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Cost–benefit, cost-effectiveness and cost–utility analyses of periodontitis prevention

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Abstract

Objective: The aim of this paper was to determine whether there is evidence that periodontitis prevention is economically justified.

Material and Methods: The characteristics of economic assessments such as cost–benefit, cost-effectiveness and cost–utility analyses were first derived from the literature on health economy. A literature search was conducted using PubMed up to December 2004. Inclusion criteria required that economic analyses be based on scientific principles including a hypothesis, valid comparative groups as well as a cost/benefit, cost/effectiveness and cost/utility assessment.

Results: Only 14 papers were located, which included, in the broadest sense, economic parameters. From these papers, three were systematic reviews, three were randomized controlled studies, four were controlled studies, one was a longitudinal cohort study and three papers were based on statistical modelling. Only one paper reported actual costs for periodontal and dental treatment. Extensive programmes aimed at prevention of periodontal disease in a general population group showed no economic benefit. Adjunctive genetic/and or microbiological testing likewise showed no economic benefit.

Economic assessments and real costs are not generally available in the literature. Statistical modelling suggested that non-surgical periodontal procedures are more economical compared with surgical interventions. The use of local delivery devices as an adjunct to Sc/RP showed no economic advantage.

Conclusion: It is suggested that economic parameters as well as patient-centred outcomes be included in clinical trials. These data are essential for the appropriate allocation of resources for preventive measures on an individual patient and population base.

Key words: cost–utility; cost–benefit; cost-effectiveness; economics; periodontitis; prevention

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Periodontitis prevention: Because of the limited availability of treatment modalities to affect the host response, for decades now, the classical recommendation for prevention of periodontal diseases was aimed at attacking the microbial deposits by mechanical means (Ainamo 1984).

Prevention thereby includes all means of home care, preferably also inter-dental plaque control by patients. If bleeding on probing (BOP) and/or calculus is found, bacterial deposits as well as retentive factors preventing proper home care are removed. Complex treatment of patients with advanced periodontal breakdown must be followed by regular meticulous professional cleanings. According to Ainamo (1984), mechanical oral hygiene is the method of choice in the prevention of periodontal disease.

Starting in 1989, a series of cross-sectional case–control and longitudinal studies have reported that signs of periodontal disease may be associated with cardiovascular events, while other studies have not demonstrated significant associations (Madianos et al. 2002, Janket et al. 2003). More recent reviews and reports have suggested that indeed such a link could exist, which would create a major public health issue (Persson et al. 2003, Scannapieco et al. 2003, Khader et al. 2004, Meurman et al. 2004, Paquette 2004, Shimazaki et al. 2004, Vettore 2004). Costs to treat cardiovascular disease reached approximately 352 billion dollars in 2003 in the United States. If intervention studies are able to show that the control of oral infection reduces the risk of cardiovascular diseases, then both dentists and physicians will need to pay more attention to prevention of oral infection. Anti-inflammatory and anti-infective pharmacological strategies combined with conventional mechanical concepts for high-risk patients are currently important topics of research (Saito et al. 2003, D'Aiuto et al. 2004, Joshipura et al. 2004).

A potential economic benefit from preventive periodontal measures could ultimately be expected once caregivers are provided with better diagnostic tools to identify patients at increased risk (Renvert et al. 2004).

Economic aspects: The resources available to a society for the treatment and prevention of diseases, i.e. oral/periodontal disease are limited. However, individuals value their personal health as a basic human right and therefore the unlimited demand for treatment and care can never be met.

This calls for instruments to optimize the allocation of resources for the best possible outcome. While resource allocation can be measured in material used, time spent and monetary costs, the assessment of the outcome after interventions, i.e. prophylactic measures is much more problematic. Getting transparent information on the providers' decisions is even more difficult because of the asymmetry of the information, i.e. patients have no clue whether and how they may profit from a surgical intervention to reduce pocket depths and change bone morphology around molar teeth.

The principles of a market may come into play if patients are paying out of their own pocket, if they have free access to services and if they are able to inform themselves about proposed procedures/services (personal responsibility). For most medical/dental systems, however, no free open market model can be assumed. In cases of third parties involved in financing the services, an even more complex relationship between consumer, provider and insurer will influence the use of services. Further, politicians and health care provider organizations need to base their decisions on data reflecting the cash flow as well as the value and prospect of the services rendered.

The aim of this review therefore was to determine whether there is evidence that periodontitis prevention is economically justified.

Material and Methods

A PubMed search up to and including December 2004 resulted in 654 titles with the words ''cost–benefit'' and ''dental'' and 694 titles using the words ''cost-effectiveness'' and ''dental''. In addition, the words ''economics'' and ''periodontal disease'' resulted in 414 titles. While the search using ''periodontitis prevention'' resulted in only four hits combined with ''cost–benefit'', six titles were found with ''cost-effectiveness''.

Many of the initially listed papers mentioned or discussed economic aspects; however, only the 14 actually dealing with economic parameters were included. The characteristics of economic analyses were derived from the literature on health economy. Inclusion criteria required that economic analyses be based on scientific principles including a hypothesis, valid comparative groups as well as a cost–benefit/cost-effectiveness/cost–utility assessment.

Direct costs for prevention include the costs for all periodontal services by general dentists, periodontists, hygienists, the use of drugs, mouthrinses, cleaning aids, diagnostic tests.

Indirect costs are all expenditures for the treatment of side-effects such as treatment of recessions, toothbrush abrasions. Indirect costs arise through the loss of productivity calculated on the basis of the human capital method (Linnerooth 1979, Bergstom 1982).

Intangible costs would represent a monetary validation of anxiety, pain, distress, discomfort, esthetic impairment and social handicap, which are very difficult to express in monetary terms.

Direct benefit of periodontitis prevention could be expressed with

- saving money by avoiding having to pay for treatment after the incidence of preventable damage occurred without prevention, i.e. periodontal surgery, extractions and need for prosthetic replacement of teeth lost because of periodontal disease;
- saving money by avoiding having to pay for re-treatment because of loss of abutment teeth of fixed or removable partial dentures because of progression of periodontal disease;
- having a higher chance of maintaining teeth for life;
- having less teeth with exposed roots, increased mobility, functional, phonetic and aesthetic impairment;
- the patient-centred outcomes: better cosmetics, better appearance, self-esteem, fresh breath and social advantages.

Patient-centred outcomes are unfortunately often not reported in clinical studies. Usually, surrogate endpoints such as changes in probing pocket depths (PPDs), clinical attachment levels (CALs), change in radiographic appearance and reduction in indices reflecting the degree of inflammation are thoroughly analysed in order to prove a ''benefit''.

Indirect benefits from periodontitis prevention may include the following:

- saving money from avoiding having to pay for the preventable damages from caries and endodontic problems, severe infections like abscesses and tooth extractions;
- saving money from avoiding having to pay for re-treatment because of progression of caries;
- saving money from avoiding peri-implantitis and loss of implants and
- having a reduced risk for cardiovascular events.

Intangible benefit would be reflected by the increased quality of life, enjoyable with a healthy dentition and no anxiety, pain, discomfort and distress or from undergoing interventions – hospitalization in the extreme case, which again is problematic to calculate in Dollars or Euros.

Discount

Economic view

Costs and benefits activated in the future need to be considered in a different way than immediately effective consequences. Therefore, future costs and benefits need to be discounted to represent the present equivalent (Parsonage 1992, Krahn 1993) (see Appendix 1).

Cost–benefit analysis (Szucs 1997)

A cost–benefit analysis weighs all costs against all consequences of an intervention in monetary units (Fig. 1). The disadvantage of cost–benefit analyses is that a validation in monetary units of the clinical outcome has to be presented, i.e. the monetary value of a surviving tooth and or reconstruction or the money saved by avoiding therapy.

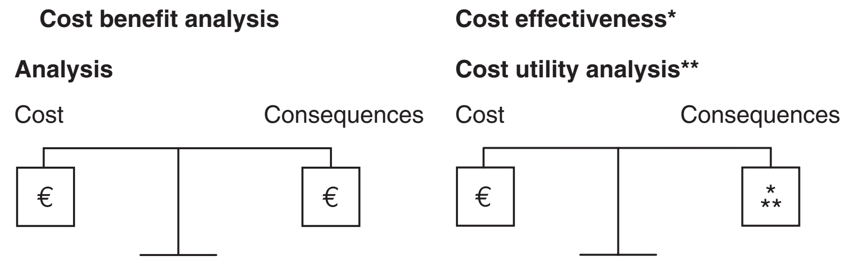

Fig. 1. Economic analyses, with input and output. *Change in clinical parameters or survival, years of life, number of retained teeth or **quality adjusted life years of teeth/dentition/ reconstruction.

Cost-effectiveness analyses (Szucs 1997)

This type of economic evaluation balances costs in monetary units against the outcome presented in non-monetary units, i.e. change in clinical parameters, survival, prevented surgical interventions and reduction of tooth mortality (Fig. 1). It is important to clearly separate the term *efficacy*, defined as the probability of a service being beneficial to patients provided under ideal conditions, from the term *effectiveness*, which concerns the care provided to the general population under conditions usually found in practice (Banta et al. 1981, Roper et al. 1988, Marcus & Spolsky 1998). A disadvantage of cost-effectiveness analyses is that only interventions with the same clinical endpoint can be compared. In reality, however, the clinical outcome may vary considerably (survival of a tooth with/ without recession, mobility, sensitivity, aesthetic impairment, etc.)

Cost–utility analysis (Szucs, 1997)

This type of economic analysis weighs monetary costs against consequences represented in a respective utility unit, i.e. quality-adjusted tooth years (QUATY) (adopted from quality-adjusted years of life) (Antczak-Bouckoms & Weinstein 1987). Utilities represent how much a tooth, dentition and patient profits from a service rendered. Utility values range from 0 (death, loss) to 1 (healthy). For general health problems, rating scales were developed scoring for the degree of disability, the grade of distress and the utility value (Rosser & Kind 1978); such tools were also developed for teeth.

Once utilities are defined, the number of years in a certain health condition can be compared with the number of years in another condition. Clinical endpoints with different quality can thus be related to monetary costs involved in reaching the respective condition. Cost–utility analyses allow to ''prioritize'' the allocation of resources, i.e. for prevention.

The disadvantage of cost–utility analyses is that validated utility values do not exist for all clinical endpoints. Therefore, in some studies, utility values were constructed empirically sometimes on weak evidence (based on consensus) (Marcus et al. 1983, Antczak-Bouckoms & Weinstein 1987).

If the quality of life (i.e. comfort with a certain periodontal condition) is the main outcome, or if the intervention influences morbidity as well as mortality, cost–utility analyses may be recommended. With such analyses, comparisons between new data and older studies are also feasible.

Results

From the 14 papers meeting the criteria of an economic evaluation, three were systematic reviews (Allen et al. 2000, Niederman et al. 2002, Davenport et al. 2003), five were based on randomized-controlled studies (De Lissovoy et al. 1999, Frenkel et al. 2001, Henke et al. 2001, Wennström et al. 2001, Hugoson et al. 2003), two were controlled studies (Killoy et al. 1993, Ide et al. 2001), one was a longitudinal cohort study (Brown 1975) and three papers proposed calculation models (Antczak-Bouckoms & Weinstein 1987, Sintonen & Tuominen 1989, Higashi et al. 2002).

Cost–benefit

The only study suitable as an example of a cost–benefit analysis was a systematic review by Allen et al. (2000). These authors evaluated clinical trials from 1980 to 1998, related to the effect of hormone replacement therapy (HRT) on dental outcomes in postmenopausal women. Having started out with 1518 citations according to a search protocol, the authors ended up with 20 studies reporting on 13,735 postmenopausal women. The information extracted from the trials included study parameters, patient parameters and parameters related to HRT.

From the 20 studies included in the economic analysis, there were no randomized-controlled trials, four were large longitudinal studies, three were non-randomized controlled studies, two were case–control studies and eleven were uncontrolled studies.

Tooth loss and the rate of partial or full dentures observed in the different groups were used to estimate an economic effect (DerSimonian & Laird 1986).

For postmenopausal women not involved in any HRT, 41% (95% CI 14–68%) more individuals presented full or partial dentures (Table 1). Women on HRT presented on average five more teeth (95% CI, 0–12 teeth). The overall additional costs for extraction and prosthetic treatment were estimated for 1000 women not on HRT over a 5-year period. The low- and high-end estimates were based on the range of averaged dental charges in 1998 dollars, which were set at $60–200 for a tooth extraction and $500–2200 for prostheses (Allen et al. 2000). The mean values were averages of the high- and low-range charges.

When annualizing the excess costs in the non-HRT group, an estimated difference ranging from $14,000 (low estimate), and $100,000 (average) to

Table 1. Number of studies, the number of patients, the mean age of individuals, percentage number of individuals with dentures/partial dentures, the mean number of remaining teeth in women with or without HRT or osteoporosis (Table adapted from Allen et al. 2000)

	Studies (*N*)	Patients (*N*)	Age (Mean ± SD)	Dentures* (%)	Remaining teeth*
All women	10	5,757	66.5 ± 10.3	46.8% ± 43.8%	19.6 ± 8.2
HRT	4	2,881	69.0 ± 13.3	27.4% ± 27.8%	21.7 ± 7.1
No HRT	8	2,073	69.4 ± 9.0	68.5% ± 42.7%	16.1 ± 6.8
OP	3	203	68.4 ± 3.2	73.1% ± 68.3%	4.8 ± 9.7
No OP	3	112	67.6 ± 4.0	69.2% ± 78.2%	6.4 ± 10.1

*Random effect model with 95% confidence interval.
N, number; SD, standard deviation; HRT, hormone replacement therapy; OP, osteoporosis.

300,000 (high estimate) per thousand women was calculated.

Cost-effectiveness studies

A critical issue for the calculation and presentation of cost-effectiveness analysis is the definition of the respective outcome, i.e. success criteria. Lundgren et al. (2001) calculated the success rates 3 years after periodontal treatment of 36 patients with moderate to advanced periodontal disease as related to different clinical and radiographic criteria.

The evaluation criteria staircase comprised five different levels (See Appendix 2). At the final examination, after 30 months of supportive periodontal care, only 52.1% of the sites and 15.8% of the individuals exhibited perfect health, reaching level 1. Successful treatment increased to 65.5%/34.2% accepting level 2, 73.2%/39.5% with level 3 and 83.1%/55.3% with level 4. By applying the criteria ''no further bone loss'' as assessed in bitewing radiographs, 95.1% of the sites and 86.8% of the individuals were categorized as successfully treated and maintained (with level 5).

Local delivery devices

Reducing the number of ''necessary'' surgical interventions to reach a periodontal condition controllable by means of supportive periodontal care reflects a parameter that is not only of economic importance but also a patient-centred outcome.

Clinical trials demonstrated that a sustained-release system for local delivery of chlorhexidine (CHX) (Perio Chip, Perio Products, Ltd., Jerusalem, Israel) inserted into sites with PPD $\geqslant 5$ mm was effective in reducing PPD and maintaining CALs (Soskolne et al. 1997, Jeffcoat et al. 1998). From two 9 month clinical trials, the economic impact of the use of CHX chips in the periodontal therapy of patients randomly assigned either to the Sc/Rpl group or the group exposed to Sc/Rpl in combination with CHX application was estimated (De Lissovoy et al. 1999). On the basis of the remaining pocket depth and presence or absence of BOP, scenarios were constructed to assign additional supportive care, additional Sc/Rpl and periodontal surgery to test and control patients as decided by two of the authors. Fewer maintenance procedures and periodontal surgical interventions were planned for patients treated with Sc/Rpl and CHX compared with Sc/Rpl alone (54.4% *versus* 46.4% and 29.2% *versus* 35.5%). The average total costs for patients with Sc/Rpl and CHX were \$737 $\pm$ 244 compared with \$734 $\pm$ 235 for the Sc/Rpl group. The adjunctive use of the CHX chip was proposed to reduce the need for periodontal surgery at little or no additional costs.

Using a different study design of a somewhat longer duration, these results favouring the additional use of CHX chips were questioned (Henke et al. 2001). Four hundred and eighty-four patients with chronic periodontitis were treated in 52 general practices across the United States. Initial therapy and maintenance procedures included Sc/Rpl alone or Sc/Rpl with additional use of CHX chips. Economic data were retrieved from bills, case reports and from the 12-month recommendations from blinded periodontists. The total cost for services over 12 months was higher in the CHX group (\$175 per patient). The likelihood to undergo surgery during the first few months was reduced by about 50% in the CHX group. On a per-patient bases, only \$17 $\pm$ 8 were spent for surgery in the CHX group, while in the Sc/Rpl group, \$46 $\pm$ 8 were spent over 12 months. The periodontal parameters assessed at 12 months were the basis for two blinded periodontists to indicate treatment recommendations for each patient. The total charges for services recommended amounted to \$2097 in the Sc/Rpl group and to \$2119 in the Sc/Rpl plus CHX group.

In this study, the adjunctive use of CHX chips was not of economic or quality-of-life benefit (15.5% of Sc/Rpl patients and 9.2% of CHX patients underwent surgery in the first year, and in 55.9% of Sc/Rpl patients and in 62.9% of CHX patients additional surgery was recommended after 1 year).

One systematic review (Niederman et al. 2002) extracted data on the efficacy of local antimicrobial drug delivery systems for the treatment of periodontal disease. As an outcome parameter, the number of teeth needed to treat (NNT) to achieve an additional site with a PPD reduction of $\geqslant 2$ mm was chosen.

In addition, the cost-effectiveness was assessed:

$$\text{cost-effectiveness} = (\text{estimated product cost} + \text{care cost}) \times \text{NNT}$$

The authors decided to examine only the data derived from products used in FDA pivotal studies in which NNT was articulated. A 2 mm and more change in PPD was used as a statistically and clinically significant change.

For the cost-effectiveness analysis, the costs involved for the agents, costs for wasting, costs for number of drug placements, costs for scaling and root planing and costs associated for clinician time were considered. The treatment costs for two local delivery systems for treatment of a single tooth and a complete quadrant are listed in Table 2.

Based on the listed treatment costs, the cost-effectiveness was calculated representing the cost over and above regular Sc/Rpl in order to achieve one additional pocket reduced by $\geqslant 2$ mm (Table 3).

To treat a single tooth with system A cost \$99. Because of the better efficacy, the cost-effectiveness was calculated to reach \$495. This was three to four times more cost-effective compared with system B (\$2016 spent to achieve one more benefit).

When a quadrant was treated as an additional procedure with system A, cost-effectiveness reached approximately \$200 per tooth, whereas with system B, about \$320 per tooth had to be spent in order to reach one more benefit.

Wennström et al. (2001) compared the clinical outcome of Sc/Rpl with a simplified subgingival instrumentation combined with local drug delivery in deep periodontal sites. The clinical outcomes at 6 months were similar. Some potential cost savings were suggested by the fact that the total treatment time for the simplified method plus the local delivery device was 2:00 hours per patient compared with 3 h and 11 min. for the Sc/Rpl group.

Adjunctive diagnostic tests

As mentioned before, allocation of resources to perform periodontitis pre-

$$\text{NNT*} = \frac{1}{\%\,\text{experimental sites changing} \geqslant 2\,\text{mm} - \%\,\text{control sites changing} \geqslant 2\,\text{mm}}$$

*NNT=number of teeth needed to treat

Table 2. Estimated costs to treat one tooth separately or within a procedure treating one entire quadrant using two different local drug delivery devices

Product	Cost/unit purchase*	Teeth treated/unit	Treatment visits required	Non treatment visits	Placement time (min./tooth)	Total set-up cost†
Assumptions						
A	$24	2	1	1	15	$50
B	$12	1	3	0	3	$75

Product	Used product cost	Waste product cost	Placement cost†	Cost/tooth	As an add-on‡
Treatment of one tooth					
A	$12	$12	$25	$99	$49
B	$36	$0	$15	$126	$51
Product	**Used product cost**	**Waste product cost**	**Placement cost**	**Cost/tooth**	**As an add-on§**
Treatment of one quadrant‡					
A	$84	$12	$175	$46	$39
B	$36	$0	$105	$31	$20

Calculations also considered the cost savings by applying the devices in combination with another dental procedure
(Table adapted from Niederman et al. 2002).
*Assumptions: A at $24 per fibre, two teeth per fibre, $12 per tooth, 15 min. for placement per tooth, one treatment and one removal visit.
B at $12 per cartridge, one tooth per cartridge, $12 per tooth, 1 min. per placement per tooth, three treatment visits.
†Assumptions: Set-up cost = $25 per visit (treatment or non-treatment). Chair time = $100 per h × (placement time per tooth/60 min.).
‡Assumptions: One quadrant = seven teeth (treatment cost – $200/quadrant = 29/tooth).
§Assumptions: When used as an additional or add-on procedure, set-up costs have been covered by the first procedure.

Table 3. Cost-effectiveness of two different local drug delivery devices
(Table adapted from Niederman et al. 2002)

Product	Total cost ($)/tooth	NNT	Cost-effectiveness ($)
To treat one tooth			
A	99	5	99 × 5 = 495
B	126	16	126 × 16 = 2016
Cost/tooth when treating one quadrant as an additional procedure			
A	39	5	39 × 5 = 195
B	20	16	20 × 16 = 320

Cost, over and above SRP, to have one additional pocket reduced by ⩾2 mm.
NNT, number needed to treat; SRP, scaling and root planing.

vention would be optimized if diagnostic information would assist in locating susceptible patients. Higashi et al. (2002) applied a disease simulation model using decision analytic techniques over a 30-year time frame.

Genetic testing for interleukin-I (IL-I) genotype was to be assessed for its cost-effectiveness. The model started out with a decision tree to perform the test.

The model also incorporated the genotype status, smoking status, compliance with treatment recommendations and compliance with smoking cessation. The test result could be IL-I (+) or IL-I (–). The test's accuracy was incorporated by using positive and negative predictive parameters. Based on the test result, patients could have different rates of smoking cessation compliance and different treatment compliance rates compared with a no-test strategy. The effectiveness could also be different. It was assumed that the knowledge of the genotype could influence treatment decisions as well as maintenance procedures.

Eight sub-cohorts were followed using a Markov model (Sonnenberg & Beck 1993) to measure the varying cost and quality-adjusted life years. The hypothetical patient population represented Caucasian male and female patients at age 35, who were referred to a periodontist with a diagnosis of mild periodontitis.

The likelihood of events was retrieved from the literature, from an insurance and as a modelling assumption.

The Markov model for disease progression included the probabilities for moving between the different disease states. A background mortality rate was considered as well. Costs for periodontal treatment were provided by the Washington Dental Services. Costs for the genetic test were set at $218. All costs were discounted at a rate of 3%. Using different modelling scenarios, the genetic test produced results ranging from cost savings of $830,140 and 52.8 fewer cases of severe periodontitis, to increased costs of $300,430 and 3.6 additional severe periodontitis cases (per 1000 patients). The authors discussed that mainly three parameters, the compliance rate for maintenance therapy in test-positive *versus* non-tested patients, the effectiveness of non-surgical therapy and the relative risk of disease progression for test-positive patients, were influencing the results. The results suggested that using a periodontal susceptibility test as a tool to motivate high-risk patients for better compliance may result in savings because of the prevention of severe cases. The costs for testing 1000 patients, however, would be considerable. Therefore, it seems to be unlikely that enough cases could be presented to justify the costs for testing.

The authors stated that as long as there exist no separate prevention/treatment strategies for high- and low-risk periodontal patients, an obvious cost–benefit advantage of identifying ''susceptibility'' cannot be expected.

From a marketing point of view, the advocation of monitoring periodontal pathogen levels ''for providing optimal care for all periodontitis patients'' in general may be desirable (van Arsdell et al. 1996). However, after having evaluated the available literature on this issue, Listgarten and Loomer (2003) found that microbiological monitoring may be useful only in the management of selected patients who do not respond to standard therapy. They also concluded that although there is a lack of strong evidence, some practitioners considered microbial identification a valuable adjunct to managing patients with certain forms of periodontitis.

When double samples from 23 patients were sent to two independent laboratories for bacterial identification and antibiotic sensitivity testing, rather different results were obtained (Mellado et al. 2001). Agreement for bacterial identification was only found in nine out of the 23 patients. For antibiotic sensitivity (100% kill of all pathogens), the agreement between the laboratories was poor. Agreement for recommendation of amoxicillin was 17% of the time, for tetracycline 20% of the time and metronidazol 48% of the time.

Technical limitations while sampling as well as different standards in laboratories might even question the use of microbiological testing as clinically sound and cost-effective.

Cost–utility analysis

Antczak-Bouckoms & Weinstein (1987) were pioneers in introducing economic principles to periodontology. Cost-effectiveness, decision and utility analyses were applied as tools to estimate the economics of periodontal disease control.

For the cost-effectiveness model, the formula by Weinstein and Statson (1977) was used (see Appendix 3).

Only direct costs for periodontal treatment and drugs were considered in the model (American Dental Association survey of charges for periodontal services).

Treatment alternatives considered were as follows:

(1) no specific periodontal treatment, which includes twice-yearly prophylaxis without subgingival cleaning;
(2) non-surgical treatment, which includes scaling and root planing of all four quadrants of the mouth;
(3) surgical treatment, such as the modified Widman flap or pocket elimination surgery without osseous recontouring;
(4) surgical treatment with osseous recontouring; and
(5) antimicrobial therapy (tetracycline or metronidazole) with a non-surgical scaling and root planing phase.

These treatments were applied to hypothetical patients 45 years of age, with good general health, with an average of 25 teeth and moderate to advance periodontitis with pockets varying from 3 to 10 mm and attachment loss from 0 to 12 mm.

The effectiveness of the various periodontal treatments was estimated from change in CAL and PPD from randomized control trials available at the time, and expert periodontists provided subjective probability estimates for tooth loss and the incidence of side-effects for the various different treatment alternatives.

The ultimate outcome in this analysis was tooth loss. For the utility analysis, the term QUATY was adopted from quality-adjusted life years (Pliskin et al. 1980, Weinstein et al. 1980, McNeil & Pauker 1982).

For each treatment option, the expected number of tooth years for each treatment option was estimated from the expert questionnaire. Each year of tooth survival was then related to the decrease in quality resulting from the side-effects of treatment.

Patients seeking routine dental care were interviewed to obtain estimates of the relative value of teeth with the treatment side-effects of sensitivity and poor aesthetics, the relative value of posterior *versus* anterior teeth and a discount rate for future tooth years (see Appendix 4).

By estimating lifetime treatment costs based on a 30-year life expectancy for non-surgical and surgical interventions, with and without the use of antibiotics, and estimating the incremental costs compared with no periodontal therapy or compared with the next treatment category of lower complexity, the authors calculated cost-effectiveness ratios whenever a treatment option offered an increased expected QUATY over no treatment or the next less treatment category. For non-surgical periodontal therapy, cost-effectiveness ratios could be calculated for most clinical situations except for teeth with shallow pockets.

These ratios ranged between $12.31/QUATY for teeth with PPD 4–6 mm and $\geqslant 10$ mm clinical attachment loss (CAL) and $400/QUATY for teeth with PPD $\leqslant 3$ mm and no CAL if treatment was performed in the general practice. For a specialist, the costs per gained QUATY ranged from $19.58 to $636.50.

Improved standard of living, better personal hygiene, knowledge about dietary risks and the use of toothpaste containing fluorides are probably the most cost-effective preventive means for oral diseases. All these measures are at no cost for the public.

Manufacturers of oral hygiene products are continuously developing new devices for home care procedures. A recent systematic review (Forrest & Miller 2004) concluded that some electric toothbrushes removed plaque deposits more efficiently compared with manual toothbrushes. The paper, however, also ended with a remark for better quality of study designs.

In an economic evaluation (Killoy et al. 1993), a group of patients using electric toothbrushes achieved better clinical periodontal conditions compared with the patients instructed in the use of manual toothbrushes. An experienced clinical investigator examined the patients at baseline and up to 18 months.

Treatment costs planned, already provided and still required were calculated and compared. Additional surgical procedures were mainly assigned based on remaining PPD >5 mm still BOP.

The authors found a better cost-effectiveness for those patients using the electric toothbrush – the cost saving reaching 546 US$ at 18 months. That particular study design is, however, difficult to repeat. At baseline, the planned treatment needs were higher for the control group ($1712) compared with the test group ($1544). Costs for actually provided therapy were not statistically significantly different in the two groups. Only 16 test and 13 control patients completed the study at 18 months.

Preventive Programmes

Davenport et al. (2003) were undertaking a systematic review to gain support for the clinical effectiveness and cost-effectiveness of 6-monthly dental checks, which were customary in the General Dental Service in the UK. Specifically, the authors wanted to know the cost-effectiveness of routine dental checks of different recall frequencies in improving quality of life, reducing the morbidity associated with dental caries and periodontal disease in children. For adults, the search also included the aspect of reducing the mortality associated with oral cancer.

The authors concluded that there was little evidence to support or refute the practice of six-monthly dental checks in adults and children. There were enough data in the literature for decision analysis modelling the cost-effectiveness of different dental check recall frequencies on the experience of caries in deciduous and permanent teeth. Moving from 6- to 12-month intervals would increase caries experience, but would at the same time be more cost effective. Because of the lack of epidemiologic data, it was not possible for the authors to model the impact of different recall frequencies on the periodontal condition. The same applied for the morbidity and mortality with oral cancer.

Periodontal and caries prophylaxes are difficult to separate since improved oral hygiene measures will have an effect on both diseases. Also, for prophylactic measures, health authorities should balance the benefit of an additional prophylactic service to an individual or a population against the costs that this intervention would create.

In 1971, in the district of Värmland, Sweden, a team around Per Axelsson started prospective preventive programmes including 555 individuals (Axelsson & Lindhe 1978, 1981). About two-thirds were assigned to the test group and one-third to the control group. After initial periodontal therapy and restorative treatment, the control patients received maintenance procedures every second and later every third month.

When the preventive programme according to the Karlstad model had reached the first 6 years, 375 individuals had developed only 75 new DF-s (0.2 DF-s per individual), while 180 individuals assigned to the test group (conventional dental checkups) had, on average, developed 14 new DFs, resulting in 2520 tooth surfaces to be treated and filled (Axelsson & Lindhe 1981). The control group had lost 1.3 mm of clinical attachment, whereas, in the test group, the periodontal tissue levels remained stable.

Total costs arising from all prophylactic services and dental fees to treat lesions amounted to $\sim$150 Marks in the test group compared with $\sim$300 Marks per year in the control group of observation (Axelsson 1985).

The effect of different dental health programmes for prophylaxis of oral diseases was tested in 400 Swedish individuals of age 20–27 years (Hugoson et al. 2003). The individuals were sent a written invitation to participate free of charge in a dental examination and were contacted by phone. The individuals were not supposed to move from the area within the next 5 years.

After a baseline examination, subjects were randomly assigned into four groups.

Group 1 represented the control group with no organized prophylactic measures for caries or gingivitis/periodontitis. They received traditional dental care.

Group 2, the Karlstad Model group, received prophylactic care every second month (six times/year) according to the Karlstad model for adult individuals (Axelsson & Lindhe 1978).

Group 3, the basic programme – individual:

In this group, each individual underwent an individual basic programme according to the National Swedish Board of Health and Welfare dental health programmes for adults (Nyman et al. 1984).

Group 4, the basic programme – group:

The individuals in this group underwent the remedial measures recommended by the National Swedish board of Health and Welfare for dental health programmes for adults (Nyman et al. 1984) and modified for group-based basic prophylaxis with three visits that had essentially the same content as the programme followed by group 3.

Knowledge about preventive measures as well as behaviour related to inter-proximal cleaning had significantly improved. At baseline, about 50% of the individuals cleaned interproximallly compared with 90% at the end of a 3-year period. There were significant differences compared with the control group but not within the test groups. The structured prophylactic programme had a long-lasting effect over five and ten years for the knowledge aspect; however, behaviour (inter-proximal cleaning) receded from 90% to about 60% of the test individuals, while in the control group, some more individuals started to clean inter-proximally ($\sim$60%).

The personnel time and indirect costs arising from the patient time involved were calculated (Table 4). By defining a monetary value per minute spent, an actual cost analysis would be possible. It is obvious that one of the test programmes (the Karlstad model) was the least cost-effective compared with the other two prophylactic programmes. Direct costs were least for the group-based programme while indirect costs were least in the individual basic programme.

Oral health conditions of institutionalized elderly people are very poor, with restrictions related to the individual as well as the team of care givers. Frenkel et al. (2001) designed a randomized-controlled trial to test whether oral health care estimation (OHCE) for nursing home caregivers would achieve improvements in clients' oral health.

Twenty-two nursing homes were randomly assigned to the OHCE group or a control group. The outcomes assessed at baseline, one and six months were denture plaque, denture-induced stomatitis, dental plaque and gingivitis. The conditions at baseline were very poor but the OHCE intervention resulted in a significant improvement of the scores. In order to achieve this effect in 100 homes, the Health Care Authorities would have to spend an additional £6700 per year per institution.

When handicapped children were referred to a specialist and involved in a preventive programme, not only was dental caries effectively reduced, but also the oral cleanliness and the degree of gingivitis improved (Brown 1975). The costs for initial treatment per child were calculated to be 43.05 Aus$ for children <7 years, 75.85 Aus$ at age 7–11 years and 103.75 Aus$ for kids <11 years. Recall visits and cost for treatment per year were then drastically

Table 4. Direct costs/indirect costs

Group	1	2	3	4
Year 1	0/0	130/130	65/65	10.5/105
Year 2	0/0	130/130	30/30	5/50
Year 3	0/0	130/130	30/30	5/50
All 3 years	0/0	390/390	125/125	20.5/205

Personnel costs (min.)/Patient time (min.) per individual and year during years 1, 2 and 3. (Adapted from Hugoson et al. 2003).

reduced to 19.13 Aus$, 27.77 Aus$, respectively. The ratio of maintaining/preventing *versus* restoring dental health of newly referred kids was 1.0:1.25 <7 years, 1.0:1.73 at 7–11 years and 1:3.16 for children above 11 years.

The workplace could be regarded as an important provider of prophylactic services (Ide et al. 2001). At a Japanese ship yard, an oral health promotion programme was established in 1989. In fact, the periodontal conditions of the participants improved (Ide et al. 1997). The annual dental care costs and the annual dental visits of the 87 participants were compared with a control group of 261 individuals. While during the first year the participants of the prophylactic programme consumed more dental services compared with the test group (¥26,642 compared with ¥19,481 and 4.1 visits compared with 3.4 visits per individual), already after the third year, a mean reduction of the mean annual dental care costs per person from ¥21,920 to ¥16,911 was observed. Fewer dental visits were also needed in the participants (2.7) compared with 3.3 in the controls.

Cost-effectiveness of smoking cessation

Periodontal disease development and costs for treatment needs were modelled and tested on about 8000 Finnish individuals aged >30 years (Sintonen & Tuominen 1989). Theoretical modelling was based on the health production theory (Grossman 1972). Eight endogenous variables (number of teeth, PD, caries, visiting a dentist repeatedly, brushing, toothpicking, flossing, smoking) and three exogenous variables (education, income and age) would interact and determine the periodontal treatment costs.

The actual dental and periodontal conditions were clinically scored and the treatment needs were calculated based on the findings. For gingivitis cases, 10 min. were allocated for oral hygiene education and motivation, and 45 min./quadrant of scaling and 50 min. of oral hygiene instruction were required.

Patients with shallow pockets required 45 min./quadrant of scaling and 50 min. of oral hygiene instruction.

Patients with deep pockets were allocated 45 min./quadrant of deep scaling, 60 min. for surgery per quadrant, time for postoperative care of 30 min. and oral hygiene instruction of 50 min.

The examined individuals were questioned about all the factors related to endogenous and exogenous variables used in the model. Of particular interest was the smoking aspect.

Estimated costs for periodontal disease treatment amounted to 897.50 Finnish Marks per male and 641.43 per female.

Vector/matrix calculations revealed that the needed costs for periodontal treatment were explained with 48% (male) and 41% (female) by the endogeneous and exogeneous variables.

It was, however, evident that the variable smoking was positively associated with costs for periodontal treatment. Even a dose response could be calculated. In fact, a 10% increase of the number of cigarettes smoked per day increased the cost by 0.7% for males and 0.4% for females.

This very interesting model, which has not been tested so far in other populations, suggested that by systematically adding smoking cessation to the concept of periodontitis prevention, cost savings could be achieved.

Discussion

In 1995, Hujoel surveyed the selected designs and analysis characteristics of randomized-controlled periodontal trials published between 1988 and 1992. Eighty-six studies were located, all of which were explanatory in nature, i.e. the primary goal was to point out biological treatment mechanisms. The author listed several disadvantages of the study designs chosen, such as testing of multiple hypotheses, small sample size and short duration. To put it bluntly, bias is often accepted to obtain quick answers at low cost.

The goal of definitive studies would be to provide unequivocal evidence of a treatment's tangible benefit to the patient. Obviously, there existed many obstacles for the periodontal research community to perform such studies, since many of the RCTs on periodontal topics published from 1996 to 1998 did not fully meet recommended standards as, for example, proposed by the CONSORT guidelines (Montenegro et al. 2002).

The different characteristics of clinical studies and economic studies are listed in Table 5.

The qualitatively best RCT will be focused on proving efficacy, while only economic studies will finally be able to conclude whether new drugs/new intervention/new techniques are truly beneficial for the society, i.e. to validate their effectiveness.

From the sparse amount of papers published on economic issues, it seems obvious that the performance of effectiveness studies is even more demanding. Economic studies must require strict standards in order to allow drawing conclusions on a sound basis. False-positive and/or false-negative outcomes would have a much more severe effect on the society than the false outcomes of one particular RCT.

A search of the literature by the end of 2004 related to economic evaluations of periodontal prevention in the broadest sense located few studies that have actually addressed and actually used monetary parameters.

One cost–benefit analysis (Allen et al. 2000) indicated that patients on HRT were observed to have maintained more teeth with less need for extractions and prosthetic replacement of missing teeth. On the basis of 1000 women on HRT over ~5 years, a considerable amount of money could be saved by avoiding extractions and prosthetic replacement of missing teeth. The direct evidence that by advocating HRT, periodontal disease progression is arrested, however, could not be derived from that review. Recent papers have also expressed severe concerns related

Table 5. Characteristics of clinical and economic studies (Table adapted from Szucs 1997)

	Clinical study (efficacy)	Economic studies (effectiveness)
Aim	Approval of a product (i.e. FDA)	Clinical guidelines, standards
Comparison	Placebo/active substance	Old procedure/new procedure
Result	Well-defined	Broad
Outcome	Narrow, surrogate endpoints	Final, tangible outcome
Research, Concept design	Maximize internal validity	Maximize external validity
Sample size	Smaller	Larger
Observation time	Relatively short	Long term
Perspectives	Narrow	Wide
Inclusion criteria	Strict, limited	Reality in practice

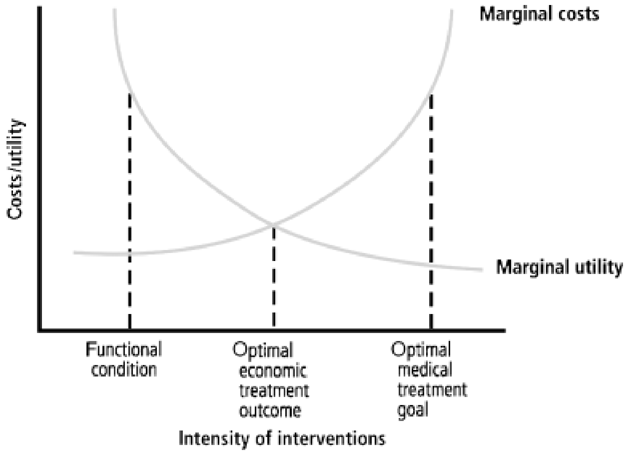

Fig. 2. Balance between marginal costs and marginal utility.

to HRT leading to a higher risk of breast cancer (Bakken et al. 2004).

The superior cost-effectiveness of non-surgical therapy compared with surgical periodontal interventions with or without bone surgery to control most of the periodontal conditions was reported in Antczak-Bouckoms & Weinstein (1987). Modelling the scenarios, however, was based on a limited number of RCTs as well as expert opinions. Based on current information, the cost-effectiveness of the use of systemic antibiotics as an adjunct to Sc/Rpl would need a thorough revision.

Decision making and risk assessment in periodontal care might be influenced by additional diagnostic information gained through microbiological and/or genetic testing. No economic study so far could demonstrate a clear long-lasting advantage of using adjunctive diagnostic tests for the patients.

Higashi and Veenstra (2003) stated that recent technological progress in the genomic area has led to the rapid marketing of genetic tests – no or few long-term data, however, support, their use. The authors screened the literature for disease-risk genetic tests and found three tests, hereditary nonpolyposis colorectal cancer for colon cancer, IL-I for periodontal disease, B Rr CA 1/2 for breast cancer, and they added two pharmacogenomic tests from a prior analyses: Cy P 2 C9 for warfarine therapy and thiopurine S-methyl transferase for 6-mercapto purine therapy. The authors identified five key criteria which would assist in calculating the cost-effectiveness. According to the authors, cost-savings and cost-effectiveness can be assessed if data demonstrate the following:

1. an association between the variant group and an elevated risk of an event occurring;
2. the prevalence of the variant gene in the treated population;
3. the role of the clinical event in the treated population; and
4. an intervention that can reduce the rate in the variant group, i.e. sensitive and specific tests with rapid results exist.

For the example of 100 patients treated for one year with the anti-coagulant warfarine, a cost-effectiveness analysis was proposed. Patients with a Cy P 2 C9 gene, who have a 2.54 times higher risk of bleeding compared with patients without the variant gene, could be detected by the test, and, therefore, treatment could be adapted. This may include a lower initial dose, increased surveillance for bleeding risk factors, etc. If these adaptations would reduce the risk of the variant group to the same risk as the normal genotype group (bleeding rate in the variant group (13.3%) reduced to the 5.7% observed in the normal group).

The NNT = 1/0.076 = 13 would indicate that 13 patients from the variant group need to be managed in order to prevent one bleeding event. The number needed to screen NNS = NNT; prevalence of the variant genotype = 13:0.3 = 44 could also be estimated. If the authors assessed costs for the test at \$135, the total screening cost to prevent one adverse event would cost \$135 × 44 = \$5940.

In addition to these costs for testing, a formal cost-effectiveness study would require the calculations of costs arising from additional counselling and increased surveillance.

This example, however, demonstrates that by using the test in these cases, expensive days of hospitalization may be prevented.

The authors concluded that manufacturers of tests need to produce data that allow the calculation of cost-effectiveness studies in order to market reasonable, safe and economic tools (Higashi & Veenstra 2003).

For preventive programmes, usually offered for children and young adults, it is not possible to clearly differentiate between the periodontitis- and the caries-affecting input and output. For adults, it would also be of interest to define how much is spent purely for cosmetics and for comfort.

Young Swedish adults followed, over 10 years, relatively intensive additional time-consuming prophylactic programmes (Hugoson et al. 2003). At the end of the study this did not result in a clear difference in behaviour compared with individuals seeking traditional dental care. The data reporting on the actual clinical conditions and costs spent for fillings, scaling, etc., are not yet published. Cost-effectiveness and cost–benefit analyses, however, seemed to indicate some advantage for elderly institutionalized individuals as well as handicapped patients (Brown 1975, Frenkel et al. 2001). Cost-savings were, however, mainly because of reduction of the progression of caries lesions.

These two extremes indicate that allocation of resources is mainly cost-effective and cost-beneficial in cohorts with poor oral health conditions and with poor or even non-existent home care procedures (Hujoel et al. 1997, O'Reilly 2003). The better the personal hygiene standard and the healthier the lifestyle of a group of individuals, the less economic additional preventive measures are from a public health point of view (Fig. 2).

In Fig. 2, the balance between marginal costs and marginal utility is depicted according to Oberender (1990). With a reasonable increase in the intensity of interventions, a relatively significant improvement in the functionality of a patient/dentition/tooth can be achieved. The optimal balance between prophylactic input and effectiveness is reached at the intersection of the two functions. The utility of a tooth can, however, only marginally be improved when the ultimate medical treatment goal is achieved by applying the latest marginally effective intervention (Tonetti et al. 2004).

Fejerskov (1995) claimed that care by providers cannot prevent caries owing to the nature of disease – a dynamic process that occurs in all individuals, where a tooth site is covered by dental plaque for a certain period of time. Strategies to control dental caries could, however, drastically reduce the prevalence and severity of its manifestation in the younger age group. Once caries is clinically manifest, lesions could be arrested and progression of decay could be controlled (Nyvad & Fejerskov 1986).

Since a general decline in caries experience in populations with or without caries prevention programmes was seen, fluoridation programmes on a whole population have no longer become cost-effective (Heidmann et al. 1992). Prevention of oral diseases based on a whole population strategy would have advantages. For attempts to alter social norms and knowledge by making individuals aware of their own responsibility to maintain oral health by the use of fluoridated toothpastes and by considering diet and nutrition factors, especially in developing countries, allocation of resources would be cost-effective.

The cumulative frequency distributions of both caries experience as well as periodontal attachment loss are skewed in each age cohort. A high-risk strategy would concentrate more input for the life-long monitoring of this portion of the population with more lesions, which are ideally identified by one or a combination of tests.

Still, even if such test results were predictive, it would be crucial to motivate affected individuals to comply. Social and economic circumstances may still question a favourable cost–benefit ratio.

Periodontitis prevention seems to be of even greater importance if patients (third parties) had invested in expensive reconstructions on teeth or implants (Morhart et al. 1986). Karlsson et al. (1995) reported on the added up dental care costs of partially edentulous patients with advanced periodontal disease. Thirty-seven out of 45 patients who had been restored with maxillary FPDs (12 ± 2 units on 7 ± 2 abutment teeth) and/or mandibular FPDs (10 ± 1 units, 5 ± 1 abutment teeth) could be re-examined 7–10 years thereafter.

The added-up costs for the treatments were listed for six patients with mandibular (35,550 ± 1950 SEK), for 25 patients with maxillary (45,380 ± 11,390 SEK) and for six patients with both upper and lower FPDs (74,230 ± 8100 SEK).

From the total costs, only 6–4% were used for non-surgical and 8–10% for surgical periodontal services.

Due to ethical reasons, there exists, however, no study design assessing the long-term outcome and financial consequences without tertiary prevention in periodontitis patients with extensive reconstructions.

Summary

- An economic benefit from intensive programmes aimed at prevention of periodontal disease in a general population group could not be found.
- An economic advantage from the use of adjunctive genetic/and or microbiological testing for managing periodontal disease could not be demonstrated.
- Statistical modelling suggests that non-surgical periodontal procedures are more economical compared with surgical interventions to ''control'' periodontal disease.
- An economic advantage of the use of local delivery devices as an adjunct to Sc/RP could not be demonstrated.
- Economic assessments and actual costs charged and billed to patients are not generally available in the literature.

Conclusion

It is strongly suggested that economic parameters as well as patient-centred outcomes be included in any RCT. These data are essential for allocating resources for preventive measures on an individual patient, practice and population base.

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Appendix 1

$$p = \frac{S}{(1+r)^N}$$

where p is the cash value of present equivalent, S the future value, r the interest rate p.a. and N the years. By preventing a €25,000 expensive restoration for the reconstruction of a maxillary dental arch with periodontal interventions, over 20 years are saved and theoretically available for preventive measures.

$$p = \frac{S}{(l+r)^N} = \frac{25000€}{(1+0.04)^{20}} = 11409€$$

Appendix 2. Evaluation criteria staircase (Table adapted from Lundgren et al. 2001)

Inclusion criteria for different levels of ''success''	Level				
Inclusion criteria	1	2	3	4	5
Probing pocket depth $\leqslant$ 4 mm	√	–	–	–	–
No clinical signs of gingival inflammation	√	√	–	–	–
No bleeding on pocket probing	√	√	√	–	–
No further loss of clinical attachment	√	√	√	√	–
No further loss of alveolar bone	√	√	√	√	√

Appendix 3. Cost Effectiveness Model according to Weinstein and Statson (1977)

$$\frac{\Delta C}{\Delta E} = \frac{\Delta C_{RX}}{\Delta Y - \Delta YSE}$$

where ΔC is the overall change in costs attributable to the treatment, ΔE the overall changes in effectiveness attributable to the treatment, ΔC_{RX} the direct health costs of treatment, ΔY the expected number of unadjusted tooth-years and ΔYSE the adjustments in the quality of those tooth-years because of side-effects of treatment (used to adjust downward the number of tooth-years expected).

Appendix 4. Utility Assessment Results (Table adapted from Antczak-Bouckoms & Weinstein 1987)

Variable	Median	25th%	75th%
Discount rate*	7%	4.5%	9.5%
Relative value of posterior teeth (without sensitivity)†	0.8	0.5	1.25
Relative value of sensitivity‡			
Anterior	0.6	0.4	0.8
Posterior	0.5	0.3	0.8
Relative value of poor aesthetics§			
Anterior	0.7	0.4	0.9
Posterior	1.0	–	–

*The discount rate concerns the trade-off between present and future tooth-years. For example, a discount rate of 7% means that each year of tooth survival is valued at 1.07 times as much as the subsequent year.

†The relative value of posterior teeth is the ratio of value of a tooth. For example, a relative value of 0.8 means that a posterior tooth-year is valued only 80% as much as an anterior tooth-year.

‡The relative value of sensitivity is the ratio of the value of a tooth-year with sensitivity to the value of a tooth-year with no sensitivity. For example, a relative value of 0.6 means that a tooth-year with sensitivity is valued only 60% as much as a tooth-year with no sensitivity.

§The relative value of poor esthetics is the ratio of the value of a tooth-year with poor esthetics to the value of a tooth-year with good esthetics. For example, a relative value of 0.7 means that a tooth-year with poor esthetics is valued only 70% as much as a tooth-year with good esthetics.