene or care) adj3 (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or message$ or advice or counsel$ or intervention$ or information$ or advise$ or campaign$ or initiative$ or strateg$)).ti. (2531)
6. (dental$ adj3 (promotion$ or program$ or outreach$ or instruct$ or advice or message$ or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$)).ti. (2434)
7. oral hygiene/ed (423)
8. oral health/ed (64)
9. oral hygiene/ and (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or message$ or advice or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$).ti. (1121)
10. oral health/ and (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or message$ or advice or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$).ti. (1053)
11. public health dentistry/ or community dentistry/ (3581)
12. exp preventive dentistry/ (30041)
13. ((dentist$ or dental) and ((public adj3 health) or (community adj3 health) or (community adj3 (program$ or project$)))).tw. (3639)
14. ((dentist$ or dental) and (health adj2 (general or public))).ti. (920)
15. ((dentist$ or dental$) adj4 ((early adj intervention$) or (early adj diagnos$) or prevent$)).tw. (5692)
16. (dentist$ or dental).tw. and (exp public assistance/ or medicaid.tw.) (1194)
17. exp periodontal diseases/pc (5935)
18. exp tooth diseases/pc (22121)
19. oral hygiene/ (10529)
20. oral health/ (10515)
21. ((oral or dental) adj3 (health or hygiene or care)).tw. (36795)
22. (toothbrush$ or floss$ or interdental or dental or dentist$ or dentition or tooth or teeth or mouthwash$ or mouthrinse$ or toothpaste$ or dentifrice$ or caries or periodont$ or gingiv$).tw. (322754)
23. ((caries or periodont$) and (prevent$ or control$)).ti. (4073)
24. exp health promotion/ (55585)
25. Patient education as topic/ (71389)
26. health education/ (52835)
27. health communication/ (656)
28. information dissemination/ (10596)
29. persuasive communication/ (3038)
30. exp educational technology/ (87925)
31. exp "Tobacco Use Cessation"/mt (7627)
32. exp substance-related disorders/ed, pc (18359)
33. exp diet/ed (12)

34. ((health or prevention or preventive) adj3 (promotion$ or education or instruction$ or advice or program$ or outreach or communication$ or information or message$ or counsel$ or intervention$ or advise$ or campaign$ or initiative$ or strateg$)).ti. (47353)
35. or/1-7 (9497)
36. or/8-20 (341549)
37. or/21-31 (312645)
38. 33 and 34 (8749)
39. 32 or 35 (15212)
40. limit 36 to (english language and yr="1993 -Current") (6883)
41. economics/ (27125)
42. exp "costs and cost analysis"/ (184746)
43. economics, dental/ (1867)
44. exp "economics, hospital"/ (19806)
45. economics, medical/ (8680)
46. economics, nursing/ (3985)
47. economics, pharmaceutical/ (2574)
48. (economic$ or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic$).ti,ab. (431861)
49. (expenditure$ not energy).ti,ab. (17649)
50. value for money.ti,ab. (910)
51. budget$.ti,ab. (17373)
52. or/38-48 (558129)
53. ((energy or oxygen) adj cost).ti,ab. (2704)
54. (metabolic adj cost).ti,ab. (788)
55. ((energy or oxygen) adj expenditure).ti,ab. (16809)
56. or/50-52 (19580)
57. 49 not 53 (553858)
58. 37 and 54 (530)

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations September 04, 2014

Search Strategy:

7. ((dental or oral) adj3 (health or hygiene or care) adj3 (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or message$ or advice or counsel$ or intervention$ or information$ or advise$ or campaign$ or initiative$ or strateg$)).ti. (141)
8. (dental$ adj3 (promotion$ or program$ or outreach$ or instruct$ or advice or message$ or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$)).ti. (81)
9. or/1-2 (198)
10. public health dentist$.mp. or community dentist$.ti,ab. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier] (43)
11. preventive dentistry.ti,ab. (44)
12. ((dentist$ or dental) and ((public adj3 health) or (community adj3 health) or (community adj3 (program$ or project$)))).tw. (321)
13. ((dentist$ or dental) and (health adj2 (general or public))).ti. (33)
14. ((dentist$ or dental$) adj4 ((early adj intervention$) or (early adj diagnos$) or prevent$)).tw. (363)
15. (dentist$ or dental).tw. and (exp public assistance/ or medicaid.tw.) (36)
16. periodontal disease$.ti. (393)

17. tooth disease$.ti. (57)
18. ((oral or dental) adj3 (health or hygiene or care)).tw. (3067)
19. (toothbrush$ or floss$ or interdental or dental or dentist$ or dentition or tooth or teeth or mouthwash$ or mouthrinse$ or toothpaste$ or dentifrice$ or caries or periodont$ or gingiv$).tw. (22476)
20. ((caries or periodont$) and (prevent$ or control$)).ti. (246)
21. or/4-14 (23011)
22. health promot$.ti. (520)
23. Patient educat$.ti. (141)
24. health educat$.ti. (530)
25. disseminat$.mp. or communicat$.ti. (10709)
26. educational technology.ti. (6)
27. (smoking adj cessation).ti. (526)
28. (substance adj3 disorder$).ti. (206)
29. diet$.ti. (9495)
30. ((health or prevention or preventive) adj3 (promotion$ or education or instruction$ or advice or program$ or outreach or communication$ or information or message$ or counsel$ or intervention$ or advise$ or campaign$ or initiative$ or strateg$)).ti. (3673)
31. or/16-24 (24579)
32. (economic$ or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic$).ti,ab. (51135)
33. (expenditure$ not energy).ti,ab. (1486)
34. value for money.ti,ab. (103)
35. budget$.ti,ab. (2203)
36. or/26-29 (53359)
37. 15 and 25 (357)
38. 4 or 31 (397)
39. 30 and 32 (35)

Database: Embase (Ovid) 1974 to 2014 September 04

Search Strategy:

1 dental health education/ (5307)
2 ((dental or oral) adj3 (health or hygiene or care) adj3 (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or messag$ or advice or counsel$ or intervention$ or information or advis$ or campaign$ or initiative$ or strateg$)).ti. (2532)
3 (dental$ adj3 (promot$ or program$ or outreach$ or instruct$ or teach$ or messag$ or advice or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$)).ti. (2834)
4 mouth hygiene/ (18348)
5 educat$.ti. (132630)
6 4 and 5 (402)
7 oral health.mp. (14936)
8 5 and 7 (510)
9 mouth hygiene/ and (educat$ or promot$ or program$ or outreach$ or instruct$ or teach$ or message$ or advice or counsel$ or intervention$ or information or advise$ or campaign$ or initiative$ or strateg$).ti. (1480)
10 exp preventive dentistry/ (40357)
11 ((public health or community) adj3 dentist$).tw. (1081)
12 (dentist$ or dental).tw. (201151)

13 ((public adj3 health) or (community adj3 health) or ((community adj3 program$) or project$)).tw. (476177)
14 12 and 13 (6683)
15 ((dentist$ or dental) and (health adj2 (general or public))).ti. (881)
16 ((dentist$ or dental$) adj4 ((early adj intervention$) or (early adj diagnos$) or prevent$)).tw. (6099)
17 (dentist$ or dental$).tw. and (exp social care/ or medicaid.tw.) (1205)
18 periodontal disease/pc [Prevention] (2858)
19 tooth disease/pc [Prevention] (3420)
20 mouth hygiene/ (18348)
21 ((oral or dental) adj3 (health or hygiene or care)).tw. (39784)
22 (toothbrush$ or floss$ or interdental or dental or dentist$ or dentition or tooth or teeth or mouthwash$ or mouthrinse$ or toothpaste$ or dentifrice$ or caries or periodont$ or gingiv$).tw. (344597)
23 ((caries or periodont$) and (prevent$ or control$)).ti. (4176)
24 health promotion/ (70300)
25 patient education/ (86806)
26 health education/ (79446)
27 medical information/ (52419)
28 information dissemination/ (14080)
29 persuasive communication/ (6516)
30 educational technology/ (2315)
31 smoking cessation programs/ (1)
32 addiction/pc [Prevention] (4021)
33 diet/ (155434)
34 ((health or prevention or preventive) adj3 (promotion$ or education or instruction$ or advice or program$ or outreach or communication$ or information or message$ or counsel$ or intervention$ or advise$ or campaign$ or initiative$ or strateg$)).ti. (56053)
35 1 or 2 or 3 or 6 or 8 or 9 (9432)
36 10 or 11 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 (362552)
37 or/24-34 (472199)
38 36 and 37 (10270)
39 35 or 38 (16651)
40 limit 39 to (english language and yr="1993 -Current") (8230)
41 economics/ (209013)
42 "cost benefit analysis"/ (65188)
43 exp health economics/ (624444)
44 exp pharmacoeconomics/ (168359)
45 (economic$ or cost or costs or costly or costing or price or prices or pricing or pharmacoeconomic$).ti,ab. (606916)
46 (expenditure$ not energy).ti,ab. (24524)
47 value for money.ti,ab. (1400)
48 budget$.ti,ab. (24799)
49 or/41-48 (1121031)
50 ((energy or oxygen) adj cost).ti,ab. (3199)
51 (metabolic adj cost).ti,ab. (918)
52 ((energy or oxygen) adj expenditure).ti,ab. (20714)
53 or/50-52 (24000)
54 49 not 53 (1115930)
55 40 and 54 (1327)

Database: Cochrane Library 2014 CENTRAL (Wiley) Issue 8 of 12 DARE (Wiley) issue 3 of 4 CDSR Issue 9 of 12 EED and HTA issue 3 of 4

Searched: 3/09/2014

Search strategy:

1 MeSH descriptor: [Health Education, Dental] explode all trees
2 (Dental or oral) near/3 (health or hygiene or care) near/3 (educat* or promot* or program* or outreach* or instruct* or teach* or message* or advice* or counsel* or intervention* or information* or advise* or campaign* or initiative* or strateg*) .ti.
3 MeSH descriptor: [Oral Health] explode all trees and with qualifier(s): [Education - ED]
4 MeSH descriptor: [Oral Hygiene] explode all trees and with qualifier(s): [Education - ED]
5 MeSH descriptor: [Oral Hygiene] explode all trees
6 (educat* or promot* or program* or outreach* or instruct* or teach* or message* or advice$ or counsel* or intervention* or information* or advise* or campaign* or initiative* or strateg*) .ti.
7 #5 and #6
8 MeSH descriptor: [Oral Health] explode all trees
9 #8 and #6
10 #1 or #2 or #3 or #4 or #7 or #9
11 MeSH descriptor: [Public Health Dentistry] explode all trees
12 MeSH descriptor: [Community Dentistry] explode all trees
13 MeSH descriptor: [Preventive Dentistry] explode all trees
14 (dentist* or dental) and (public near/3 health) or (community near/3 health) or (community near/3 program* or project*) .tw.
15 (dentist* or dental) and (health) near/2 (general or public) .ti.
16 (dentist* or dental) near/4 (early near/1 intervention*) or (early near/1 diagnos$) or prevent*.tw.
17 dentist* or dental.tw.
18 MeSH descriptor: [Public Assistance] explode all trees
19 MeSH descriptor: [Medicaid] explode all trees
20 #18 or #19
21 #17 and #20
22 MeSH descriptor: [Periodontal Diseases] explode all trees and with qualifier(s): [Prevention & control - PC]
23 MeSH descriptor: [Tooth Diseases] explode all trees and with qualifier(s): [Prevention & control - PC]
24 MeSH descriptor: [Oral Hygiene] explode all trees
25 MeSH descriptor: [Oral Health] explode all trees
26 (oral or dental) near/3 (health or hygiene or care) .tw.
27 (toothbrush* or floss* or interdental or dental or dentist* or dentition or tooth or teeth or mouthwash* or mouthrinse* or toothpaste* or dentifrice* or caries or periodont* or gingiv*) .tw.
28 (caries or periodont*) and (prevent* or control*) .ti.
29 #11 or #12 or #13 or #14 or #15 or #16 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or 28
30 MeSH descriptor: [Health Promotion] explode all trees
31 MeSH descriptor: [Patient Education as Topic] explode all trees
32 MeSH descriptor: [Health Education] this term only
33 MeSH descriptor: [Health Communication] this term only
34 MeSH descriptor: [Information Dissemination] this term only
35 MeSH descriptor: [Persuasive Communication] this term only

36 MeSH descriptor: [Educational Technology] explode all trees
37 MeSH descriptor: [Substance-Related Disorders] explode all trees and with qualifier(s): [Prevention & control - PC]
38 MeSH descriptor: [Diet] explode all trees
39 (health or prevention or preventive) near/3 (promotion* or education or instruction* or advice or program* or outreach or communication* or information or message* or counsel* or intervention* or advise* or campaign* or initiative* or strateg*) .ti.
40 #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39
41 #29 and #40
42 #41 or #10 Publication Year from 1993 to 2014
43 cost* or economic* or price or pricing or prices or pharmacoeconomic* or value or budget* or expenditure*
44 #42 and #43

Databases: Science Citation Index (ISI Web of Science) (1900 – present) ; Conference Proceedings Citation Index (ISI Web of Science) (1900-present)

Search strategy:

1 1 (((dental or oral) near/3 (health or hygiene or care) near/3 (educat* or promot* or program* or outreach* or instruct* or teach* or message* or advice or counsel* or intervention* or information* or advise* or campaign* or initiative* or strateg*)))
2 ((dentist* or dental)
3 ((public near/3 health) or (community near/3 program* or project)
4 #3 and #2
5 ((health) near/2 (general or public) .ti.
6 #5 and #2
7 ((dentist* or dental) near/4 ((early near/1 intervention*) or (early near/1 diagnos*) or (prevent*)))
8 (((dentist* or dental*) near/3 (Medicaid) or (public assistance)))
9 (((oral or dental) near/3 (health or hygiene or care)))
10 ((toothbrush* or floss* or interdental or dental or dentist* or dentition or tooth or teeth or mouthwash* or mouthrinse* or toothpaste* or dentifrice* or caries or periodont* or gingiv*)).ti.
11 (caries or periodont*) and (prevent* or control*)).ti.
12 #4 or #6 or #7 or #8 or #9 or #10 or #11
13 ((health or prevention or preventive) near/3 (promotion* or education* or instruction* or advice* or program* or outreach or communication* or information or message* or counsel* or intervention* or advise* or campaign* or initiative* or strateg*)).ti.
14 #13 and #12
15 #1 or #14
16 ((economic* or cost or costs or costing or costly or price or prices or pricing or pharmacoeconomic* or expenditure* or value or budget*)).ti
17 #16 and #15

Limit timespan 1993-2014

Database: EconLIT (EBSCO) 1969- present

Search strategy:

1 1 dental health education

2 (((dental or oral) near/3 (health or hygiene or care) near/3 (educat* or promot* or program* or outreach* or instruct* or teach* or message* or advice or counsel* or intervention* or information* or advise* or campaign* or initiative* or strateg*))).ti
3 oral health
4 oral hygiene
5 #3 or #4
6 (educat* or promot* or program* or outreach* or instruct* or teach* or message* or advice or counsel* or intervention* or information* or advise* or campaign* or initiative* or strateg*)
7 #5 and #6
8 #1 or #2 or #7
9 public health dentist*
10 community dentist*
11 preventive dentist*
12 dentist* or dental
13 public N3 health or community N3 health or community N3 program* or project*
14 #12 and #13
15 health N2 (general or public)
16 #12 and #15
17 (early N1 intervention*) or (early N1 diagnos*) or (prevent*)
18 #12 and #17
19 (Medicaid) or (public assistance)
20 #12 and #19
21 periodontal disease*
22 tooth or teeth N disease*
23 oral N2 (hygiene or health)
24 (oral or dental) N3 (health or hygiene or care)
25 (toothbrush* or floss* or interdental or dental or dentist* or dentition or tooth or teeth or mouthwash* or mouthrinse* or toothpaste* or dentifrice* or caries or periodont* or gingiv*)
26 (caries or periodont*) and (prevent* or control*)
27 #9 or #10 or #11 or #14 or #16 or #18 or #20 or #21 or #22 or #23 or #24 or #25 or #26
28 health promot*
29 patient educ*
30 health educ*
31 health communic*
32 information N2 dissemin*
33 persuasive communic*
34 educational technology
35 substance N3 disorder*
36 diet
37 (health or prevention or preventive) N3 (promotion* or education* or instruction* or advice* or program* or outreach or communication* or information or message* or counsel* or intervention* or advise* or campaign* or initiative* or strateg*)
38 #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37
39 #27 and #38
40 #8 or #39

Limiters : Published date 1993-2014

Appendix C: Economic evidence review - grey literature searches

Oral health Grey literature searches 4 September 2014

Source - OpenGrey

A review of training in dental/oral health education/promotion for dental staff London: Health Education Authority ; 1992 http://www.opengrey.eu/item/display/10068/475136

Effectiveness of oral health promotion an overview. London: Health Education Authority ; 1997 http://www.opengrey.eu/item/display/10068/425670

Dubois S. Traminy P. First oral health knowledge of the child. Unversity of Montpellier; 2013 http://www.opengrey.eu/item/display/10068/895067

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First European Oral health summit. 5 September 2012 European Commission Better Oral Health European Platform. http://www.oralhealthplatform.eu/sites/default/files/field/document/All%20presentations.pdf

Clinical Trials Registers

Source - WHO ICTRP

Australian and New Zealand Clinical Trials Register

Smiles Not Tears an Aboriginal Health Worker Led Dental Health Education Program. Registered July 2012 https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?ACTRN=12612000712808

Iranian Registry of Clinical Trials.

Dental Health Education program for 6-olds: A Cluster Randomized Controlled Trial

Registration date April 2010

http://www.irct.ir/searchresult.php?id=3484&number=1

Iranian Registry of Clinical Trials.

Effects of oral health education on observing health behaviors of mentally disabled boy students

Registered July 2013

http://www.irct.ir/searchresult.php?id=12439&number=2

Clinical Trials Register of India

Evaluation of a school based oral health promotion programme to improve its effectiveness- A randomized controlled trial.

Registered April 2013

http://www.ctri.nic.in/Clinicaltrials/pmaindet2.php?trialid=5805

Australian and New Zealand Clinical Trials Register

The effect of an oral health education program for mothers and fluoride treatment on oral health in Indigenous Maori children Submitted May 2010

https://www.anzctr.org.au/Trial/Registration/TrialReview.aspx?ACTRN=12610000422022

Source – Current Controlled Trials

Tooth Smart Healthy Start Oral Health Advocates in Public Housing. Boston University. January 2011

http://www.controlled-trials.com/mrct/trial/1141891/oral+health+education

Source - NIHR CRN Portfolio

No relevant refs

CEA Registry

No relevant refs

Additional sites searched:

British Dental Association http://www.bda.org/

American Dental Association http://www.ada.org/en/

Centre for Evidence Based Dentistry http://www.cebd.org/

Center for Evidence Based Dentistry (ADA) http://www.ada.org/en/science-research/evidence-based-dentistry/

Economic and Social Research Council http://www.esrc.ac.uk/

National Oral Health Promotion Group http://nohpg.org/

National Institute for Health and Care Excellence https://www.nice.org.uk/

- Oral health promotion approaches for dental teams

  https://www.nice.org.uk/guidance/indevelopment/GID-PHG60

NHS Choices http://www.nhs.uk/Pages/HomePage.aspx

NHS Evidence https://www.evidence.nhs.uk/

Appendix D: Economic evidence review – search audit

Database name	MEDLINE
Database host	Ovid
Database coverage dates	1946 – August week 4
Searcher	Sue Bayliss
Search date	4/9/2014
Search strategy checked by	Daniel Tovey
No of records retrieved	530

Database name	MEDLINE In Process
Database host	Ovid
Database coverage dates	1946 – August week 4 2014
Searcher	Sue Bayliss
Search date	4/9/2014
Search strategy checked by	
No of records retrieved	35

Database name	EMBASE
Database host	Ovid
Database coverage dates	1974 – August week 4 2014
Searcher	Sue Bayliss
Search date	4/9/2014
Search strategy checked by	
No of records retrieved	1327

Database name	Cochrane CENTRAL Register of Controlled Trials

Database host	Wiley
Database coverage dates	2014 Issue 8 of 12
Searcher	Sue Bayliss
Search date	3/9/2014
Search strategy checked by	
No of records retrieved	253

Database name	Cochrane DARE Database of Abstracts of Reviews of Effects
Database host	Wiley
Database coverage dates	2014 Issue 3 of 4
Searcher	Sue Bayliss
Search date	3/9/2014
Search strategy checked by	
No of records retrieved	53

Database name	CDSR Cochrane Database of Systematic Reviews
Database host	Wiley
Database coverage dates	2014 Issue 9 of 12
Searcher	Sue Bayliss
Search date	3/9/2014
Search strategy checked by	
No of records retrieved	592

Database name	Cochrane EED Economic Evaluation Assessment
Database host	Wiley
Database coverage dates	2014 Issue 3 of 4

Searcher	Sue Bayliss
Search date	3/9/2014
Search strategy checked by	
No of records retrieved	65

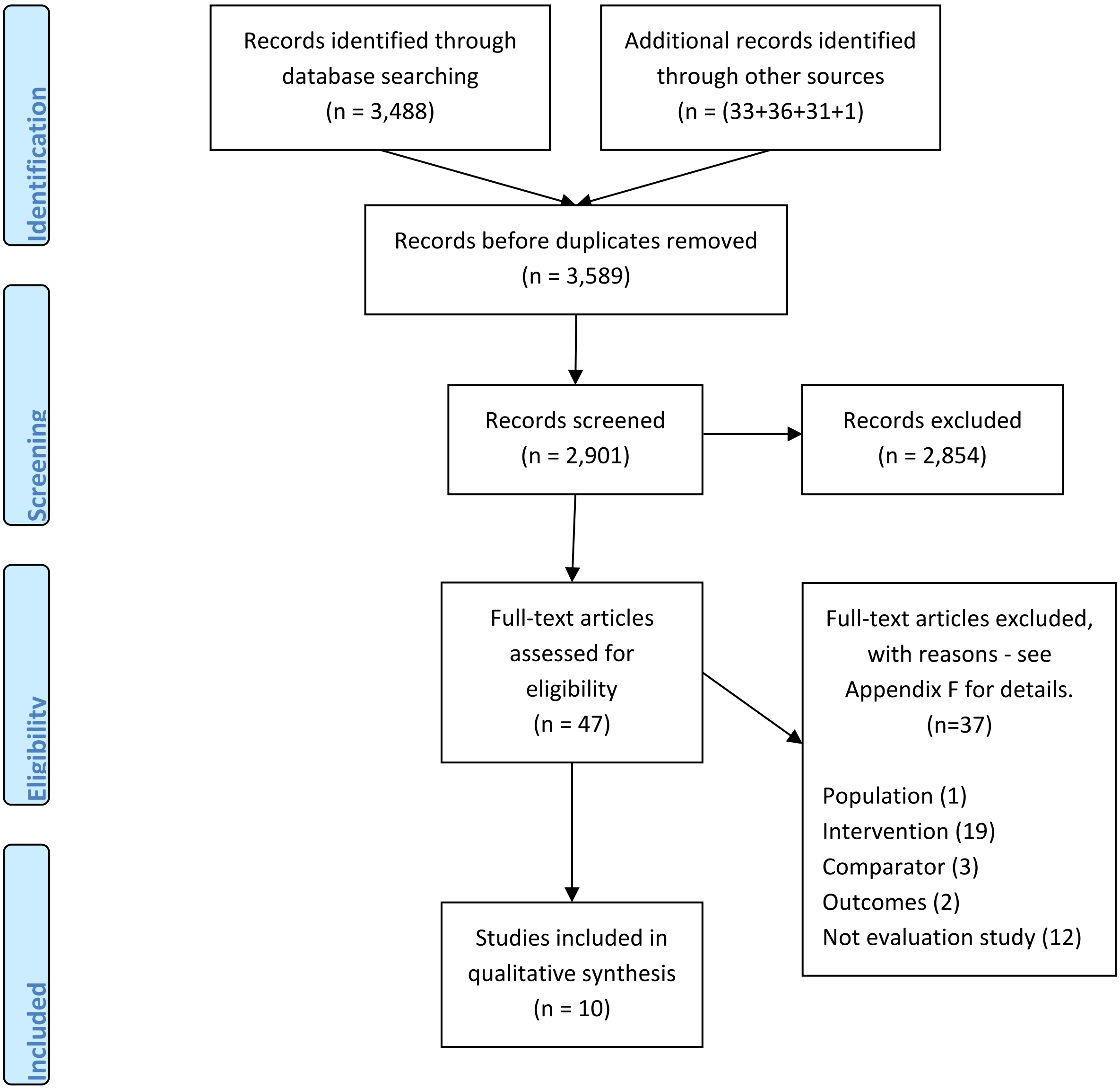
Database name	Cochrane HTA Database of Health Technology Assessment
Database host	Wiley
Database coverage dates	2014 Issue 3 of 4
Searcher	Sue Bayliss
Search date	3/9/2014
Search strategy checked by	
No of records retrieved	3

Database name	Science Citation Index
Database host	ISI Web of Science
Database coverage dates	1900 – September 2014
Searcher	Sue Bayliss
Search date	5/9/2014
Search strategy checked by	
No of records retrieved	578

Database name	EconLit
Database host	EBSCO
Database coverage dates	1969 – 4 August 2014
Searcher	Sue Bayliss
Search date	4/9/2014

Search strategy checked by	
No of records retrieved	51

Appendix E. Economic evidence review - PRISMA diagram



Appendix F: Economic evidence review - excluded studies

Paper	Reason for exclusion
POPULATION IN RESIDENTIAL SETTING	
Frenkel et al. 2001 [96]	RCT of oral health education for nursing home caregivers
INTERVENTION NOT ORAL HEALTH PROMOTION ADVICE BY DENTAL TEAM	
Babazono et al. 2011 [97]	General lifestyle intervention, not targeted at oral health promotion
Feldman et al. 2005 [98]	Intervention to remind nurses of clinical recommendations for patients with heart failure
Yee et al. 2004 [99]	Estimates cost of dental caries with fluoride toothpaste vs non-fluoride toothpaste in Nepal
Louw et al. 1995 [100]	Evaluates school-based daily tooth brushing programme with fluoride dentifrice/mouthwash in South Africa
Jedele & Ismail 2010 [101]	Evaluation of social marketing campaign in Detroit
Beil & Rozier 2010 [102]	Association between advice from doctor to see a dentist and dental visits and costs (US MEPS)
Selby-Harrington et al. 1995 [103]	Comparison of invitation methods for 'well child' screening (mailed, phone, home visit or usual advice at Medicaid intake)
Jokela & Pienihakkinen 2003 [104]	Screening and preventive treatment based on risk assessment at age 2 (MS and incipient carious lesions) compared with routine examinations for all children
Kaakko et al. 2002 [105]	Access to Baby and Child Dentistry (ABCD) programme aimed to increase access for Medicaid enrolled children. Pack included enhanced benefits package and fee structures
Eklund et al. 2003 [106]	Change in payment plan (reimbursement levels and administrative system) for children registered on Medicaid in Michigan.
Kobayashi et al. 2005 [107]	Evaluation of ABCD programme to increase utilisation in Medicaid enrolled children in Spokane County (included changes in reimbursement, preventive treatment, patient education, professional training, community outreach and marketing).
MIXED ORAL HEALTH PROMOTION/TREATMENT INTERVENTION	
Stearns et al. 2012 [108]	'Into the Mouths of Babes' programme (screening, parent counselling, topic fluoride and referral to dentist if needed) compared with no intervention. Cannot separate effect of oral health advice.
Ichihashi et al. 2007 [109]	Workplace program including oral health check up by dentists (3 min), oral health instruction (7 min) and scaling (10 min) by hygienist. Compared employees with 0, 1, 2-4, 5-6 visits. Cannot separate effect of oral health advice.
Hietasalo et al. 2009 [12]	Patient-centred programme of oral health advice, products and treatment and preventive procedures

Paper	Reason for exclusion
Jackson et al. 2007 [110]	Description of mobile dental programme, which included screening and treatment
Bailit et al. 2008 [111]	Description and costing of programme for school-based screening, prevention and treatment
Lundgren et al. 2001 [112]	Treatment program for periodontal disease, including education, scaling, root planing and surgery
Dini & Castellanos 1995 [113]	Cost impact assessment for provision of periodontal prevention and treatment in Brazil
Kallestal et al. 1997 [114]	Comparison of expenditure on prevention vs treatment in cohort of Swedish teenagers
COMPARATOR DOES NOT ENABLE EVALUTION OF ORAL HEALTH PROMOTION	
Morgan et al. 1997 [115]	Both groups received oral health education
Tickle et al. 2011 [116]	Protocol. Both groups to receive oral health education
Arrow 2000 [117]	Compared professional cleaning and oral health education with selective fissure sealing and topical fluoride
NO ECONOMIC OUTCOMES	
Mohebbi et al. 2014 [118]	No costs or resource use reported. Poor applicability.
Weinstein 1996 [119]	Evaluated impact of behaviour modification techniques on patient compliance
NOT EVALUATIVE STUDY	
Lewis 1996 [120]	Validation of DMFT, utility-weighted indices an single measures of caries incidence
Birch et al. 1998 [121]	Survey to test the feasibility and importance of measuring preferences using Healthy Years Equivalents
Armstrong et al. 1995 [122]	Survey of young adults to assess preferences relating to third molar care
Tuominen 2008 [123]	Student survey to compare WTP, VAS and Rank Order methods for valuing health programmes
Marino et al. 2013 [9]	Systematic review of economic evaluations of caries prevention programmes
Gray & McIntyre 2008 [124]	Systematic review of oral health promotion for patients undergoing fixed appliance orthodontic treatment
Twetman 2008 [8]	Systematic review of prevention of early childhood caries
Lee et al. 2006 [7]	Narrative review of evidence for early dental visits
Holloway & Clarkson 1994 [125]	Survey of general dental practitioners working under a capitation payment system to elicit their views on prevention

Paper	Reason for exclusion
Ismail 2011 [126]	Comment on paper by Ayala and Elder
Manski 2011 [127]	Comment on paper by O'Connell and Griffin
Griffin & Jones 2013 [128]	Comment on paper by Marino, Khan and Morgan 2013

Appendix G: Economic evidence review - evidence tables

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Blinkhorn 2003 ***Aim:*** To evaluate the effectiveness and cost of primary care trusts seconding dental health educators free of charge to suitable general dental practices to provide dental health counselling to mothers of regularly attending pre-school children at risk of caries ***Type of economic evaluation:*** CCA – cost of intervention and outcomes reported separately ***Study type:*** Cluster RCT ***Applicability:*** partially applicable (+) ***Quality:*** very serious limitations (-)	***Source population(s):*** Pre-school children (1-6 yrs) attending dental care, judged by dentist to be at risk of caries over the next two years. Mean dmft in deciduous molars and canines at baseline: 1.97 (SD 2.19) in test group and 2.17 (SD 2.33) in controls. ***Setting:*** 30 general dental practices in economically disadvantaged areas of NW England ***Data sources:*** Questionnaire to mother, observation and examination at baseline (by dental health educator). Follow-up examination by independent dental epidemiologist ***Follow up:*** 2 years	***Intervention(s):*** One-to-one dental health counselling by hygienist/ therapist with MSc in Dental Public Health at clinic. Initial counselling over two visits included advice on use of fluoride toothpaste and sugar control, hands-on demonstration, fluoride toothpaste and brush, and leaflets. Recall visits every 4 months over 2 years to reinforce advice and provide toothpaste and brush as required. ***Comparator(s):*** Parents and children seen by health educator once at beginning of the study and given instruction on tooth brushing and a tube of fluoride toothpaste. ***Sample size:*** 269 mothers and 334 children randomised. Exam at 2 years for 137/172 test children and 134/162 controls.	***Outcomes:*** Dental health knowledge and attitudes (9 item multi-choice questionnaire); observation of mothers tooth brushing skills (5 criteria); caries (dmft and dmfs in deciduous molars and canines); plaque deposits (yes/no); cost of intervention (UK £, year not stated). ***Time horizon***: 2 years ***Discount rate(s):*** None ***Perspective(s):*** NHS (costs of intervention paid by PCT). ***Model type:*** None

Results:

- No significant difference in dental health at final examination: mean [SD] dmft in deciduous molars and canines 2.65 [2.56] in test group and 3.22 [2.85] in controls (p=0.21); number (%) of children with plaque at final examination: 72/137 (53%) in test group and 82/134 (61%) in controls.
- Reports significantly better dental health knowledge, attitudes and skills in mothers in test group compared with controls.
- Cost per session for 10 patients estimated at £39.37: £28.87 for dental educator time (3 hours per session and 1 session per week for admin); £4.30 travel expenses (at 43p per mile); £6.20 for materials (toothpaste, toothbrushes and leaflets).
- Maximum number of sessions in test group was 8 over 2 years. Three quarters of mothers attended at least 5 sessions (mean attendance not reported).

Comments:

- The sample size was calculated to detect a reduction from 50% to 25% of children with a caries increment of >1 over two years.
- Examination conducted by the dental hygienist who delivered the intervention at baseline and by an independent dentist at follow up. Because of this, authors did not calculate change in dmft, or adjust for baseline. This makes the difference at 2 years difficult to interpret.
- Authors did not estimate costs/savings on other dental treatment because of the lack of significant findings for oral health outcomes. Current guidance on economic evaluation would recommend estimation and quantification of uncertainty over incremental costs and effects despite these findings. Given the low cost of the intervention it is possible that this intervention would be cost-effective by conventional standards.

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Hietasalo 2009 (Hausen 2007) ***Aim:*** To assess the cost-effectiveness of an experimental caries-control regimen in an RCT conducted in Pori, Finland in 2001-2005 ***Type of economic evaluation:*** CEA (cost per DMFS avoided) ***Study type:*** RCT ***Applicability:*** ***Quality:***	***Source population(s):*** Children age 11-12 with at least one initial active caries lesion ***Setting:*** Public dental clinics in Pori, Finland ***Data sources:*** Clinical and radiological exam at baseline and end of trial. 'Bottom-up' collection of resource use data for individuals from dental records. Unit costs estimated by micro-costing approach, including allocation of overheads. ***Follow up:*** Mean 3.4 years follow-up.	***Intervention(s):*** Individually designed patient-centred regimen for caries control, delivered by dental hygienists. Included instructions on diet and oral hygiene, preventive procedures (chorhexadine and fluoride varnish), and provision of toothpaste and brushes, xylitol and fluoride lozenges. The mean number of sessions per child was 12.4 during follow up. ***Comparator(s):*** Standard dental care, including caries prevention (including varnish up to twice in follow-up period). Community-level oral health promotion programme for both groups. ***Sample size:*** 497 (250 intervention and 247 control)	***Outcomes:*** Increment in DMFS over follow-up period; use of dental resources (dentist and hygienist time, procedures etc); costs of intervention and procedures (2004 €). ***Time horizon***: Follow-up period (3.4 years) ***Discount rate(s):*** Not applied ('due to short time horizon') ***Perspective(s):*** Healthcare provider ***Model type:*** None. Within-study analysis using bootstrapping to estimate confidence interval for ICER.

Results:

- The mean increment in DMFS was 2.56 in the experimental group and 4.60 in the control group: mean difference 2.04 averted DMFS (95% interval 1.26 to 2.82)
- Mean cost per child was €496.45 in the experimental group and €426.95: mean difference €69.50 (95% interval: 28.25 to 110.75)
- Incremental cost per DMFS avoided €34.07. Bootstrapping showed high level of certainty (99.9%) that the intervention would be more effective but more expensive (upper right quadrant). If willingness to pay per DMFS avoided were €40, there is a 65% probability that the intervention is cost-effective.

Comments:

- This is a well-conducted 'within-trial' economic evaluation. Methods of costing were detailed and well-reported.
- Costs were higher in the intervention group, due to preventive procedures and counselling by dental hygienists. However, costs of dental treatment were higher in the control group, and by the end of follow-up the total between-group difference in costs was relatively small.
- Whether this represents a cost-effective use of resources depends on the willingness to pay per DMFS avoided.
- The authors noted that it is not possible to separate the effects of health promotion advice from additional preventive procedures (and materials) provided to the experimental group.
- Both groups were also subject to a community-level oral health promotion programme. This might possibly have influenced the effectiveness of the intervention.

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Holst 1994 ***Aim:*** 1) To evaluate dental assistants' selection of children at caries risk up to the age of 3 by comparing dental health variables in 4 year olds in the test clinic and whole county; 2) to compare the time spent per child by dentists and dental assistants in test clinic and in the whole county up to the age of four. ***Type of economic evaluation:*** CCA ***Study type:*** Cohort with retrospective control ***Applicability:*** Partly applicable (+) ***Quality:*** Very serious limitations (-)	***Source population(s):*** Pre-school children (0-4) - birth cohort ***Setting:*** Small-town dental clinic (test), compared with children in the rest of the county, Blekinge, Sweden ***Data sources:*** Routine data sources (county records) ***Follow up:*** 4 years	***Intervention(s):*** Oral health information for at-risk pre-school children by dental assistant: annual questionnaire to assess caries risk factors; oral health intervention for parents of children identified as at risk. ***Comparator(s):*** Standard care – other children in County ***Sample size:*** 119 children in test clinic (102 followed up to age 4); 1501 other children in birth cohort in county (1335 followed up to age 4).	***Outcomes:*** Caries (% of children with 0 dfs, >=4deft, >=8defs at age 4); time spent (minutes per child) by dentists and dental assistants up to age four. ***Time horizon***: 4 years ***Discount rate(s):*** NA ***Perspective(s):*** NA ***Model type:*** NA

Results:

- Dental health was worse in the test clinic than in the rest of the county in year 1.
- After 4 years, the proportion of children with no decayed or filled surfaces was higher in the test clinic : 83/102 (81.4%) for the test clinic vs 1030/1335 (77.2%) for other children in the county.
- However, there was no difference in the proportion of children with >=4deft or >=8defs in the test clinic compared with the rest of the county
- Mean time per child was lower in the test clinic than for other children in the county: 71min vs 90min for dental assistants; and 27min vs 60min for dentists

Comments:

- Content of the intervention is not very clearly described: it's unclear which parents received what information at what time.
- The authors concluded that caries prevention improved dental health in four year old children, but that most of the 'at risk' children developed caries lesions, and that the 'talk and training' caries prevention methods were 'rather ineffective'.

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Hugoson 2003 ***Aim:*** • To report the long-term effect of different prophylactic programmes on young adult individuals' knowledge and behaviour (reported by the participants) concerning oral health. • To discover whether the cost of dental care programmes measured in time is a determining factor. ***Type of economic evaluation:*** Resource use only ***Study type:*** RCT ***Applicability:*** Partly applicable (+) ***Quality:*** Very serious limitations (-)	***Source population(s):*** Young adults (age 20-27) recruited from large public dental clinic and private practice ***Setting:*** Jönköping, Southern Sweden ***Data sources:*** Questionnaire and exam at baseline and annually ***Follow up:*** Three years initially. Additional prophylaxis for individuals with >20% gingivitis at year 4 and 5. Then follow up at year 10.	***Intervention(s):*** Prophylactic care by dental hygienist: Karlstad model – 6 visits per year (1 30 min & 5 20 min) for 3 years with review of oral health status and information and instruction. Group randomised to professional tooth cleaning. Remedial visits at year Basic program individual – 3 visits (30 min, 20min then 15 min) at 2-week intervals in first year, review and information and instruction. Basic program group – 3 visits (60, 30 & 15min) at 2-week intervals in first year in groups of 10 All groups given fluoride toothpaste. ***Comparator(s):*** Control group – no organised prophylactic measures. Traditional dental care by regular dentists. ***Sample size:*** 400 (100 per group) randomised. Drop out rates: 3.8% by end of year 3; 13.5% after 5 years; 9.8% after 10 years.	***Outcomes:*** Knowledge, attitudes and behaviour; plaque gingivitis, pocket depth, caries, attachment, calculus and previous dental care; time costs for dental hygienist and patient (minutes) ***Time horizon***: 3 years ***Discount rate(s):*** None - results presented as time costs (minutes) per patient per year ***Perspective(s):*** Not stated, but includes time costs for dental hygienists and patients ***Model type:*** None

Results:

- Effects on knowledge and reported behaviour were similar with basic programmes (individual and group) as for more intensive Karlstad model. Statistics for between-group differences not clearly presented (chi-squared tests for differences between all groups).
- Dental hygienist time per patient over 3 years was greatest in the Karlstad model (390 min), compared with 125min in the basic individual intervention and 20.5 in basic group intervention.
- Patient time spent with dental hygienist over 3 years: Karlstad (390 min); basic individual (120min) and basic group (205min).

Comments:

- This was a large trial, with long term follow up, and good retention at 10 years.
- The authors concluded that although the Karlstad approach was more intensive (and therefore more expensive in terms of dental hygienist and patient time) than the two basic programmes, it had similar effects on knowledge and behaviour.
- Minimal economic data was reported: only the time spent by dental hygienists with patients and vice versa. These figures assumed 100% attendance, and included no variation in time actually spent with each patient.

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Ide 2001 ***Aim:*** To assess the impact of oral health promotion in the workplace in terms of dental care costs and frequency of dental visits ***Type of economic evaluation:*** Cost impact study ***Study type:*** Case control ***Applicability:*** Not applicable (-) ***Quality:*** Very serious limitations (-)	***Source population(s):*** Male workers, mean age 44 years ***Setting:*** Shipyard in Nagasaki Prefecture, Japan ***Data sources:*** Health insurance claims ***Follow up:*** One year before and three years after intervention	***Intervention(s):*** Workplace programme for existing peer groups (about 20 people): series of orientation sessions during lunch periods (20 mins each) delivered by dentist; 5-min baseline examination; general oral hygiene education in groups of 5; face-to-face instruction by hygienist (four 10-min sessions); personal information sheet and group discussion with dentist and hygienist (during lunch periods, 20 min); recall visit every 6 months for 2 years. ***Comparator(s):*** No intervention ***Sample size:*** 87 participants in the programme and 261 controls, matched by age and job status	***Outcomes:*** Dental care costs and number of visits ***Time horizon***: Three years ***Discount rate(s):*** Not stated ***Perspective(s):*** Workplace based health insurance plan ***Model type:*** None
Results: • Dental care costs were higher for participants than for controls in the year before and in the year after intervention, but these differences were not significant. • In the second year after intervention, costs were lower for the programme participants than for controls: mean ¥18,305 for participants and ¥22,841 for controls (p=0.014) • Similarly, costs were lower for participants than for controls in the third year after intervention: mean ¥16,911 compared with ¥21,920 (p=0.017).			
Comments: • The authors stated that this was not an economic evaluation. Health outcomes were not measure or valued, and costs for delivering the programme were not quantified. The authors noted that this was not possible as the prevention programme was provided to family members as well as employees. • The authors commented that high levels of participation were achieved in this programme. They attributed this to the use of existing peer groups for teaching; the repetition of sessions, and implementation at the place of work.			

<table>
<tr><th>Study Details</th><th>Population and setting</th><th>Intervention/ Comparator</th><th>Outcome and analysis</th></tr>
<tr><td>Jönsson 2012
Aim:
To compare the costs and consequences of an individually tailored oral health educational programme (ITOHEP) based on cognitive behavioural strategies integrated in non-surgical periodontal treatment compared with a standard treatment programme.
Type of economic evaluation:
CEA
Study type:
RCT (Jönsson 2009 and 2010)

Applicability: Partly applicable (+)
Quality: Potentially serious limitations (+)</td><td>Source population(s):
Patients with moderate-to-advance periodontitis (mean age 51)
Setting:
Periodontics clinic in Uppsala, Sweden
Data sources:
Clinical assessments at baseline, 3 and 12 months. Cost data from clinic accounts.
Follow up:
12 months</td><td>Intervention(s):
Programme based on a cognitive behavioural perspective and motivational interviewing delivered by trained dental hygienists, alongside non-surgical periodontal treatment.
Comparator(s):
Standard oral hygiene educational programme delivered by the hygienists alongside non-surgical periodontal treatment.
Sample size:
113 randomised, 108 completed 12 month assessment (57 ITOHEP an 56 control).</td><td>Outcomes:
Achievement of pre-set treatment goals, based on three criteria: % closed pocket, % bleeding on probing and % plaque index; costs of periodontal treatment programme (2007 SEK)
Time horizon:
12 months
Discount rate(s):
3% for costs
Perspective(s):
Societal (including patient travel, out-of-pocket expenditure and time)
Model type:
None</td></tr>
<tr><td colspan="4">Results:
Proportion of patients successful in achieving pre-set criteria by 12 months: 35/57 (61.4%) in ITOHEP group and 19/56 (33.9%) in control group (p=0.003)
Mean (sd) treatment time: 433 (67) minutes for ITOHEP group and 412 (91) minutes for controls
Mean cost of treatment over 12 months (2007 SEK): 6713 for ITOHEP group and 6386 in control group.
Mean costs for individual patients over 12 months(2007 SEK): 3402 for ITOHEP and 3255 for controls
Total costs: 10,115 for ITOHEP and 9641for controls
Incremental cost per successful case 1724</td></tr>
<tr><td colspan="4">Comments:
The authors concluded that there was a small increase in the time required for the consultations with ITOHEP compared with conventional treatment (additional 10 minutes in the two first sessions), which gave a small additional cost of 474 SEK.
They argued that this cost differences ‘must be considered low with regard to potential future gains’, but that further work would be required to quantify future gains and measure outcomes.
They also noted that the ITOHEP intervention requires additional training for hygienists, and that its generalizability needs confirmation.</td></tr>
</table>

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Kowash 2006 ***Aim:*** To evaluate the benefit-cost and cost-effectiveness of a long-term dental health education program to prevent early childhood caries through home visits. ***Type of economic evaluation:*** CBA, CEA ***Study type:*** nRCT (Kowash 2000) ***Applicability:*** partially applicable (+) ***Quality:*** very serious limitations (-)	***Source population(s):*** Children (8 months) and mothers identified and recruited by OPCS. ***Setting:*** Poor socio-economic area of Leeds, visited at home. ***Data sources:*** Questionnaire and examination administered at home ***Follow up:*** 3 years	***Intervention(s):*** Regular home visits by dental health educators (senior paediatric surgical nurse and senior dental hygienist): A) focus on diet (3 monthly); B) focus on oral hygiene instruction (3 monthly); C) diet and oral hygiene (3 monthly); D) diet and oral hygiene (annual). ***Comparator(s):*** E) Control group identified by OPCS at recruitment, but not recruited until end of study. ***Sample size:*** 228 in 4 active groups (179 examined at 3 years); 55 controls.	***Outcomes:*** Caries (dmfs); gingivitis; costs and savings for intervention and dental care (UK £, year not stated). ***Time horizon***: 3 years ***Discount rate(s):*** No ***Perspective(s):*** NHS ***Model type:*** Simple estimates for hypothetical community to compare with other programmes: community water fluoridation and school-based fissure sealant (Niesson an Douglas 1984) and slow releasing fluoride device (Toumba & Curzon 2005).

Results:

- Caries incidence: A) 2/45 (4%); B) 0/47; C) 0/51; D) 0/36; E) 18/55 (33%).
- Mean [SD] dmfs: A) 0.29 [1.64]; B-D) 0; E) 1.75 [5.09]. A vs E $p < 0.001$
- Savings estimated at £36,386 over 3 years (n=179 completing, groups A-D): restorations 179 x £6.35 x 1.46 (1.75-0.29); general anaesthesia 179 x 33% x £582
- Cost of programme £12,891: salaries for two dental health educators; capital (lights, mirrors and explorers); videos and disposables; travel.
- The authors reported a benefit/cost ratio of 5.6 (£36,386/£6,445) and cost/effectiveness ratio of 1.8 (=£6,445 / 3580)

Comments:

- The lack of baseline assessment in the control group and relatively high dropout rate (78%) are potential sources of bias
- Details of calculations of programme cost (e.g. unit costs and resource use) are not reported
- A conservative estimate of mean dmfs in the treatment arms is used in benefit calculations (0.29 for group A, but groups B-D reported no caries).
- Calculations assumed 33% of children avoid need for general anaesthesia, but in the text it is stated that 25% is assumed
- The bases for benefit/cost and cost/effectiveness calculations are unclear: e.g. benefit/cost ratio used one-year costs but three-year savings
- Calculations of results for ‘hypothetical cohort’ for comparison with published results use some crude assumptions that are not justified

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Mariño 2014 ***Aim:*** Economic evaluation comparing a community-based oral health promotion programme aimed at improving gingival health of immigrant older adults, with one-to-one chairside oral hygiene instructions. ***Type of economic evaluation:*** CMA ***Study type:*** Program costs estimated from non-randomised study (Mariño 2013) ***Applicability:*** partly applicable (+) ***Quality:*** Very serious limitations (-)	***Source population(s):*** Immigrant older adults, mean age 72, recruited from social clubs. ***Setting:*** 11 Italian social clubs in Melbourne, Australia ***Data sources:*** Study records ***Follow up:*** Intervention over 16 weeks, although timing of post-test is not explicitly stated (Mariño 2013).	***Intervention(s):*** Oral Health Information Seminars/Sheets (ORHIS) delivered by lay health workers (paid at Research Assistant rates) at social club, comprising: i) ten 20-min oral hygiene education seminars to groups of 6-7 participants; ii) oral health information sheets; iii) four 10-min one-to-one oral hygiene sessions; iv) provision of oral hygiene products ***Comparator(s):*** The effectiveness study (Mariño 2013) used a no-intervention control group. For this CMA, the assumed comparator was oral hygiene instruction by dental hygienist at a public dental clinic, comprising: i) two 20-min group sessions of dental education; ii) four 8-min one-to-one chairside sessions; iii) oral hygiene products. ***Sample size:*** Reported 83 in test group and 100 controls with complete data, but these numbers differ from those reported in Mariño (2013).	***Outcomes:*** Plaque Index; Gingival Index and self-efficacy questionnaire (reported in Mariño 2013); costs of intervention an assumed comparator (2008 Aus $) ***Time horizon***: 16 weeks ***Discount rate(s):*** NA (single intervention within year) ***Perspective(s):*** Stated as 'societal', although costs to patients were not included ***Model type:*** None

Results:

- Estimated cost of ORHIS programme $6,965 per 100 participants: includes payment for lay educators (including travel time and training); rent; travel expenses; oral health products; printed materials.
- Estimated cost of oral hygiene programme at public dental clinic $40,185 per 100 participants: 9 x 8-min sessions (72 minutes) with hygienist at $44.65 per session

Comments:

- The effectiveness study (Mariño 2013) found no significant difference in the Plaque Index, but there were significantly greater pre-test to post-test improvements in the Gingival Index and self-efficacy scores for the ORHIS intervention group than in the no-intervention controls.
- For this CMA study, the authors used a different (expensive) comparator (clinic based education programme delivered by hygienist), and assumed equivalent effectiveness outcomes. This assumption was not supported by any cited evidence.
- It is therefore difficult to assess the relative cost-effectiveness of the OHIS programme from this study.

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Pukallus 2013 ***Aim:*** To quantify the healthcare costs of delivering a telephone education programme and the potential cost savings through prevention of dental caries in children from a low socioeconomic, socially-disadvantaged area. ***Type of economic evaluation:*** CEA (Markov) ***Study type:*** nRCT (Plonka et al. 2007) ***Applicability:*** partially applicable (+) ***Quality:*** minor limitations (++)	***Source population(s):*** Children (6 months) from birth cohort. Mothers recruited from public birthing facilities. ***Setting:*** Socially disadvantaged area in Queensland, Australia ***Data sources:*** Prevention programme results, review of dental records from district service's clinical database ***Follow up:*** 18 months in clinical study (to age 2), extrapolated to 5.5 years in model	***Intervention(s):*** Telephone call at 6, 12 and 18 months (average duration 15-20 mins), including advice on diet and tooth brushing; free toothbrushes and toothpastes posted. ***Comparator(s):*** Control group from same birth cohort with no previous contact with dental service was recruited from child care centres in district at age 2 ***Sample size:***	***Outcomes:*** Caries incidence, treatment probabilities and costs for intervention and dental care (2012 UK £) ***Time horizon***: 5.5 years (from 6 months to age 6) ***Discount rate(s):*** 5% for costs and effects ***Perspective(s):*** Health service ***Model type:*** Markov model with six-month cycle. Incident caries could remain untreated a maximum of 18 months. Treatment simple restoration, restoration with crowns or extraction.

Results:

- The clinical study found a caries incidence of 0.0108 (0.003 to 0.017) in the intervention group (n=185) and 0.0547 (0.04 to 0.07) in the control group (n=40).
- The cost of the intervention was estimated at £53 per participant: including staff time, call costs, oral care products, post and packing, administration.
- Estimated healthcare costs were: £1707 for general anaesthesia; £104 restoration; £275 crowns; £169 extraction; £9 medication.
- The model estimated 43 caries prevented with a cost saving of £69,984 per 100 children.
- Results were most sensitive to changes in the estimated cost of general anaesthesia and caries incidence in the two groups.
- The intervention remained cost saving under one-way deterministic and probabilistic sensitivity analysis.

Comments:

- This is a well-conducted and reported economic evaluation that meets current methodological guidelines.
- The results provide evidence that the programme of telephone-delivered oral health advice was cost-effective, and this finding was robust to sensitivity analysis.
- However, the findings do rely on a single study in a single centre. The control group was small, and not randomised.
- The authors note that their results do not include quality of life/ well-being benefits associated with avoiding caries and treatment, or wider societal benefits (e.g. educational benefits, out of pocket expenses and time off work).

Study Details	Population and setting	Intervention/ Comparator	Outcome and analysis
Vermaire 2014 ***Aim:*** To assess the cost-effectiveness of caries treatment and prevention strategies in the Netherlands ***Type of economic evaluation:*** CEA ***Study type:*** RCT ***Applicability:*** partly applicable (+) ***Quality:*** Potentially serious limitations (+)	***Source population(s):*** Children (6 years) ***Setting:*** Large dental clinic in Hertogenbosch, Netherlands ***Data sources:*** Trial records ***Follow up:*** 3 years	***Intervention(s):*** IPFA: standard dental care plus increased professional fluoride application (up to four times per year). NOCTP: non-operative caries treatment and prevention by dentists including: individualised recall intervals; assessment, oral health advice, fluoride varnish and treatment as needed. ***Comparator(s):*** Standard dental care, checkups twice per year, including professional fluoride application and preventive treatment. ***Sample size:*** N=230: 79 NOCTP; 77 IPFA; 74 control. Follow up at 3 years: 54, 62 and 63.	***Outcomes:*** DMFS prevented; resource use and costs ***Time horizon***: 3 years ***Discount rate(s):*** 4% for costs, 1.5% for effects ***Perspective(s):*** Healthcare and societal ***Model type:*** None

Results:

- Follow up at three years was worse in the NOCTP group (68%) than in the IPFA (80%) and control (85%) groups.
- Mean discounted costs over 3 years (including patient costs): NOCTP €318 (€297-340); IPFA €476 (€451-500); control €298 (€279-317)
- Mean discounted DMFS increment over 3 years: NOCTP 0.34; IPFA 0.40; control 0.54.
- Incremental cost per DMFS prevented (discounted, societal perspective): €100 for NOCTP vs control
- From a healthcare perspective, the incremental cost per DMFS prevented was €30 for NOCTP vs control
- For comparison, IPFA was dominated by NOCTP (it was more expensive and less effective at preventing DMFS)

Comments:

- This analysis was based on a relatively small sample in a single clinic
- The difference in follow-up rates between arms might have biased results, although multiple imputation was used. The main reason for dropout in the NOCTP arm was reported as the burden of travel. Travel time was higher in first year, but similar by year 3.
- The follow-up period was relatively short (3 years). When extrapolated over a longer time period, the cost per DMFS avoided would likely be lower.
- The authors noted that the interventions were all delivered by dentists, but that the NOCTP could have been delivered by hygienists.

<table>
<tr><th>Study Details</th><th>Population and setting</th><th>Intervention/ Comparator</th><th>Outcome and analysis</th></tr>
<tr>
<td>Wennhall 2010
Aim:
To calculate the total and net costs per child included in a 3-year caries preventive program for preschool children and to make estimates of expected lowest and highest costs in a sensitivity analysis
Type of economic evaluation:
CMA
Study type:
nRCT (Wennhall et al. 2005)

Applicability: partly applicable (+)
Quality: potentially serious limitations (+)</td>
<td>Source population(s):
Children (age 2)
Setting:
Low socio-economic multi-cultural urban area in southern Sweden
Data sources:
Study report for savings on defs prevented; costs for preventive programme estimated assuming 100% compliance and using published estimates of unit costs
Follow up:
3 years</td>
<td>Intervention(s):
Recall to outreach facility 6 times up to age 5. Diet information and tooth brushing instruction delivered by dental health nurse (15 min + 5 min administration per session)
+ free fluoride tablets and toothpaste
Comparator(s):
Reference group of children with a similar background from the same area born before the project (usual care).
Sample size:
800 in text cohort; size of control group not stated.</td>
<td>Outcomes:
Prevented defs; costs and savings from preventive programme (2008 SEK and Euros)
Time horizon:
3 years
Discount rate(s):
3% per year
Perspective(s):
Not stated, but costs were only reported for dental care and treatment
Model type:
NA</td>
</tr>
<tr><td colspan="4">Results:

Mean prevented defs up to age 5 was 3 (95% CI: 1.66 to 4.34) (27% reduction): mean 8.2 in test group and 11.2 in controls
Total direct cost of preventive care in the intervention group was estimated at €310 compared with €96 in the control group.
At €67.15 per filling, the (discounted) saving in dental treatment per child was €184
Net cost of the programme was therefore €30 per child
Based on the lower and upper limits of estimated mean defs prevented, the net cost per child was €109 to a saving of €61 per child.
</td></tr>
<tr><td colspan="4">Comments:

Costing methods were quite thorough. Included time for dental team (nurse, hygienist and dentist); materials; rent; equipment; overheads and project management.
The authors noted a number of limitations of their analysis: neither indirect nor intangible costs were included; costing was based on 100% attendance (although they report a 19% attrition rate during the 3-year study period); costs of future replacements of fillings were not included.
</td></tr>
</table>

Appendix H. Economic evidence review - quality appraisal checklists

Study: Blinkhorn 2003		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	At risk pre-school children attending dentist
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Comparison of more vs less intensive oral health education at clinic. Difference between arms in quantity of oral hygiene products provided – exclude?
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Yes	UK study
1.4 Was/were the perspective(s) clearly stated and what were they?	No	NHS costs only
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	Partly	Impact on quality of life or well-being not measured
1.6 Are all future costs and outcomes discounted appropriately?	No	Total costs over 2 years not calculated
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No patient costs
Overall judgement: partly applicable (+)		
Other comments: This is a recent UK study in a relatively deprived at-risk population. No comparison of different methods of delivering oral health advice, although the study does provide a comparison of different intensity of intervention (up to 8 vs 1 clinic visits over 2 years). The intervention included a package of oral health education advice and materials (toothpaste and brushes), and the effects of these different components cannot be separated.		

Study: Blinkhorn 2003		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	2 year follow up. May be longer term benefits of knowledge/attitude/skills
2.3 Are all important and relevant outcomes included?	No	No estimate of impact on QoL/well-being
2.4 Are the estimates of baseline outcomes from the best available source?	Partly	Trial sample may not be representative
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Single RCT (underpowered?)
2.6 Are all important and relevant costs included?	No	Only cost of intervention reported
2.7 Are the estimates of resource use from the best available source?	Unclear	Source of estimate for hygienists time, travel and materials not stated.
2.8 Are the unit costs of resources from the best available source?	Unclear	Not reported
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	No	No estimate of costs for control group.
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	No sensitivity analysis
2.11 Is there any potential conflict of interest?	Unclear	No CoI declaration, Funded by National Primary Dental Care Research and Development Programme
Overall assessment: very serious limitations (-)		
Other comments: Costs were only presented for components of the intervention: not for the total discounted cost of the intervention per patient. No estimate of costs for the control group or for other dental care and treatment for either group. As the examination at baseline and follow-up were performed by different people, no estimate of change in dmft is presented. This makes interpretation of the incremental effect difficult.		

Study: Hietasalo 2009 (Hausen 2007)		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	11-12 year olds with at least one active carious lesion attending dental clinic
1.2 Are the interventions appropriate for the topic being evaluated?	No?	In addition to oral health advice, the experimental group received preventive treatment (varnish) and materials (fluoride toothpaste and lozenges etc).
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Finland
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Healthcare provider
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	Partly	Quality of life or well-being impact not assessed
1.6 Are all future costs and outcomes discounted appropriately?	No	No discounting applied, 'due to short time horizon'.
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No patient costs
Overall judgement: Not applicable (-)		
Other comments: • There was an imbalance in preventive treatments and materials between the arms, and it is not possible to separate the effects of oral health advice per se.		

Study: Hietasalo 2009 (Hausen 2007)		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	Within-trial evaluation with 3.4 year time horizon. It is possible that with longer follow-up the intervention could have been cost-saving (as treatment costs were reduced)
2.3 Are all important and relevant outcomes included?	No	Only DMFS, no quality of life or well-being effects
2.4 Are the estimates of baseline outcomes from the best available source?	Partly	From control group in large trial, but may not be representative of whole population.
2.5 Are the estimates of relative 'treatment' effects from the best available source?	Partly	Single RCT
2.6 Are all important and relevant costs included?	Partly	All dental care costs, but no costs to patients
2.7 Are the estimates of resource use from the best available source?	Yes	Clinic notes for trial participants
2.8 Are the unit costs of resources from the best available source?	Partly	Good quality 'bottom up' costing, but only from one area in Finland
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	No sensitivity analysis reported, although confidence intervals from a bootstrap analysis are given.
2.11 Is there any potential conflict of interest?	Unclear	No explicit statement of conflicts. Funding from various non-commercial sources are acknowledged.
Overall assessment: Potentially serious (+)		
Other comments: • This was a well-conducted and reported 'within-trial' economic evaluation. The costing procedures were thorough and clearly explained. The main methodological limitation of the study was the short time horizon.		

Study: Holst 1994		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Children (age 0-3) judged as being at risk of caries
1.2 Are the interventions appropriate for the topic being evaluated?	Yes	Information on eating habits and oral health protection behaviour
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Small town in Sweden
1.4 Was/were the perspective(s) clearly stated and what were they?	No	No costing
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	No	
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	
Overall judgement: partially applicable (+)		
Other comments: • Content of intervention not well described. • No estimation of costs, only reported mean time per child spent by dentist and dental assistant		

Study: Holst 1994		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	Follow up to age 4, but may be subsequent costs and effects
2.3 Are all important and relevant outcomes included?	No	No quality of life or well-being
2.4 Are the estimates of baseline outcomes from the best available source?	Yes	Administrative data for county
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Non-randomised comparison for single clinic
2.6 Are all important and relevant costs included?	No	No costs presented
2.7 Are the estimates of resource use from the best available source?	Yes	Administrative data for county
2.8 Are the unit costs of resources from the best available source?	NA	No costing
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	Differences in dental outcomes and time can be calculated
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	
2.11 Is there any potential conflict of interest?	Unclear	Not stated
Overall assessment: very serious limitations (-)		
Other comments: • Effects of the intervention are estimated from a non-randomised study for a single clinic • No estimates of costs		

Study: Hugoson 2003		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Young adults (age 20-27) recruited from general dental clinics
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Compares 3 programmes of education and instruction with usual care control. Education programmes provided free fluoride toothpaste, so may not be comparable with control group.
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Sweden. Study started in early 1980s
1.4 Was/were the perspective(s) clearly stated and what were they?	No	Time costs for preventive programmes (healthcare) and patients (societal)
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	Only knowledge, attitudes and behaviours reported here.
1.6 Are all future costs and outcomes discounted appropriately?	No	
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No estimates of patient out of pocket expenditure
Overall judgement: partially applicable (+)		
Other comments: • This study is now quite old, and was conducted in Sweden, so may have limited applicability.		

Study: Hugoson 2003		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	Partly	3 years for first part of trial, but 10 year follow-up after additional remedial interventions
2.3 Are all important and relevant outcomes included?	No	No dental health outcomes, quality of life or well-being reported here
2.4 Are the estimates of baseline outcomes from the best available source?	Partly	Trial population
2.5 Are the estimates of relative 'treatment' effects from the best available source?	Yes	
2.6 Are all important and relevant costs included?	No	Only costs of time for hygienist and patient to participate in intervention – no other dental costs
2.7 Are the estimates of resource use from the best available source?	No	Does not allow for differences in attendance
2.8 Are the unit costs of resources from the best available source?	NA	No unit costs applied
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	No	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	
2.11 Is there any potential conflict of interest?	Unclear	Not explicitly stated in paper, although funding from County Council acknowledged.
Overall assessment: Very serious limitations (-)		
Other comments: • This paper only presented very limited information on outcomes and costs of the programmes.		

Study: Ide 2001		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Men of working age
1.2 Are the interventions appropriate for the topic being evaluated?	Yes	Workplace oral health education programme, compared with no intervention.
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	No	This intervention is unlikely to be transferable to the UK
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Employer/ healthcare insurer
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No health effects, quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	No	
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No costs to individuals
Overall judgement: not applicable		
Other comments: There are substantial cultural differences between Japanese and UK workplaces. The system of payment for dental care is also substantially different. In Japan, employees of large companies are covered by a group insurance plan managed by their employer. The employer therefore has an incentive to pay for preventive care in the expectation of reduced claims for dental care.		

Study: Ide 2001		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	Partly	Three year follow up is longer than other studies, but there may be subsequent costs and effects
2.3 Are all important and relevant outcomes included?	No	No measure of dental health outcomes, quality of life or well-being
2.4 Are the estimates of baseline outcomes from the best available source?	Yes	Health Insurance claims data for controls
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Non-randomised study, and methods of analysis do not attempt to control for baseline differences
2.6 Are all important and relevant costs included?	No	
2.7 Are the estimates of resource use from the best available source?	Yes	Health insurance claims data
2.8 Are the unit costs of resources from the best available source?	Yes	
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	No	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	
2.11 Is there any potential conflict of interest?	Unclear	Financial support from Occupational Health Advance Financial Group
Overall assessment: very serious limitations (-)		
Other comments: This study does not provide evidence of the incremental cost of the intervention, as the costs of the preventive programme were not estimated. Furthermore, it did not include any measurement of health outcomes, other than frequency of visits to the dentist.		

Study: Jönsson 2012		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Adults with moderate to advanced periodontal disease undergoing non-surgical treatment
1.2 Are the interventions appropriate for the topic being evaluated?	Yes	Comparison of a cognitive behavioural approach to oral health education with a standard educational approach. Both groups received non-surgical periodontal treatment.
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Sweden 2007-8
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Societal
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No quality of life or well-being outcomes
1.6 Are all future costs and outcomes discounted appropriately?	Unclear	Time horizon is one year, but it is stated that costs were discounted at 3%
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	Yes	Includes patient expenditure and value of patient time
Overall judgement: partially applicable (+)		
Other comments: This study compared two methods of oral health education (cognitive behavioural vs standard) delivered by hygienists as part of a non-surgical periodontal treatment programme. The population and setting is similar to a UK setting, but there may be some problems with transferability. The authors comment that the hygienists required special training, and noted that further study is needed to confirm whether the programme can be generalised.		

Study: Jönsson 2012		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	12 month, benefits if intervention likely to persist
2.3 Are all important and relevant outcomes included?	No	Intermediate outcome measure (treatment success) used. No quality of life or well-being.
2.4 Are the estimates of baseline outcomes from the best available source?	Yes	Small control group in RCT (n=56).
2.5 Are the estimates of relative 'treatment' effects from the best available source?	Yes	Single RCT
2.6 Are all important and relevant costs included?	Yes	Although cost of training hygienists is not included
2.7 Are the estimates of resource use from the best available source?	Yes	Dental records
2.8 Are the unit costs of resources from the best available source?	No	Estimates for single clinic
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	Partly	One-way deterministic analysis, but ranges for input parameters base on standard +/- 10%, not based on parameter uncertainty
2.11 Is there any potential conflict of interest?	No	
Overall assessment: potentially serious limitations (+)		
Other comments: This was quite a well-conducted and reported CEA. The analysis was based on a single, small RCT in one clinic. Results were limited to a one-year time horizon and used an intermediate outcome measure (treatment success). Sensitivity analysis was limited.		

Study: Kowash 2006		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Infants (8 months) and mothers recruited from community
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Study compared oral health education packages with emphasis on diet and/or oral hygiene instruction. However, the intervention was delivered at home.
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Yes	Poor socio-economic area of Leeds.
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	NHS
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No estimates of impacts on quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	No	
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	
Overall judgement: Partly applicable (+)		
Other comments: This paper was based on a comparative study of long-term oral health promotion at home for mothers of infants in a poor socio-economic area of the UK. It compared different emphasis on oral health promotion messages (diet and/or oral hygiene), and different intensities of intervention (3 monthly vs annual). However, this paper does not present any comparison of the different methods or intensities of oral health promotion messages (as there were no caries in 3 of 4 intervention groups).		

Study: Kowash 2006		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	No	Very simple CBA model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	There may be impacts of health promotion advice beyond 3 years.
2.3 Are all important and relevant outcomes included?	No	No measures of quality of life or well-being. Only tangible impacts on costs and savings for dental care are estimated
2.4 Are the estimates of baseline outcomes from the best available source?	No	Small control group (n=55), with no baseline assessment
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Single study
2.6 Are all important and relevant costs included?	Yes	
2.7 Are the estimates of resource use from the best available source?	Unclear	Not reported
2.8 Are the unit costs of resources from the best available source?	Unclear	Not reported
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	
2.11 Is there any potential conflict of interest?	Unclear	CoI not stated. Study was partly funded by a grant from the 'Sugar Bureau'.
Overall assessment: very serious limitations (-)		
Other comments: There are some potential sources of bias in the RCT: no baseline assessment in control group; dropout rate (78%). The CBA and CEA calculations use some strong assumptions that are not explained or justified. There is no assessment of uncertainty over these assumptions or input parameters.		

Study: Mariño 2014		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Older adults from immigrant population
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Programme of lay-delivered oral health education in social club
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Melbourne, Australia
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Stated as 'societal', although not all costs were included
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No health outcomes or impacts on quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	NA	Costing only for short (16 week) programme
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	Costs to individuals not included
Overall judgement: partially applicable (+)		
Other comments: This study evaluated a lay-delivered programme of oral health education in an older (mean age 72) Italian immigrant population at a social club in the community. The comparator presented in this paper was with an intensive oral health education programme delivered by hygienists at a public dental clinic. This comparison was not evaluated in the related effectiveness study (Mariño 2013), and no evidence of relative effectiveness is provided. Nevertheless, this paper does provide a reasonably detailed costing of the lay intervention.		

Study: Mariño 2014		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	Pre-post intervention only (16 weeks)
2.3 Are all important and relevant outcomes included?	No	No dental outcomes, quality of life or well-being
2.4 Are the estimates of baseline outcomes from the best available source?	No	
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	No relative treatment effects presented. Authors assumed equivalent effectiveness.
2.6 Are all important and relevant costs included?	No	No estimation of costs of subsequent dental care
2.7 Are the estimates of resource use from the best available source?	Unclear	Sources not stated.
2.8 Are the unit costs of resources from the best available source?	Unclear	
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	No	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	No	
2.11 Is there any potential conflict of interest?	No	
Overall assessment: very serious limitations (-)		
Other comments: This was a limited costing study. It assumed equivalent health outcomes between the Oral Health Information Seminars (ORHIS) programme delivered by lay educators at social clubs, and a programme delivered by hygienists in a public dental clinic. However, no evidence to support this assumption was presented (the related effectiveness study Mariño 2013 used a no-intervention comparator). It is therefore difficult to draw any conclusions from this study about the relative cost-effectiveness of the ORHIS approach.		

Study: Pukallus 2013		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Children at 6 months to 6 years from deprived community
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Telephone delivered oral health advice and posted oral hygiene products. Control group did not receive oral hygiene products.
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Participants recruited from public birthing centre socially disadvantaged area in Queensland, Australia
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Healthcare
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	Quality of life/ well-being effects not estimated
1.6 Are all future costs and outcomes discounted appropriately?	Yes	5% for costs and effects
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No estimates of wider societal costs
Overall judgement: partly applicable (+)		
Other comments: No direct comparison of methods of delivering oral health advice: compared telephone delivered programme with no intervention control group. The intervention programme included free dental care products as well as advice. The effects of these components cannot be separated.		

Study: Pukallus 2013		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	Yes	Markov model tracking incidence of caries and treatment.
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	Follow up to age 6 (based on start of loss of deciduous teeth). But effects of education could persist for longer.
2.3 Are all important and relevant outcomes included?	No	Quality of life / well-being not included
2.4 Are the estimates of baseline outcomes from the best available source?	Partly	Caries incidence in usual care group comes from small sample (n=40). Treatment rates from 100 dental records from routine care.
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Single non-randomised controlled study
2.6 Are all important and relevant costs included?	No	No wider social costs
2.7 Are the estimates of resource use from the best available source?	Yes	Programme costs from study records. Treatment from routine database.
2.8 Are the unit costs of resources from the best available source?	Yes	
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	Yes	One-way deterministic and probabilistic sensitivity analysis reported
2.11 Is there any potential conflict of interest?	No	
Overall assessment: minor limitations (++)		
Other comments: This is generally a well-conducted and clearly reported economic evaluation. It is based on a single clinical study, which has some limitations.		

Study: Vermaire 2014		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Children age 6 recruited at routine checkup at dental clinic
1.2 Are the interventions appropriate for the topic being evaluated?	No?	NOCTP intervention included more preventive treatment than standard care comparator
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Dutch general dental clinic
1.4 Was/were the perspective(s) clearly stated and what were they?	Yes	Healthcare and societal both reported
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No measure of impact on quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	Yes	4% for costs, 1.5% for health effects
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	Yes	Out of pocket costs, travel and time for parents included
Overall judgement: Not applicable (-)		
Other comments: It is unclear from this report to what extent the NOCTP intervention included additional preventive treatment compared with the standard care comparator.		

Study: Vermaire 2014		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	3 year follow-up. This is long for an RCT, but still might omit longer term impacts of DMFS prevention
2.3 Are all important and relevant outcomes included?	No	No quality of life or well-being effects
2.4 Are the estimates of baseline outcomes from the best available source?	No	Relatively small sample in RCT control group (n=74) from one clinic
2.5 Are the estimates of relative 'treatment' effects from the best available source?	No	Single RCT
2.6 Are all important and relevant costs included?	Partly	Included costs to healthcare system and parents, but relatively limited time horizon.
2.7 Are the estimates of resource use from the best available source?	Yes	Trial data
2.8 Are the unit costs of resources from the best available source?	No	References Dutch costing manual, but based on single clinic
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	Yes	
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	Partly	Relatively limited one-way sensitivity analysis. Bootstrapping used to estimate uncertainty around costs and effects.
2.11 Is there any potential conflict of interest?	Unclear	Not stated
Overall assessment: potentially serious limitations (+)		
Other comments: This was quite a well-conducted and reported within-trial economic analysis. There are some limitations related to the relatively modest sample size, differences in follow-up between groups, limited time horizon, and in the interpretation of willingness-to-pay per DMFS prevented. Good discussion of strengths and weaknesses in paper.		

Study: WennHall 2010		
Section 1: Applicability	*Yes/ partly/ no/ unclear/ not applicable*	*Comments*
1.1 Is the study population appropriate for the topic being evaluated?	Yes	Children (age 2) from deprived population
1.2 Are the interventions appropriate for the topic being evaluated?	Yes?	Outreach preventive information and training from dental nurse and fluoride tablets and toothpaste were provided. Control group did not receive oral health products – exclude?
1.3 Is the system in which the study was conducted sufficiently similar to the current UK context?	Partly	Low-socioeconomic multi-cultural urban area in southern Sweden
1.4 Was/were the perspective(s) clearly stated and what were they?	No	Not stated, but only dental care costs were estimated
1.5 Are all direct health effects on individuals included, and are all other effects included where they are material?	No	No quality of life or well-being
1.6 Are all future costs and outcomes discounted appropriately?	Yes	3% pa
1.7 Is the value of health effects expressed in terms of quality-adjusted life years (QALYs)?	No	
1.8 Are costs and outcomes from other sectors fully and appropriately measured and valued?	No	No costs to parents
Overall judgement: Partially applicable (+)		

Other comments:

- Intervention included provision of free fluoride tables and toothpaste that was not provided in the control group. Exclude?

Study: WennHall 2010		
Section 2: Study limitations	*Yes/ partly/no/ unclear/ not applicable*	*Comments*
2.1 Does the model structure adequately reflect the nature of the topic under evaluation?	NA	No model
2.2 Is the time horizon sufficiently long to reflect all important differences in costs and outcomes?	No	3 years (up to age 5). Does not included longer term benefits
2.3 Are all important and relevant outcomes included?	No	No quality of life or well-being
2.4 Are the estimates of baseline outcomes from the best available source?	Unclear	Size of control group not stated in this paper
2.5 Are the estimates of relative 'treatment' effects from the best available source?	Partly	Non-randomised study. Comparability of control group not considered
2.6 Are all important and relevant costs included?	No	Excludes preventive care for controls and longer-term costs
2.7 Are the estimates of resource use from the best available source?	No	Costs assume 100% attendance at programme, no individual data
2.8 Are the unit costs of resources from the best available source?	Yes	
2.9 Is an appropriate incremental analysis presented or can it be calculated from the data?	No	Costs for control group limited to treatment for defs
2.10 Are all important parameters whose values are uncertain subjected to appropriate sensitivity analysis?	Partly	Included sensitivity analysis for confidence interval around estimated desf prevented. But not over other elements of cost calculation
2.11 Is there any potential conflict of interest?	No	
Overall assessment: potentially serious limitations (+)		
Other comments: • Simple, but relative well conducted costing exercise. • Details of study not reported here, so it is difficult to judge the underlying strength of evidence		

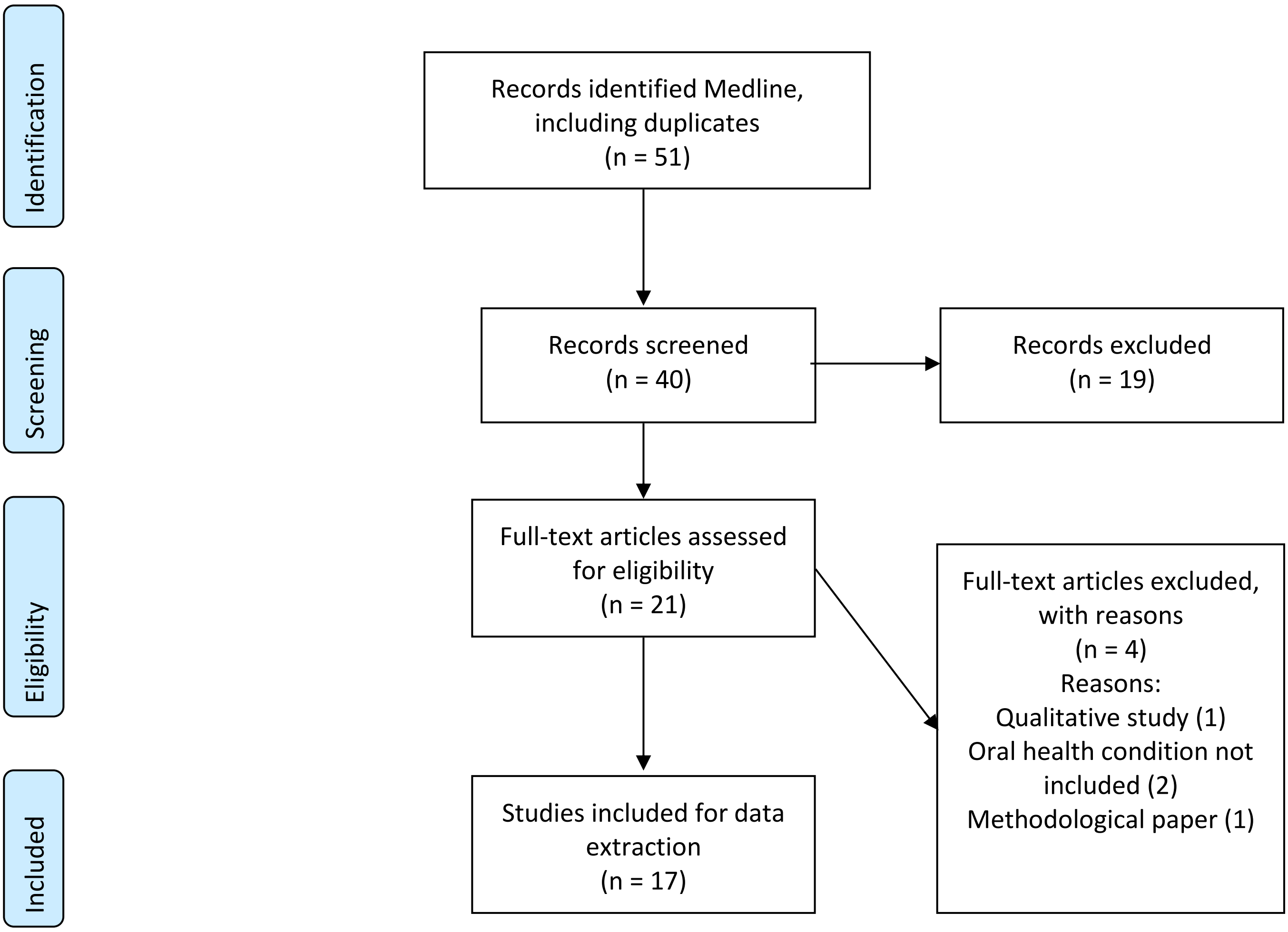
Appendix I: Valuation review - search strategy

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations September 04, 2014

Search Strategy:

1.	exp Dental Health Services/ or exp Dental Health Surveys/ or exp Oral Health/	53489
2.	exp Oral Hygiene/	16071
3.	exp Tooth Diseases/	146007
4.	exp Periodontal Diseases/	72320
5.	(toothbrush* or floss* or interdental or dental or dentist* or dentition or tooth or teeth or mouthwash* or mouthrinse* or toothpaste* or dentifrice* or caries or periodont* or gingiv*).tw.	348905
6.	1 or 2 or 3 or 4 or 5	425599
7.	discrete choice$.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	763
8.	DCE$.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	3432
9.	conjoint analysis.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	434
10.	choice experiment$.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	1234
11.	willingness to pay.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	2569
12.	contingent valuation$.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]	450
13.	exp Dental Implants/ or exp Dental Implants, Single-Tooth/	15838
14.	6 or 13	429603
15.	7 or 8 or 9 or 10 or 11 or 12	7530
16.	14 and 15	51

Appendix J: Valuation review - PRISMA diagram



Appendix K: Information sheet and consent form

INFORMATION SHEET

We at the Health Economics Research Group (HERG) in Brunel University are conducting a study to estimate the values placed on different health states related to oral health of adults and children. We would like to invite you to participate in our study. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information.

Why are we conducting this study?

We are conducting an evaluation of the costs and benefits of different ways of improving oral health. As part of this evaluation, we are interested in how good or bad people perceive different oral health problems to be, and to imagine how much they would be willing to pay to avoid them. The results from this survey will be used in the evaluation of costs and benefits, and may inform which types of oral health promotion services are available through the NHS. Please note that the questions relating to costs are hypothetical and that the survey is not to inform any future charging of dental care services.

Why have I been chosen?

You are being invited to take part in this study as a member of general public in the UK.

What will participation involve?

The total questionnaire will last around 45 minutes. We will ask you some general questions about you and your health. You will also be presented with a series of imaginary health states describing oral health problems and you will be asked to state which you would prefer.

What will happen to my responses?

All of your answers will be treated anonymously so that your responses will not be attributable directly to you. You will be able to withdraw from the interview at any time or decline to answer any question. If you withdraw from the study all of your data will be destroyed.

Who is funding the study?

HERG has been funded by the National Institute for Health and Care Excellence to conduct this important study and will form part of an evaluation of services to improve oral health.

The project has been approved by the Brunel University Research Ethics Committee. If you want further information regarding the study or interview, please feel free to contact Jeshika Singh (Jeshika.singh@brunel.ac.uk) or Dr Louise Longworth (Louise.longworth@brunel.ac.uk) who is leading this study. If you have any complaints about the research we are conducting, please contact the Chair of the University Research Ethics Committee, Mr David Anderson-Ford at res-ethics@brunel.ac.uk.

CONSENT FORM

Introduction

Thank you very much for allowing me to interview you today. My name is [Insert Name] and I am a researcher at Brunel University. The information you provide me today will be used in designing the questionnaire we will use to estimate value of different types of oral health outcomes from this exercise.

This interview will take around 45 minutes to complete.

Consent

I will need your consent to carry out the interview.

Please tick the appropriate box	**Yes**	**No**
Have you read the Information Sheet?		
Have you had an opportunity to ask questions and discuss this study?		
Have you received satisfactory answers to all your questions?		
Do you understand that you will not be referred to by name in any report concerning the study?		
Do you understand that you are free to withdraw from the study without having to give a reason for withdrawing:		
I agree to my interview being recorded. *Note: all recorded data will be destroyed after interviews are transcribed.*		
Do you agree to take part in this study?		

Signature of Research Participant:

Date:

Name in capitals:

Witness statement

Date:

Researcher name:

Signature:

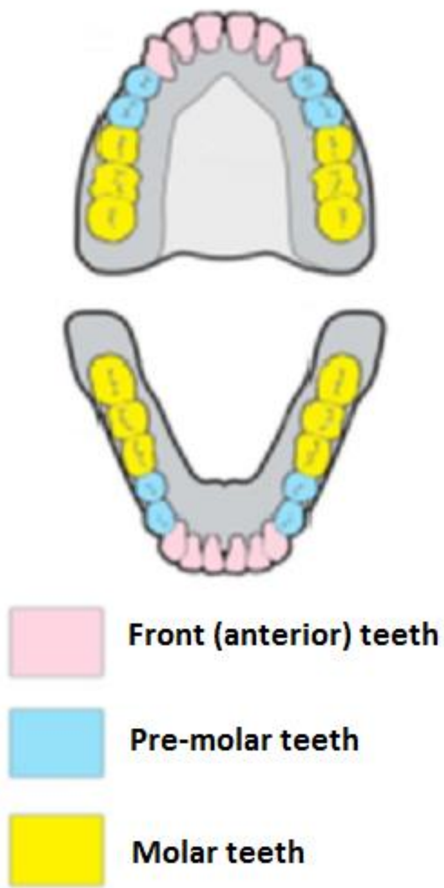
Appendix L: Oral health conditions and OHIP-14 dimensions

OHIP	Decay		Missing Molar		Missing Pre-molar		Missing Anterior		Gums
	One tooth	Two teeth	One tooth	Two tooth	One tooth	Two teeth	One tooth	Two teeth	Some problem
Trouble pronouncing words	-0.04 (0.68)	-0.05 (0.80)	-0.09 (0.65)	0.13 (0.42)	**0.21 (0.02)**	**0.18 (0.05)**	**0.22 (0.01)**	**0.21 (0.05)**	0.09 (0.29)
Sense of taste worsened	0.08 (0.33)	-0.05 (0.78)	-0.13 (0.43)	-0.10 (0.50)	0.00 (1.00)	0.16 (0.06)	**0.20 (0.01)**	**0.26 (0.01)**	**0.25 (0.00)**
Painful aching in mouth	**0.13 (0.03)**	0.12 (0.35)	0.07 (0.40)	0.06 (0.38)	-0.02 (0.68)	0.03 (0.61)	0.00 (0.93)	-0.04 (0.61)	-0.05 (0.32)
Uncomfortable eating	0.03 (0.56)	-0.02 (0.86)	0.05 (0.54)	-0.03 (0.64)	-0.01 (0.81)	**0.11(0.02)**	-0.10 (0.07)	**0.13 (0.05)**	0.04 (0.38)
Felt self-conscious	0.07 (0.24)	**0.35 (0.00)**	0.16 (0.70)	0.12 (0.13)	**0.10 (0.05)**	**0.12 (0.02)**	**0.20 (0.00)**	**0.16 (0.02)**	**0.09 (0.04)**
Felt tense	-0.08 (0.28)	0.06 (0.68)	-0.11 (0.37)	-0.04 (0.69)	-0.09 (0.22)	-0.11 (0.13)	-0.02 (0.83)	-0.15 (0.12)	-0.09 (0.20)
Diet unsatisfactory	0.05 (0.63)	-0.26 (0.14)	-0.07 (0.67)	**-0.31 (0.04)**	0.02 (0.81)	-0.04 (0.66)	0.07 (0.45)	0.03 (0.78)	-0.08 (0.36)
Interrupt meals	0.03 (0.78)	-0.16 (0.33)	-0.12 (0.41)	0.12 (0.37)	-0.05 (0.53)	-0.03 (0.75)	0.05 (0.59)	-0.06 (0.57)	0.01 (0.91)
Difficulty relaxing	-0.05 (0.61)	0.24 (0.18)	0.12 (0.43)	0.09 (0.51)	0.04 (0.68)	0.00 (0.99)	-0.09 (0.32)	-0.09 (0.49)	0.00 (0.96)
Being embarrassed	**0.23 (0.00)**	0.11 (0.49)	-0.05 (0.68)	0.08 (0.45)	-0.01 (0.87)	0.06 (0.42)	0.10 (0.17)	**0.23 (0.01)**	0.03 (0.67)
Irritable with other people	-0.03 (0.80)	0.13 (0.52)	-0.16 (0.34)	-0.05 (0.70)	**0.18 (0.06)**	0.02 (0.84)	0.08 (0.36)	-0.20 (0.15)	0.16 (0.07)
Difficulty doing usual jobs	0.08 (0.54)	-0.10 (0.72)	0.45 (0.07)	0.25 (0.27)	-0.14 (0.27)	**-0.38 (0.01)**	-0.02 (0.88)	-0.14 (0.49)	-0.20 (0.11)
Life less satisfying	0.05 (0.59)	-0.15 (0.36)	0.00 (0.99)	0.04 (0.76)	0.08 (0.39)	0.03 (0.77)	-0.02 (0.82)	0.06 (0.63)	0.09 (0.30)
Unable to function	-0.13 (0.43)	0.09 (0.77)	0.06 (0.84)	0.12 (0.65)	0.02 (0.88)	0.04 (0.82)	-0.04 (0.80)	-0.12 (0.62)	-0.11 (0.45)
_cons	-3.27 (0.00)	-5.06 (0.00)	-0.64 (0.06)	-0.57 (0.05)	-1.54 (0.00)	-1.55 (0.00)	-2.72 (0.00)	-3.14 (0.00)	1.38 (0.00)

Note: Coefficient and p-value in parenthesis. Statistically significant coefficients in bold.

Appendix M: Information on oral health provided in Questionnaire

A) For Adults



Dental Feature	Types of problem	Implications	Possible treatments
	Tooth decay	Tooth decay may not cause any symptoms until advanced stages when people may report dental pain.	Most decay can be removed by a dentist and the tooth restored with a filling. In some cases people may need root canal treatment and the tooth restoring with a filling or crown.
Molar tooth	No problem Decay without pain Decay with pain Tooth needs to be removed	Some people with missing molar teeth may find eating food difficult, especially if pre-molar teeth are also missing.	
Pre-molar tooth	No problem Decay without pain Decay with pain Tooth needs to be removed	Some people with missing pre-molar teeth report feeling self-conscious and embarrassed. They may find eating food difficult if molar teeth are also missing.	If a tooth is removed, you can be left with a gap or it may be possible to replace it with a bridge, dental implant or denture.
Front (anterior) tooth	No problem Decay without pain Decay with pain Tooth needs to be removed	Some people with missing front teeth report difficulties with eating and occasionally feeling self-conscious and embarrassed.	
Gum problems	No problems Some gum problems	Gum problems include bleeding during brushing and flossing. Some people with gum problems report a worsened sense of taste and bad breath. If untreated the bone in your jaw can decay and small spaces can open up between the gum and teeth.	Gum disease can usually be treated by maintaining a good level of oral hygiene and a thorough clean and plaque removal by your dentist or dental hygienist.
Cost to you	£10, £50, £150, £300, £500, £800	This is how much you would hypothetically have to pay for the dental service. Please consider which you would be prepared to pay personally even if your dental care is usually provided wholly or in part by the NHS.	

B) For Children

Dental Feature	**Types of problem**	**Possible implications**
Tooth decay in baby teeth	• **No problem** • **Tooth decay in a baby tooth without pain** • **Tooth decay in a baby tooth causing pain and needing a filling** • **Tooth decay in a baby tooth causing pain and needing removal**	**The baby teeth are the first teeth, and these are later replaced by the permanent teeth.** **Tooth decay in primary teeth may not cause any pain until advanced stages. If the tooth decay is painful for the child the tooth may need a filling or to be removed.**
Tooth decay permanent teeth	• **No problem** • **Tooth decay in a permanent tooth without pain and needing a filling** • **Tooth decay in a permanent tooth causing pain and needing a filling** • **Tooth decay in a permanent tooth causing pain and needing removal**	**Tooth decay in permanent tooth may not cause any symptoms until advanced stages when children may report dental pain and difficulties with eating.** **Most tooth decay in children can be treated by removing the decay and filling the tooth. In some cases the tooth may need to be removed. If the tooth is removed the child can be left with a gap, or may have a crown or denture fitted.**
Cost to you	**£10, £50, £150, £300, £500, £800**	**This is how much would hypothetically have to pay for the service to prevent the health state in the child. Please consider which you would be prepared to pay personally even if your dental care is usually provided wholly or in part by the NHS.**

Appendix N: Worked-out DCE Example

Before launching the main exercise, we will start with a simple example to help you understand the type of choice questions we will be asking you. We are interested in your opinion and there are no wrong answers.

Making choices – an example

Imagine that you have a choice of two dental services that vary according to the amount of time you usually have to wait for an appointment, the distance of the dental surgery from your home and the cost to you personally of a check-up. Indicate which dentist you would prefer by putting a tick in the appropriate box.

	Dentist A		Dentist B	
Waiting time for an appointment	1 day		3 days	
Distance from home	Less than one mile		Between one and three miles	
Check-up cost	£20		£0 (no cost)	
Which option would you choose (*tick one box only*)	Dentist A	☐	Dentist B	✓

Let's say a person answering this question preferred Dentist B. This would indicate that he preferred a service where he had to wait 3 days for an appointment, travel between 1-3 miles from home to visit the surgery and to pay nothing for a check-up.

On the other hand say the person preferred Dentist A. This would indicate that he prefers to have the dental appointment sooner and closer to home, even if he has to pay £20.

Appendix O: Example of DCE question in the main survey

Imagine that you have oral health problems.

You can pay for a dental service now (Service A or B) which will partly resolve your oral health problem and stop it from getting worse, but at your next six-month dental visit you will still have the problems described below. The cost of your next dental visit will be covered by the NHS.

Please consider the two services available. Which would you prefer?

● **Service A**	○ **Service B**
£300 as cost of dental appointment now	£150 as cost of dental appointment now
At next dental visit you will have	***At next dental visit you will have***
No problems in front teeth	Decay without pain in a front tooth
Need to have a pre-molar tooth removed	Decay with pain in a pre-molar tooth
Need to have a molar tooth removed	Decay with pain in a molar tooth
Some gum problems	No gum problems

Appendix P: Full conditional Logit models

Adult's oral health

					95% confidence limit	
pref	Coef.	Std. Err.	z	P>z	Lower	Upper
anter1	-0.1616	0.0569	-2.84	0.005	-0.2731	-0.0501
anter2	-0.7133	0.0604	-11.80	0	-0.8317	-0.5949
anter3	-1.0100	0.0664	-15.22	0	-1.1401	-0.8799
premo1	-0.0017	0.0609	-0.03	0.978	-0.1210	0.1176
premo2	-0.3108	0.0450	-6.91	0	-0.3989	-0.2227
premo3	-0.0150	0.0416	-0.36	0.719	-0.0966	0.0666
molar1	0.0181	0.0506	0.36	0.721	-0.0811	0.1172
molar2	0.1976	0.0534	3.70	0	0.0928	0.3023
molar3	-0.0163	0.0529	-0.31	0.758	-0.1200	0.0874
gum	-0.3591	0.0284	-12.65	0	-0.4148	-0.3035
cost	-0.0029	0.0001	-25.96	0	-0.0031	-0.0027

Notes: anter1 (decay without pain in anterior tooth); anter2 (decay with pain in anterior tooth); anter3 (requiring removal of anterior tooth); premo1 (decay without pain in premolar); premo2 (decay with pain in premolar); premo3 (requiring removal of premolar); molar 1(decay without pain in molar); molar2 (decay with pain in molar); molar3 (requiring removal of molar); gum (some gum problems).

Children's oral health

					95% confidence limit	
pref	Coef.	Std. Err.	z	P>z	Lower	Upper
Baby0	(reference)					
baby1	0.0381	0.0734	0.5200	0.6040	-0.1057	0.1819
baby2	-0.3895	0.0966	-4.0300	0.0000	-0.5788	-0.2001
baby3	0.1266	0.0992	1.2800	0.2020	-0.0679	0.3211
Perm 0	(reference)					
perm1	-0.3086	0.1011	-3.0500	0.0020	-0.5067	-0.1105
perm2	-0.8615	0.1131	-7.6200	0.0000	-1.0831	-0.6398
perm3	-0.7028	0.1260	-5.5800	0.0000	-0.9498	-0.4559
cost	-0.0028	0.0002	-13.8500	0.0000	-0.0032	-0.0024

Notes: baby1 (decay without pain in baby tooth); baby 2 (decay with pain in baby tooth); baby3 (requiring removal of baby tooth); perm1 (decay without pain in permanent tooth); perm2 (decay with pain in permanent tooth); perm3 (requiring removal of permanent tooth).

Appendix Q: Stata do-files for analysis of ADHS data

```
*************************************************************************************
* BBC EAC: NICE PUBLIC HEALTH
* ANALYSIS OF ADULT DENTAL HEALTH SURVEY 1998
*************************************************************************************

* INITIALISE
*************************************************************************************

       version 12.1
       set more off
       clear all

* Open log file for results

       capture log close _all
       log using "ADHS 1998 analysis", replace

* Retrieve dataset

       cd "G:\Projects\NICE EAC\Oral health\3. Model\Calibration"
       use "ADHS_1998.dta", replace



* Drop unnecessary variables

       keep    ISerial iweight eweight natural regular yearden lastden howden
       ///
                      country sex agegrp1 scgrp ohiptot
       ///
                      tcondll1 tcondll2 tcondll3 tcondll4 tcondll5 tcondll6 tcondll7 tcondll8
///
                      tcondlr1 tcondlr2 tcondlr3 tcondlr4 tcondlr5 tcondlr6 tcondlr7 tcondlr8
///
                      tcondul1 tcondul2 tcondul3 tcondul4 tcondul5 tcondul6 tcondul7 tcondul8
///
                      tcondur1 tcondur2 tcondur3 tcondur4 tcondur5 tcondur6 tcondur7 tcondur8
///
                      calc numpcde pcd4 pcd6 numloae loa4 loa6


* Create variable for subgroup of regular/occasional dental attenders with some teeth
       gen     Include = 0
       replace Include = 1 if (regular==1 | regular==2) & natural==1
       label   values Include YesNo

       order   ISerial iweight eweight Include natural regular yearden lastden howden     ///
                      country sex agegrp1 scgrp ohiptot                                  ///
                      tcondll1 tcondll2 tcondll3 tcondll4 tcondll5 tcondll6 tcondll7 tcondll8
///
                      tcondlr1 tcondlr2 tcondlr3 tcondlr4 tcondlr5 tcondlr6 tcondlr7 tcondlr8
///
                      tcondul1 tcondul2 tcondul3 tcondul4 tcondul5 tcondul6 tcondul7 tcondul8
///
                      tcondur1 tcondur2 tcondur3 tcondur4 tcondur5 tcondur6 tcondur7 tcondur8
///
                      calc numpcde pcd4 pcd6 numloae loa4 loa6

* Declare code for yes/no questions

       label define YesNo 0 "No" 1 "Yes"


* SUMMARISE CHARACTERISTICS OF SAMPLE
*************************************************************************************

       log on
       noisily display _n(1) "ADULT DENTAL HEALTH SURVEY 1998" _n(1)
*      noisily sum
```

```
        noisily display _n(1) "Summary of characteristics for whole sample and included
subset"
        noisily display       "(dentate reporting 'regular' or 'occasional' checkups)" _n(1)

        noisily tab natural Include, chi2 column nokey
        noisily tab regular Include, chi2 column nokey
        noisily tab howden  Include, chi2 column nokey
        noisily tab country Include, chi2 column nokey
        noisily tab sex     Include, chi2 column nokey
        noisily tab agegrp1 Include, chi2 column nokey
        noisily tab scgrp   Include, chi2 column nokey

        noisily display _n(2) "Mean OHIP scores"
        noisily ttest ohiptot, by(Include)
        log off


* Select population for further anlaysis
        drop if Include==0


* RECODE DENTAL EXAMINATION RESULTS
*************************************************************************************

* Recode results for individual teeth

        foreach M in ur1 ur2 ur3 ur4 ur5 ur6 ur7 ur8 ///
                         ul1 ul2 ul3 ul4 ul5 ul6 ul7 ul8 ///
                         ll1 ll2 ll3 ll4 ll5 ll6 ll7 ll8 ///
                         lr1 lr2 lr3 lr4 lr5 lr6 lr7 lr8 {

               recode  tcond`M'  ///
           (-9 = .)  ///  Missing/not applicable
           ( 1 = 1)  ///  1 sound
           ( 2 = 2)  ///  2 visual caries
           ( 3 = 2)  ///  3 cavitated caries
           ( 4 = 2)  ///  4 unrestorable
           ( 5 = 1)  ///  5 sound sealant
           ( 6 = 2)  ///  6 sealant with vis caries
           ( 7 = 2)  ///  7 sealant with cav. caries
           ( 8 = 1)  ///  8 fractured sealant
           ( 9 = 2)  ///  9 sealant with vis caries + other vis. caries
           (10 = 2)  /// 10 sealant with vis caries + other cav caries
           (11 = 2)  /// 11 sealant with cav. caries + other vis. caries
           (12 = 2)  /// 12 sealant with cav. caries + other cav. caries
           (13 = 2)  /// 13 fractured sealant + other vis caries
           (14 = 2)  /// 14 fractured sealant + other cav. caries
           (15 = 2)  /// 15 sound sealant + other vis. caries
           (16 = 2)  /// 16 sound sealant + other cav. caries
           (17 = 3)  /// 17 sound amalgam filling
           (18 = 4)  /// 18 am. filling with vis. caries
           (19 = 4)  /// 19 am filling with cav. caries
           (20 = 4)  /// 20 fractured am filling
           (21 = 4)  /// 21 am filling with vis caries + other vis caries
           (22 = 4)  /// 22 am filling with vis caries + other cav caries
           (23 = 4)  /// 23 am filling with cav caries + other vis caries
           (24 = 4)  /// 24 am filling with cav caries + other cav caries
           (25 = 4)  /// 25 fractured am filling + other vis caries
           (26 = 4)  /// 26 fractured am filling + other cav caries
           (27 = 4)  /// 27 sound am filling + other vis caries
           (28 = 4)  /// 28 sound am filling. + other cav caries
           (29 = 3)  /// 29 sound am filling. + shim/veneer
           (30 = 3)  /// 30 sound restoration
           (31 = 4)  /// 31 rest. with vis. caries
           (32 = 4)  /// 32 rest. with cav. caries
           (33 = 4)  /// 33 fractured rest.
           (34 = 4)  /// 34 rest. with vis caries + other vis caries
           (35 = 4)  /// 35 rest. with vis caries + other cav caries
           (36 = 4)  /// 36 rest. with cav caries + other vis caries
           (37 = 4)  /// 37 rest. with cav caries + other cav caries
           (38 = 4)  /// 38 fractured rest. + other vis caries
           (39 = 4)  /// 39 fractured rest. + other cav caries
           (40 = 4)  /// 40 sound rest. + other vis caries
           (41 = 4)  /// 41 sound rest. + other cav caries
           (42 = 3)  /// 42 sound rest. + shim/veneer
           (43 = 3)  /// 43 sound shim/veneer
           (44 = 4)  /// 44 s/v with vis. caries
```

```
          (45 = 4)  /// 45 s/v with cav. caries
          (46 = 4)  /// 46 fractured s/v
          (47 = 4)  /// 47 s/v with vis caries + other vis caries
          (48 = 4)  /// 48 s/v with vis caries + other cav caries
          (49 = 4)  /// 49 s/v with cav caries + other vis caries
          (50 = 4)  /// 50 s/v with cav caries + other cav caries
          (51 = 4)  /// 51 fractured s/v + other vis caries
          (52 = 4)  /// 52 fractured s/v + other cav caries
          (53 = 4)  /// 53 sound s/v + other vis caries
          (54 = 4)  /// 54 sound s/v + other cav caries
          (55 = 3)  /// 55 sound crown
          (56 = 4)  /// 56 crown with vis. caries
          (57 = 4)  /// 57 crown with cav. caries
          (58 = 4)  /// 58 fractured crown
          (90 = 5)  /// 90 missing
          (97 = 5)  /// 97 missing replaced by adhesive bridge
          (98 = 5)  /// 98 missing replaced by conventional bridge
          (99 = .)  /// 99 unscorable
                , gen(TS`M')

*                noisily tab tcond`M' TS`M', nolab miss

               }


* CREATE SUMMARY VARIABLES FOR ORAL HEALTH STATUS
*************************************************************************************

* Count numbers of anterior teeth by state

       gen AntS  = 0 if eweight!=0
       gen AntD  = 0 if eweight!=0
       gen AntFS = 0 if eweight!=0
       gen AntFU = 0 if eweight!=0
       gen AntM  = 0 if eweight!=0

       foreach M in ul1 ul2 ul3 ur1 ur2 ur3 ll1 ll2 ll3 lr1 lr2 lr3       {

              replace AntS  = AntS  + 1 if TS`M'==1
              replace AntD  = AntD  + 1 if TS`M'==2
              replace AntFS = AntFS + 1 if TS`M'==3
              replace AntFU = AntFU + 1 if TS`M'==4
              replace AntM  = AntM  + 1 if TS`M'==5
       }

       gen AntNum = AntS + AntD + AntFS + AntFU + AntM

       replace AntS  = AntS/ AntNum
       replace AntD  = AntD/ AntNum
       replace AntFS = AntFS/AntNum
       replace AntFU = AntFU/AntNum
       replace AntM  = AntM/ AntNum


* Count numbers of premolar teeth by state

       gen PreS  = 0 if eweight!=0
       gen PreD  = 0 if eweight!=0
       gen PreFS = 0 if eweight!=0
       gen PreFU = 0 if eweight!=0
       gen PreM  = 0 if eweight!=0

       foreach M in ul4 ul5 ur4 ur5 ll4 ll5 lr4 lr5 {

              replace PreS  = PreS  + 1 if TS`M'==1
              replace PreD  = PreD  + 1 if TS`M'==2
              replace PreFS = PreFS + 1 if TS`M'==3
              replace PreFU = PreFU + 1 if TS`M'==4
              replace PreM  = PreM  + 1 if TS`M'==5
       }

       gen PreNum = PreS + PreD + PreFS + PreFU + PreM

       replace PreS  = PreS/ PreNum
       replace PreD  = PreD/ PreNum
       replace PreFS = PreFS/PreNum
       replace PreFU = PreFU/PreNum
```

```
        replace PreM  = PreM/ PreNum


* Count numbers of molar teeth by state

        gen MolS  = 0 if eweight!=0
        gen MolD  = 0 if eweight!=0
        gen MolFS = 0 if eweight!=0
        gen MolFU = 0 if eweight!=0
        gen MolM  = 0 if eweight!=0

        foreach M in ul6 ul7 ul8 ur6 ur7 ur8 ll6 ll7 ll8 lr6 lr7 lr8  {

                replace MolS  = MolS  + 1 if TS`M'==1
                replace MolD  = MolD  + 1 if TS`M'==2
                replace MolFS = MolFS + 1 if TS`M'==3
                replace MolFU = MolFU + 1 if TS`M'==4
                replace MolM  = MolM  + 1 if TS`M'==5
        }

        gen MolNum = MolS + MolD + MolFS + MolFU + MolM

        replace MolS  = MolS/ MolNum
        replace MolD  = MolD/ MolNum
        replace MolFS = MolFS/MolNum
        replace MolFU = MolFU/MolNum
        replace MolM  = MolM/ MolNum


* Define gum disease (any pocketing >4mm)
        gen     pGumD = .
        replace pGumD = 0 if pcd4==2
        replace pGumD = 1 if pcd4==1
        label values pGumD YesNo



* SUMMARY OF ORAL HEALTH RESULTS
***********************************************************************************

* Apply survey weights for examination (adjusts sample to reflect population)
        svyset ISerial [pweight=eweight], vce(linearized) singleunit(missing)

* Print age distribution for
        log on
        noisily display _n(2) "SAMPLE UNDERGOING EXAMINATION"
        noisily display          "Age distribution (not adjusted)" _n(1)
        noisily tab agegrp1 if eweight!=0

        noisily display _n(2) "Age distribution (adjusted to reflect population)" _n(1)
        noisily svy: tab agegrp1, obs
        log off

* Calculate proportion of anterior, premolar and molar teeth by tooth state (S/D/FS/FU/M)
        foreach M in "Ant" "Pre" "Mol"       {
                local age=1

                forvalues age = 1/7    {

                        svy : mean     `M'S `M'D `M'FS `M'FU `M'M `M'Num if agegrp1==`age', noh
nol
                        matrix `M'Mean`age' = e(b)'
                        matrix `M'Vars`age' = vecdiag(e(V))'
                }

                matrix `M'Mean = `M'Mean1, `M'Mean2, `M'Mean3, `M'Mean4, `M'Mean5, `M'Mean6,
`M'Mean7
                matrix `M'Vars = `M'Vars1, `M'Vars2, `M'Vars3, `M'Vars4, `M'Vars5, `M'Vars6,
`M'Vars7

                matrix colnames `M'Mean = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
                matrix colnames `M'Vars = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
        }

* Calculate proportion with gum disease
        forvalues age = 1/7    {
```

```
        svy : mean pGumD if agegrp1==`age', noh nol
        matrix GumMean`age' = e(b)'
        matrix GumVars`age' = vecdiag(e(V))'
    }

    matrix GumMean = GumMean1, GumMean2, GumMean3, GumMean4, GumMean5, GumMean6, GumMean7
    matrix GumVars = GumVars1, GumVars2, GumVars3, GumVars4, GumVars5, GumVars6, GumVars7
    matrix colnames GumMean = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
    matrix colnames GumVars = 16to24 25to34 35to44 45to54 55to64 65to74 75plus


* Print results to log file
    log on
    noisily display _n(2) "TOOTH AND GUM HEALTH BY AGE"
    noisily display _n(1) "Means (adjusted)"
    noisily matrix list AntMean
    noisily matrix list PreMean
    noisily matrix list MolMean
    noisily matrix list GumMean

    noisily display _n(1) "Variances (adjusted)"
    noisily matrix list AntVars
    noisily matrix list PreVars
    noisily matrix list MolVars
    noisily matrix list GumVars

    log off

* FINISH
*************************************************************************************

    log close
    set more off
```

```
***************************************************************************************
* BBC EAC: NICE PUBLIC HEALTH
* ANALYSIS OF ADULT DENTAL HEALTH SURVEY 2009
***************************************************************************************

* INITIALISE
***************************************************************************************

	version 12.1
	set more off
	clear all

* Open log file for results

	capture log close _all
	log using "ADHS 2009 analysis", replace

* Retrieve dataset

	cd "G:\Projects\NICE EAC\Oral health\3. Model\Calibration"
	use "ADHS_2009.dta", replace

* Drop unnecessary variables

	keep	Serial iweight eweight dentate Regular HowLong
	///
			Country Sex ageband4 ethnicg NSSEC5 DVSMOKE CigNow TotOHIP TotOIDP
	///
			TStatUR1 TStatUR2 TStatUR3 TStatUR4 TStatUR5 TStatUR6 TStatUR7 TStatUR8
///
			TStatUL1 TStatUL2 TStatUL3 TStatUL4 TStatUL5 TStatUL6 TStatUL7 TStatUL8
///
			TStatLL1 TStatLL2 TStatLL3 TStatLL4 TStatLL5 TStatLL6 TStatLL7 TStatLL8
///
			TStatLR1 TStatLR2 TStatLR3 TStatLR4 TStatLR5 TStatLR6 TStatLR7 TStatLR8
///
			paindv gumhltg4 hasbld hascalc pcd4 pcd6 pcd9 LOAtt4 LOAtt6 LOAtt9
	///
			numsexa numsexb numsexc numsexd numsexe

* Create variable for subgroup of regular/occasional dental attenders with some teeth
	gen	Include = 0
	replace Include = 1 if (Regular==1 | Regular==2) & dentate==2
	label values Include YesNo

	order	Serial iweight eweight Include dentate Regular HowLong
	///
			Country Sex ageband4 ethnicg NSSEC5 DVSMOKE CigNow TotOHIP TotOIDP
	///
			TStatUR1 TStatUR2 TStatUR3 TStatUR4 TStatUR5 TStatUR6 TStatUR7 TStatUR8
///
			TStatUL1 TStatUL2 TStatUL3 TStatUL4 TStatUL5 TStatUL6 TStatUL7 TStatUL8
///
			TStatLL1 TStatLL2 TStatLL3 TStatLL4 TStatLL5 TStatLL6 TStatLL7 TStatLL8
///
			TStatLR1 TStatLR2 TStatLR3 TStatLR4 TStatLR5 TStatLR6 TStatLR7 TStatLR8
///
			paindv gumhltg4 hasbld hascalc pcd4 pcd6 pcd9 LOAtt4 LOAtt6 LOAtt9
	///
			numsexa numsexb numsexc numsexd numsexe

* Declare code for yes/no questions

	label define YesNo 0 "No" 1 "Yes"


* SUMMARISE CHARACTERISTICS OF SAMPLE
***************************************************************************************

	log on
	noisily display _n(1) "ADULT DENTAL HEALTH SURVEY 2009" _n(1)
*	noisily sum
	noisily display _n(1) "Summary of characteristics for whole sample and included
subset"
	noisily display 	"(dentate reporting 'regular' or 'occasional' checkups)" _n(1)

	noisily tab dentate Include, chi2 column nokey
```

```
       noisily tab Regular Include, chi2 column nokey
       noisily tab HowLong Include, chi2 column nokey
       noisily tab Country Include, chi2 column nokey
       noisily tab Sex Include, chi2 column nokey
       noisily tab ageband4 Include, chi2 column nokey
       noisily tab ethnicg Include, chi2 column nokey
       noisily tab NSSEC5 Include, chi2 column nokey
       noisily tab CigNow Include, chi2 column nokey

       noisily display _n(2) "Mean OHIP scores"
       noisily ttest TotOHIP, by(Include)
       noisily display _n(2) "Mean OIDP scores"
       noisily ttest TotOIDP, by(Include)
       log off

* Select population for further anlaysis
       drop if Include==0


* RECODE DENTAL EXAMINATION RESULTS
*************************************************************************************

* Recode results for individual teeth

       foreach M in UR1 UR2 UR3 UR4 UR5 UR6 UR7 UR8 ///
                         UL1 UL2 UL3 UL4 UL5 UL6 UL7 UL8 ///
                         LL1 LL2 LL3 LL4 LL5 LL6 LL7 LL8 ///
                         LR1 LR2 LR3 LR4 LR5 LR6 LR7 LR8 {

              recode  TStat`M'  ///
        (-9 = .)  ///  -9 No answer/refused
        (-8 = .)  ///  -8 Dont know
        (-7 = .)  ///  -7 Refused/not obtained
        (-6 = .)  ///  -6 Schedule not obtained
        (-2 = .)  ///  -2 Schedule not applicable
        (-1 = .)  ///  -1 Item not applicable
        ( 1 = 1)  ///   1 All surfaces sound
        ( 2 = 2)  ///   2 Visual caries
        ( 3 = 2)  ///   3 Cavitated caries
        ( 4 = 2)  ///   4 Unrestorable
        ( 5 = 1)  ///   5 Sealant - sound
        ( 6 = 2)  ///   6 Sealant with visual caries
        ( 7 = 2)  ///   7 Sealant with cavitated caries
        ( 8 = 1)  ///   8 Fractured sealant
        ( 9 = 2)  ///   9 Sealant with visual caries + visual caries
        (10 = 2)  ///  10 Sealant with visual caries + cavitated caries
        (11 = 2)  ///  11 Sealant with cavitated caries + visual caries
        (12 = 2)  ///  12 Sealant with cavitated caries + cavitated caries
        (13 = 2)  ///  13 Fractured sealant + visual caries
        (14 = 2)  ///  14 Fractured sealant + cavitated caries
        (15 = 2)  ///  15 Sealant - sound + visual caries
        (16 = 2)  ///  16 Sealant - sound + cavitated caries
        (17 = 3)  ///  17 Amalgam filling - sound
        (18 = 4)  ///  18 Amalgam filling with visual caries
        (19 = 4)  ///  19 Amalgam filling with cavitated caries
        (20 = 4)  ///  20 Fractured amalgam filling
        (21 = 4)  ///  21 Amalgam filling with visual caries + visual caries
        (22 = 4)  ///  22 Amalgam filling with visual caries + cavitated caries
        (23 = 4)  ///  23 Amalgam filling with cavitated caries + visual caries
        (24 = 4)  ///  24 Amalgam filling with cavitated caries + cavitated caries
        (25 = 4)  ///  25 Fractured amalgam filling + visual caries
        (26 = 4)  ///  26 Fractured amalgam filling + cavitated caries
        (27 = 4)  ///  27 Amalgam filling - sound + visual caries
        (28 = 4)  ///  28 Amalgam filling - sound + cavitated caries
        (29 = 3)  ///  29 Amalgam filling - sound + shim/veneer
        (30 = 3)  ///  30 Restoration - sound
        (31 = 4)  ///  31 Restoration with visual caries
        (32 = 4)  ///  32 Restoration with cavitated caries
        (33 = 4)  ///  33 Fractured restoration
        (34 = 4)  ///  34 Restoration with visual caries + visual caries
        (35 = 4)  ///  35 Restoration with visual caries + cavitated caries
        (36 = 4)  ///  36 Restoration with cavitated caries + visual caries
        (37 = 4)  ///  37 Restoration with cavitated caries + cavitated caries
        (38 = 4)  ///  38 Fractured restoration + visual caries
        (39 = 4)  ///  39 Fractured restoration + cavitated caries
        (40 = 4)  ///  40 Restoration - sound + visual caries
        (41 = 4)  ///  41 Restoration - sound + cavitated caries
```

```
        (42 = 3)  ///  42 Restoration - sound + shim/veneer
        (43 = 3)  ///  43 Shim/veneer - sound
        (44 = 4)  ///  44 Shim/veneer with visual caries
        (45 = 4)  ///  45 Shim/veneer with cavitated caries
        (46 = 4)  ///  46 Fractured shim/veneer
        (47 = 4)  ///  47 Shim/veneer with visual caries + visual caries
        (48 = 4)  ///  48 Shim/veneer with visual caries + cavitated caries
        (49 = 4)  ///  49 Shim/veneer with cavitated caries + visual caries
        (50 = 4)  ///  50 Shim/veneer with cavitated caries + cavitated caries
        (51 = 4)  ///  51 Fractured shim/veneer + visual caries
        (52 = 4)  ///  52 Fractured shim/veneer + cavitated caries
        (53 = 4)  ///  53 Shim/veneer - sound + visual caries
        (54 = 4)  ///  54 Shim/veneer - sound + cavitated caries
        (55 = 3)  ///  55 Crown - sound
        (56 = 4)  ///  56 Crown with visual caries
        (57 = 4)  ///  57 Crown with cavitated caries
        (58 = 4)  ///  58 Fractured crown
        (90 = 5)  ///  90 Missing
        (96 = 5)  ///  96 Missing replaced by implant
        (97 = 5)  ///  97 Missing replaced by adhesive bridge
        (98 = 5)  ///  98 Missing replaced by conventional bridge
        (99 = .)  ///  99 Unscorable
        (101= 1) /// 101 Hard arrested decay, all other surfaces sound
        (102= 1) /// 102 Hard arrested decay on all surfaces
        (103= 1) /// 103 Sealant with hard arrested decay
        (104= 1) /// 104 Sealant - sound + hard arrested decay
        (105= 1) /// 105 Sealant with hard arrested decay + hard arrested decay
        (106= 2) /// 106 Sealant with hard arrested decay + visual caries
        (107= 2) /// 107 Sealant with hard arrested decay + cavitated caries
        (108= 1) /// 108 Fractured sealant + hard arrested decay
        (109= 2) /// 109 Sealant with visual caries + hard arrested decay
        (110= 2) /// 110 Sealant with cavitated caries + hard arrested decay
        (111= 3) /// 111 Shim/veneer with hard arrested decay
        (112= 3) /// 112 Shim/veneer - sound + hard arrested decay
        (113= 3) /// 113 Shim/veneer with hard arrested decay + hard arrested decay
        (114= 4) /// 114 Shim/veneer with hard arrested decay + visual caries
        (115= 4) /// 115 Shim/veneer with hard arrested decay + cavitated caries
        (116= 4) /// 116 Fractured shim/veneer + hard arrested decay
        (117= 4) /// 117 Shim/veneer with visual caries + hard arrested decay
        (118= 4) /// 118 Shim/veneer with cavitated caries + hard arrested decay
        (119= 3) /// 119 Restoration with hard arrested decay
        (120= 3) /// 120 Restoration - sound + hard arrested decay
        (121= 3) /// 121 Restoration with hard arrested decay + hard arrested decay
        (122= 4) /// 122 Restoration with hard arrested decay + visual caries
        (123= 4) /// 123 Restoration with hard arrested decay + cavitated caries
        (124= 4) /// 124 Fractured restoration + hard arrested decay
        (125= 4) /// 125 Restoration with visual caries + hard arrested decay
        (126= 4) /// 126 Restoration with cavitated caries + hard arrested decay
        (127= 3) /// 127 Amalgam filling with hard arrested decay
        (128= 3) /// 128 Amalgam filling - sound + hard arrested decay
        (129= 3) /// 129 Amalgam filling with hard arr. decay + hard arr. decay
        (130= 4) /// 130 Amalgam filling with hard arr. decay + visual caries
        (131= 4) /// 131 Amalgam filling with hard arr. decay + cavitated caries
        (132= 4) /// 132 Fractured amalgam filling + hard arrested decay
        (133= 4) /// 133 Amalgam filling with visual caries + hard arr. decay
        (134= 4) /// 134 Amalgam filling with cavitated caries + hard arr. decay
        (135= 3) /// 135 Crown with hard arrested decay
              , gen(TS`M')

*           noisily tab TStat`M' TS`M', nolab miss

              }


* CREATE SUMMARY VARIABLES FOR ORAL HEALTH STATUS
*************************************************************************************

* Count numbers of anterior teeth by state

       gen AntS  = 0 if eweight!=0
       gen AntD  = 0 if eweight!=0
       gen AntFS = 0 if eweight!=0
       gen AntFU = 0 if eweight!=0
       gen AntM  = 0 if eweight!=0
       gen AntU  = 0 if eweight!=0

       foreach M in UL1 UL2 UL3 UR1 UR2 UR3 LL1 LL2 LL3 LR1 LR2 LR3       {
```

```
        replace AntS  = AntS  + 1 if TS`M'==1
        replace AntD  = AntD  + 1 if TS`M'==2
        replace AntFS = AntFS + 1 if TS`M'==3
        replace AntFU = AntFU + 1 if TS`M'==4
        replace AntM  = AntM  + 1 if TS`M'==5
        replace AntU  = AntU  + 1 if TStat`M'==4
}

replace AntU  = AntU/ (AntD + AntFU)  /// Proportion of D/FU unrestorable

gen AntNum = AntS + AntD + AntFS + AntFU + AntM

replace AntS  = AntS/ AntNum
replace AntD  = AntD/ AntNum
replace AntFS = AntFS/AntNum
replace AntFU = AntFU/AntNum
replace AntM  = AntM/ AntNum
```

```
* Count numbers of premolar teeth by state

        gen PreS  = 0 if eweight!=0
        gen PreD  = 0 if eweight!=0
        gen PreFS = 0 if eweight!=0
        gen PreFU = 0 if eweight!=0
        gen PreM  = 0 if eweight!=0
        gen PreU  = 0 if eweight!=0

        foreach M in UL4 UL5 UR4 UR5 LL4 LL5 LR4 LR5 {

                replace PreS  = PreS  + 1 if TS`M'==1
                replace PreD  = PreD  + 1 if TS`M'==2
                replace PreFS = PreFS + 1 if TS`M'==3
                replace PreFU = PreFU + 1 if TS`M'==4
                replace PreM  = PreM  + 1 if TS`M'==5
                replace PreU  = PreU  + 1 if TStat`M'==4
        }

        replace PreU  = PreU/(PreD + PreFU)

        gen PreNum = PreS + PreD + PreFS + PreFU + PreM

        replace PreS  = PreS/ PreNum
        replace PreD  = PreD/ PreNum
        replace PreFS = PreFS/PreNum
        replace PreFU = PreFU/PreNum
        replace PreM  = PreM/ PreNum

* Count numbers of molar teeth by state

        gen MolS  = 0 if eweight!=0
        gen MolD  = 0 if eweight!=0
        gen MolFS = 0 if eweight!=0
        gen MolFU = 0 if eweight!=0
        gen MolM  = 0 if eweight!=0
        gen MolU  = 0 if eweight!=0

        foreach M in UL6 UL7 UL8 UR6 UR7 UR8 LL6 LL7 LL8 LR6 LR7 LR8  {

                replace MolS  = MolS  + 1 if TS`M'==1
                replace MolD  = MolD  + 1 if TS`M'==2
                replace MolFS = MolFS + 1 if TS`M'==3
                replace MolFU = MolFU + 1 if TS`M'==4
                replace MolM  = MolM  + 1 if TS`M'==5
                replace MolU  = MolU  + 1 if TStat`M'==4
        }

        replace MolU  = MolU/(MolD + MolFU)

        gen MolNum = MolS + MolD + MolFS + MolFU + MolM

        replace MolS  = MolS/ MolNum
        replace MolD  = MolD/ MolNum
        replace MolFS = MolFS/MolNum
        replace MolFU = MolFU/MolNum
        replace MolM  = MolM/ MolNum
```

```
* Calculate proportion of people with any decayed/ unsound teeth who report tooth pain
	gen		anyDecay = .
	replace		anyDecay = 0 if eweight >0

	foreach M in	UR1 UR2 UR3 UR4 UR5 UR6 UR7 UR8 ///
				UL1 UL2 UL3 UL4 UL5 UL6 UL7 UL8 ///
				LL1 LL2 LL3 LL4 LL5 LL6 LL7 LL8 ///
				LR1 LR2 LR3 LR4 LR5 LR6 LR7 LR8 {

	replace anyDecay = 1 if TS`M'==2 | TS`M'==4
	}

	gen		pPain = .
	replace		pPain = 0 if anyDecay==1
	replace pPain = 1 if anyDecay==1 & paindv==1
	label values pPain YesNo


* Calculate proportion of missing teeth that have been replaced (implant or bridge)

	gen		Miss = .
	gen			Rep  = .


	* Anterior teeth
	replace		Miss = 0 if eweight >0
	replace		Rep  = 0 if eweight >0

	foreach M in	UR1 UR2 UR3 UL1 UL2 UL3 LL1 LL2 LL3 LR1 LR2 LR3 {

		replace Miss = Miss+1 if (TStat`M'==90 | TStat`M'==96 | TStat`M'==97 |
TStat`M'==98)
		replace Rep  = Rep +1 if (TStat`M'==96 | TStat`M'==97 | TStat`M'==98)
	}

	gen pAntRep  = Rep/Miss

	gen	nAntMiss = .
	replace nAntMiss = 0 if Miss==0 & eweight>0
	replace nAntMiss = 1 if Miss>0  & eweight>0


	* Premolar teeth
	replace		Miss = 0 if eweight >0
	replace		Rep  = 0 if eweight >0

	foreach M in	UR4 UR5 UL4 UL5 LL4 LL5 LR4 LR5  {

		replace Miss = Miss+1 if (TStat`M'==90 | TStat`M'==96 | TStat`M'==97 |
TStat`M'==98)
		replace Rep  = Rep +1 if (TStat`M'==96 | TStat`M'==97 | TStat`M'==98)
	}

	gen pPreRep = Rep/Miss

	gen	nPreMiss = .
	replace nPreMiss = 0 if Miss==0 & eweight>0
	replace nPreMiss = 1 if Miss>0  & eweight>0


	* Molar teeth
	replace		Miss = 0 if eweight >0
	replace		Rep  = 0 if eweight >0

	foreach M in	UR6 UR7 UR8 UL6 UL7 UL8 LL6 LL7 LL8 LR6 LR7 LR8  {

		replace Miss = Miss+1 if (TStat`M'==90 | TStat`M'==96 | TStat`M'==97 |
TStat`M'==98)
		replace Rep  = Rep +1 if (TStat`M'==96 | TStat`M'==97 | TStat`M'==98)
	}

	gen pMolRep = Rep/Miss

	gen	nMolMiss = .
	replace nMolMiss = 0 if Miss==0 & eweight>0
	replace nMolMiss = 1 if Miss>0  & eweight>0
```

```
	drop Rep Miss


* Define gum disease (any pocketing >4mm)
	gen	pGumD = .
	replace pGumD = 0 if pcd4==2
	replace pGumD = 1 if pcd4==1
	label values pGumD YesNo



* SUMMARY OF ORAL HEALTH RESULTS
**********************************************************************************

* Apply survey weights for examination (adjusts sample to reflect population)
	svyset Serial [pweight=eweight], vce(linearized) singleunit(missing)


* Print age distribution
	log on
	noisily display _n(2) "SAMPLE UNDERGOING EXAMINATION"
	noisily display		"Age distribution (not adjusted)" _n(1)
	noisily tab ageband4 if eweight!=0


* Calculate proportion of anterior, premolar and molar teeth by tooth state (S/D/FS/FU/M)
	foreach M in "Ant" "Pre" "Mol"	{
		local age=1

		forvalues age = 1/7	{

			svy : mean	`M'S `M'D `M'FS `M'FU `M'M `M'Num if ageband4==`age',
noh nol
			matrix `M'Mean`age' = e(b)'
			matrix `M'Vars`age' = vecdiag(e(V))'
		}

		matrix `M'Mean = `M'Mean1, `M'Mean2, `M'Mean3, `M'Mean4, `M'Mean5, `M'Mean6,
`M'Mean7
		matrix `M'Vars = `M'Vars1, `M'Vars2, `M'Vars3, `M'Vars4, `M'Vars5, `M'Vars6,
`M'Vars7

		matrix colnames `M'Mean = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
		matrix colnames `M'Vars = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
	}

* Calculate proportion with gum disease
	forvalues age = 1/7	{

		svy : mean pGumD if ageband4==`age', noh nol
		matrix GumMean`age' = e(b)'
		matrix GumVars`age' = vecdiag(e(V))'
	}

	matrix GumMean = GumMean1, GumMean2, GumMean3, GumMean4, GumMean5, GumMean6, GumMean7
	matrix GumVars = GumVars1, GumVars2, GumVars3, GumVars4, GumVars5, GumVars6, GumVars7
	matrix colnames GumMean = 16to24 25to34 35to44 45to54 55to64 65to74 75plus
	matrix colnames GumVars = 16to24 25to34 35to44 45to54 55to64 65to74 75plus


* Print results to log file
	log on
	noisily display _n(2) "HEALTH STATE BY AGE AND TOOTH TYPE"
	noisily display _n(1) "Means (adjusted)"
	noisily matrix list AntMean
	noisily matrix list PreMean
	noisily matrix list MolMean
	noisily matrix list GumMean

	noisily display _n(1) "Variances (adjusted)"
	noisily matrix list AntVars
	noisily matrix list PreVars
	noisily matrix list MolVars
	noisily matrix list GumVars

	noisily display _n(2) "PROPORTIONS OF D/FU TEETH UNRESTORABLE"
```

```
	noisily svy: mean AntU PreU MolU

	noisily display _n(2) "PAIN WITH DECAY"
	noisily display _n(1) "Proportion with decay or unsound filling reporting tooth
related pain (adjusted)"
	noisily tab ageband4 anyDecay
	noisily svy : tab ageband4 pPain, row


	noisily display _n(2) "REPLACEMENT OF MISSING TEETH"
	noisily display _n(2) "Proportion of missing teeth with implant or bridge (adjusted)"

	noisily display _n(2) "Anterior teeth"
	noisily tab nAntMiss
	noisily svy : mean pAntRep

	noisily display _n(2) "Premolar teeth"
	noisily tab nPreMiss
	noisily svy : mean pPreRep

	noisily display _n(2) "Molar teeth"
	noisily tab nMolMiss
	noisily svy : mean pMolRep


	noisily display _n(2) "REPORTED FREQUENCY OF DENTAL CHECKS"
	noisily tab HowLong
	noisily svy: tab HowLong ageband4, col

	log off

* FINISH
**********************************************************************************

	log close
	set more off
```

Appendix R: Results of calibration on adult tooth model

Means and standard errors for three-month transition probabilities (2,000 calibrated parameter sets)

			Mean probability (per cycle)						*Standard errors*					
			16-24	*25-34*	*35-44*	*45-54*	*55-64*	*65-74*	*16-24*	*25-34*	*35-44*	*45-54*	*55-64*	*65-74*
Anterior	Decay | S	d	0.0003	0.0001	0.0001	0.0004	0.0001	0.0006	0.0002	0.0001	0.0001	0.0003	0.0002	0.0007
	Filling | D	f1	0.3207	0.2504	0.3350	0.3777	0.3891	0.4191	0.0159	0.0187	0.0149	0.0135	0.0186	0.0195
	Extraction | D	e1	0.0217	0.0170	0.0227	0.0256	0.0264	0.0284	0.0063	0.0051	0.0066	0.0074	0.0077	0.0083
	Filling failure | FS	l	0.0041	0.0113	0.0167	0.0196	0.0228	0.0354	0.0018	0.0022	0.0024	0.0026	0.0029	0.0048
	Refilling | FU	f2	0.3191	0.2492	0.3333	0.3758	0.3872	0.4170	0.0153	0.0188	0.0146	0.0133	0.0182	0.0195
	Extraction | FU	e2	0.0234	0.0182	0.0244	0.0275	0.0283	0.0305	0.0062	0.0048	0.0064	0.0072	0.0074	0.0080
Premolar	Decay | S	d	0.0011	0.0000	0.0017	0.0001	0.0000	0.0015	0.0005	0.0001	0.0008	0.0003	0.0002	0.0017
	Filling | D	f1	0.2866	0.2238	0.2994	0.3375	0.3477	0.3746	0.0173	0.0186	0.0169	0.0169	0.0206	0.0220
	Extraction | D	e1	0.0558	0.0436	0.0583	0.0658	0.0677	0.0730	0.0120	0.0097	0.0125	0.0140	0.0145	0.0157
	Filling failure | FS	l	0.0041	0.0113	0.0167	0.0196	0.0228	0.0354	0.0018	0.0022	0.0024	0.0026	0.0029	0.0048
	Refilling | FU	f2	0.3052	0.2383	0.3188	0.3595	0.3703	0.3989	0.0150	0.0179	0.0141	0.0131	0.0178	0.0185
	Extraction | FU	e2	0.0372	0.0291	0.0389	0.0439	0.0452	0.0487	0.0062	0.0051	0.0064	0.0071	0.0074	0.0081
Molar	Decay | S	d	0.0001	0.0000	0.0024	0.0000	0.0000	0.0119	0.0003	0.0000	0.0016	0.0001	0.0001	0.0056
	Filling | D	f1	0.3051	0.2383	0.3187	0.3594	0.3702	0.3988	0.0150	0.0178	0.0141	0.0130	0.0177	0.0187
	Extraction | D	e1	0.0373	0.0291	0.0390	0.0439	0.0453	0.0488	0.0062	0.0052	0.0065	0.0072	0.0075	0.0082
	Filling failure | FS	l	0.0041	0.0113	0.0167	0.0196	0.0228	0.0354	0.0018	0.0022	0.0024	0.0026	0.0029	0.0048
	Refilling | FU	f2	0.3051	0.2383	0.3187	0.3594	0.3702	0.3988	0.0150	0.0178	0.0141	0.0130	0.0177	0.0187
	Extraction | FU	e2	0.0373	0.0291	0.0390	0.0439	0.0453	0.0488	0.0062	0.0052	0.0065	0.0072	0.0075	0.0082

Appendix S: Sensitivity analyses for children's model

In the tables below, values coded in red represent the base case parameters and results of analysis.

Children age 1-6 (Blinkhorn et al. 2003)

Model inputs	Incremental cost	Incremental QALYs	Averted dmft	WTP decay with pain	ICER (£ per QALY)
Initial dmft					
0	£3,656	0.026	-3.612	£35	£142,105
1.6	£3,682	0.022	-3.18	£32	£164,950
2.17	£3,665	0.020	-3.044	£29	£182,714
Baseline hazard of decay					
0.0005	£4,217	0.00218	-0.139	£2	£1,937,740
0.0036	£3,682	0.022	-3.18	£32	£164,950
0.0161	£1,453	0.11473	-15.743	£146	£12,667
Hazard ratio of intervention					
0.5	£3,132	0.0471	-6.734	£65	£66,451
0.63	£3,682	0.022	-3.18	£32	£164,950
0.80	£3,769	0.0194	-2.803	£27	£194,361
% of decayed teeth filled					
12.5%	£3,682	0.022	-3.18	£32	£164,950
21%	£3,662	0.0219948	-3.262	£51	£166,511
28%	£3,554	0.02741207	-3.828	£80	£129,640
% of decayed teeth extracted					
10%	£3,798	0.0184	-3.500	£36	£206,201
13.91%	£3,682	0.022	-3.18	£32	£164,950
60%	£2,085	0.0904	-3.096	£29	£23,056
% of extractions under GA					
80%	£3,877	0.0173347	-2.716	£27	£223,671
90%	£3,775	0.0136992	-1.707	£19	£275,572
100%	£3,682	0.022	-3.18	£32	£164,950

Model inputs	Incremental cost	Incremental QALYs	Averted dmft	WTP decay with pain	ICER (£ per QALY)
Cost per UDA					
£20	£3,867	0.02	-2.40	£22	£201,430
£25	£3,682	0.022	-3.18	£32	£164,950
£30	£3,679	0.02	-3.01	£28	£152,899
Cost of intervention (per session)					
£2.00	£1,111	0.0199	-2.731	£25	£55,700
£5.35	£3,682	0.022	-3.18	£32	£164,950
£10.00	£7,265	0.0285	-4.032	£39	£255,110
QALY loss from tooth loss (OM)					
0.0134	£3,763	0.0058	-3.019	£30	£648,952
0.0346	£3,748	0.0149	-3.158	£32	£251,945
0.0508	£3,682	0.022	-3.18	£32	£164,950
QALY loss per tooth extraction (GA)					
0.0002	£3,960	0.0166111	-1.966	£16	£238,413
0.0001	£3,697	0.0184079	-2.642	£26	£200,822
0.0003	£3,682	0.022	-3.18	£32	£164,950

Children age 11-12 (Hausen et al. 2009)

Model inputs	Incremental cost	Incremental QALYs	Averted DMFT	WTP decay without pain	WTP decay with pain	WTP for removals	Total WTP	ICER (£ per QALY)	WTP - cost
Initial DMFT									
0.0000	£6,431	0.4544	-65.492	£2,321	£6,189	£2,164	£10,674	£14,153	£4,243
0.8000	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
2.3000	£6,993	0.4199	-60.591	£2,141	£5,732	£2,005	£9,878	£16,654	£2,885
Baseline hazard of decay									
0.0080	£7,724	0.3803	-55.156	£1,934	£5,191	£1,829	£8,953	£20,313	£1,229
0.0093	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
0.0255	-£7,681	1.1947	-170.370	£5,959	£16,041	£5,684	£27,684	Dominant	£35,366
Hazard ratio (intervention vs control)									
0.10	£5,595	0.4980	-71.803	£2,532	£6,745	£2,387	£11,664	£11,235	£6,069
0.19	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
0.30	£7,539	0.3883	-55.652	£2,000	£5,227	£1,865	£9,092	£19,416	£1,553
% of decayed teeth filled									
0%	£9,588	0.4423	-63.739	£0	£0	£2,109	£2,109	£21,680	-£7,479
63%	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
100%	£4,765	0.4445	-63.891	£3,633	£9,612	£2,140	£15,385	£10,720	£10,620
% Extracted									
5%	£10,075	0.1584	-63.796	£2,289	£6,016	£767	£9,072	£63,603	-£1,004
14%	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
20%	£4,235	0.6423	-64.043	£2,280	£6,024	£3,084	£11,387	£6,593	£7,153
% of extractions with GA									
10%	£10,380	0.44160	-63.768	£2,230	£5,987	£2,130	£10,347	£23,505	-£33
50%	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
80%	£3,717	0.44348	-64.333	£2,291	£6,084	£2,144	£10,519	£8,382	£6,802

Model inputs	Incremental cost	Incremental QALYs	Averted DMFT	WTP decay without pain	WTP decay with pain	WTP for removals	Total WTP	ICER (£ per QALY)	WTP - cost
Cost per UDA									
£10.00	£8,519	0.4464	-64.139	£2,260	£6,058	£2,123	£10,440	£19,086	£1,921
£25.00	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
£40.00	£4,515	0.45	-64.4	£2,253	£6,052	£2,166	£10,471	£10,142	£5,956
Cost of intervention (per year)									
£40.00	£3,341	0.4512	-63.882	£2,300	£5,969	£2,143	£10,413	£7,405	£7,072
£50.89	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
£60.00	£9,214	0.4461	-64.583	£2,291	£6,054	£2,166	£10,511	£20,654	£1,297
QALY loss from missing tooth									
0.1000	£6,542	0.8751	-64.071	£2,268	£6,059	£2,140	£10,467	£7,476	£3,925
0.0508	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
0.0200	£6,535	0.1752	-63.840	£2,276	£6,048	£2,116	£10,439	£37,298	£3,904
QALY if death from GA									
20	£6,489	0.447056	-64.022	£2,261	£6,006	£2,119	£10,386	£14,515	£3,897
38	£6,529	0.4439	-63.834	£2,266	£6,045	£2,139	£10,450	£14,710	£3,921
50	£6,494	0.443964	-63.671	£2,274	£6,000	£2,127	£10,401	£14,628	£3,907