Health Economic Evaluation Methods for Decision-Making in Preventive Dentistry

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Abstract

The aims of this thesis were to evaluate caries-preventive measures from a societal perspective, to demonstrate the use of resources in preventive dentistry, to develop and discuss techniques suitable for evaluating dental care costs and outcomes, and to test costs and consequences within a health economic decision model adapted to preventive dental care.

The thesis is based on three separate studies with three separate cohorts. In the first study, performed at a single dental clinic, analysis was made of data on dental caries progression over four years in 92 adolescents, along with the use of resources for preventive treatment. In the second study, data from the intervention study “Evaluation of caries-preventive measures” (performed between 1995 and 1999 at 26 dental health clinics throughout Sweden) were used for economic evaluation. Three different approaches to calculating unit cost were discussed, each of which reflect the differences in treatment costs as influenced by the practitioner’s level of skill and competence (salary) and by methods of handling overhead cost allocation. These methods seem useful for evaluating costs in cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). The CEA showed an incremental cost-effectiveness over four years of SEK 2 043 per averted decayed (D) enamel (E) and dentine caries, missing (M) and filled (F) surface (S) (D₉E₉M₉F₉). In the third study, 82 19-year-old individuals agreed to participate in a pilot exploratory case-control study. Individuals with high caries experience formed the test group while the control group consisted of individuals with no caries experience. To explore whether any differences existed between these two groups in perceived oral health-related quality of life (OHRQOL), two OHRQOL measures were used. Additionally, the willingness of these individuals to pay (WTP) for a preventive strategy was elicited using the contingent valuation method (CVM) within a cost-benefit approach. Using these WTP values, the cost-benefit analyses showed positive net social benefit (NSB) values for both study groups, meaning that the benefits of prevention exceeded the costs. A new outcome measure, Value of Statistical Oral Health (VOSOH), was also presented.

Consideration was also made, within the economic framework fundamental to this thesis, of the trend away from a strictly bio-medical paradigm towards a biopsychosocial perspective. The health economic decision model encompasses a number of different techniques for comparing costs with consequences, each with its own advantages and disadvantages and each with its own field of application. These techniques should be seen as complementary rather than competing. Preventive dentistry plays a central role in Swedish dental health care, and it is important that resources are used properly. Accurate evaluation methods are necessary in order to improve the basis for public decision-making; the methods proposed in this thesis seem to be of potential use in this endeavour.

*SEK8.54 = US$1 (December 1999).

Key words: costs and cost analysis; cost-effectiveness analysis (CEA); cost-benefit analysis (CBA); contingent valuation method; willingness to pay; dental caries, prevention, preventive dentistry; oral health; health outcome; quality of life.
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Original papers

The thesis is based on the following papers:


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1. INTRODUCTION AND BACKGROUND

Health care and dental health care in the West have traditionally been dominated by the bio-medical paradigm, with a focus on technology and on the body as a machine. This model of care places high value on scientific rationality and numerical measurement (1). However, my daily work in dentistry has made it clear that for many groups of dental patients another approach is needed for truly effective communication, preventive care, and treatment. The guiding star for this dissertation has been the task of moving from the strictly bio-medical paradigm that was emphasised during my training as a dentist to a more explicitly patient-orientated approach with a focus on people within the social context they live in. Another objective of this work has been to bring together the field of health care research with my other main research interest, economics, in the hope that this broad and interdisciplinary scope will make for a pleasant journey towards increased understanding.

1.1 The decision-making process: the analyst and the decision-maker

Sugden and Williams (2) have described the role of an analyst as being to assist not just a decision-maker but a decision-making process that involves the community as a whole. The purpose of the analyst is to increase the probability of a good basis for decision-making, and the analysis is presupposed to be consistent with the objectives of the decision-maker. The outcome of the assessment cannot be objectively determined; its characteristics mainly depend on the interaction between the analysts and all other actors involved (directly or indirectly) in evaluation and decision-making. Actors at all levels, linked by the institutional structure, receive external input which may influence both their preferences and the decision-making process.

In the public sector, the decision-makers are politicians, professional administrators, professionally-skilled public employees, and those appointed to positions of responsibility. When it comes to public health care and dental health care, the hierarchy of the decision-making process stretches from the central government and politicians to local clinic managers, sometimes incorporating several intermediate decision levels in between. An increasingly popular method of creating incentive to achieve value for money in the public sector is to further decentralise the level at which decisions are made (3).

Figure 1 illustrates the interaction between the decision-maker and the analyst during the decision-making process. It should be noted that the decision-maker can choose to forego the use of the analyst.
Sugden and Williams (2) also discuss the role of the decision-maker, concluding that a decision-maker sees his task as being to maximise the social value of the medical care provided by that part of the health service for which he is responsible, subject to the constraint of available resources. This constraint is imposed by higher-level decision-makers — for example, the government — who must make decisions about the allocation of resources to the health service as a whole and, within the service, between its constituent sectors. The concept of the social value of medical care is somewhat vague. Ultimately, the outcome that has social value is an improvement in individuals’ states of health. However, there has been a tendency in health care and not least in dental health care to place the focus on productivity.

In Sweden, public health care provision is divided among 21 local counties and two larger regions, all with some sovereignty. While general medical health care is extensively subsidised by the Swedish taxation system, dental health care has other financing which is dependent on the patient’s age. Dental health care in each local county is provided by several dental clinics, each with its own clinic manager, and governed by the public county dental chief. The dental chief is subordinate to the central county government. Finances are negotiated yearly, with the county government stipulating the conditions under which financial assistance and reimbursement will be given; for example, a capitation fee for youth dental care, a contribution towards maintaining qualified specialists, and a contribution towards administrative costs. One approach to this financial negotiation, not unusual within the public health sector, would be for the government to explicitly state a monetary valuation for a given outcome of health care. Lower-level decision-makers would then be instructed to act in accordance with this valuation, setting aside the values and priorities of individuals in favour of the values and priorities of decision-makers. According to Sugden and Williams (2), this approach has a number of pitfalls. The imposition of this often one-sided focus on the overall budget constraint has a significant effect on the clinic-level decision-making process. In times of fewer available resources, attempts may be made to improve efficiency by
reorganising activities; for example, in Swedish public dental care services for children and adolescents many tasks have been taken over by dental nurses. Similarly, dental hygienists, despite their higher competence in prevention and health promotion and their greater experience of patient behavioural concerns, are sometimes diverted to other tasks with the clinic. It has not been proved that this reorganisation is to the benefit of either those currently suffering from disease or those at higher risk.

If the basis for public decision-making is to be improved, accurate methods of evaluation will be required. The aim of evaluation is to enable rationalisation of planning and decision-making problems by systematically structuring all the relevant aspects of policy choice. Munda et al. (4) distinguish three different behavioural paradigms for public decision-making: optimising behaviour, satisfying behaviour, and justifying behaviour. Even if the focus is mainly on the first category, in practice, policy evaluation is often also used as a means of justifying policy choice, even if the actual decisions are in agreement with neither the principles of optimisation nor the principles of satisfaction.

Historically, much attention has been focused on the welfare approach. However, this approach assumes a perfectly competitive system characterised by completeness of information and a fully-operative price system; these conditions can hardly be met in practice. The focus has been on economic efficiency, but it should be realised that not only monetary consequences but also the non-monetary impact of policy decisions must be taken into account. The social decision-maker as described by Sugden and Williams (2) makes decisions in the public interest; the object is social in the sense that it is used to determine decisions which affect society as a whole. The key to this argument is the extent to which a national government’s control of the tax system gives it the power to affect the distribution between individuals of the community’s income. Increasing awareness of the negative external effects of economic growth, along with the emergence of distribution issues in economic development, has led to the development of more appropriate analytical tools for analysing conflicts between policy objectives. Multiple criteria evaluation methods (4), are beginning to be seen as more appropriate methods for handling the multidimensional nature of current public decision-making, with its multitude of variables including such things as average income, environmental quality, distribution equity, and the provision and accessibility of public facilities. Within this context Drummond (5) concludes that the objective of economic evaluation is to be an aid to decision-making, not a complete basis for making decisions. Therefore, it is important to consider the strengths and weaknesses of all approaches rather than to suggest that there is but one theoretically-optimal approach. Health economics has the potential to help with future dental health care organisational and decision-making issues. Since one of the key issues in health economics is the nature of outcome (i.e., health), this will
enable a shift in focus from the one-sided goal of economic efficiency, productivity, towards a new objective of maximising health outcome subject to available resources.
2. HEALTH AS AN OUTCOME

2.1 Health

The natural point of departure when seeking a definition of health is the definition offered by the World Health Organization (WHO). The first version of the WHO definition was formulated in 1948 as “a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity” (6-8). Locker (9) points out that although this model emphasises the well-being of the patient, health services and health care practice have historically been more concerned with the eradication of disease. Bowling (10) calls attention to the limitations of both the widely-used negative definition of health as absence of disease, and the rather non-specific WHO definition described above. The bio-medical model is based on the Cartesian philosophy of the body as a machine and the assumption that disease is generated by specific etiological agents which lead to changes in the body’s structure and function. Hence, it takes the view that if a part malfunctions it can be repaired or replaced, thus treating the disease rather than the subjective experience of dysfunction which is illness. This model is based on scientific rationality, and puts emphasis on objective, numerical measurement and physical and chemical data. Health is seen in terms of the absence of disease. There have been extensive efforts to find consensus concerning the concept of health and even though considerable progress has been made, there is still some work that remains to be done before complete agreement can be achieved.

In 1984, the WHO reformulated the original definition as “the extent to which an individual or group is able, on the one hand, to realize aspirations and satisfy needs, and on the other hand, to change and cope with the environment” (11). This version focuses on the fulfilment of human needs as assisted by the attainment of health and wellness (12). Locker (9) summarised this redefined version by the use of words from Epp (13) that health is an integral part of our daily living and an essential dimension of the quality of our lives. Quality of life implies the opportunity to make choices and to gain satisfaction from living. Health is seen as a resource which gives people the ability to manage and change their surroundings. This definition recognises freedom of choice and emphasises the role of individuals and communities in defining what health means to them. From the oral point of view, the aim of health care according to Sheiham (14) should be to obtain and maintain a functional, pain-free, and aesthetically and socially acceptable dentition for the lifespan of most people. This also implies abandonment of the traditional view that all missing teeth should be replaced; recent research has shown that two full dental arches are not necessary for adequate functioning, well-being and aesthetics.
Bowling (10) points out that there is broad agreement that the concept of positive health is more than the mere absence of disease or disability; it also implies completeness, and full functioning, or efficiency of mind and body and social adjustment. Positive health could also be described as the ability to cope with stressful situations, the maintenance of a strong social support system, integration in the community, high morale and life satisfaction, psychological well-being, and even levels of physical fitness as well as physical health. It should be noted however that the concept of health, even when defined broadly and with a positive slant, for example in terms of the ability to function in everyday social roles, is theoretically distinct from health-related quality of life. Although health is valued highly by people, it is but one of several components of life.

Social models of health take a broader view than merely disease, functional ability, and reporting of symptoms, aiming instead to measure social health, a dimension of individual well-being distinct from both physical and mental health. Such models distinguish between disease and the subjective feelings and perceptions of disease that are often labelled as illness or sickness and that cannot necessarily be detected by biochemical indicators. Darby and Walsh (12) point out that health is perceived as a resource for everyday life, not the objective of living. They further note that it is essential to consider cultural aspects and societal norms in order to avoid imposing biases often associated with the construct of health. Health could be seen as a relatively passive state in which an individual is at peace with the environment. Wellness, on the other hand, is a dynamic method of functioning; a condition of change in which the individual moves forward, climbing toward higher functionality. Wellness is a direction of progress and an approach to living, whereas health is a state of being. Wellness is inclusive of health, but health is not inclusive of wellness, although health does contribute to wellness in that it provides a foundation for relative homeostasis versus confusion and unrest. The evolution of the concept of wellness has gone through three stages: the treatment and disease paradigm, which equates the level of health with the quality of medicine; the disease prevention-oriented paradigm, which claims that disease is best treated by identifying the causative agent and avoiding it, and the health promotion paradigm, which focuses on creating an environment that enables people to increase their control over their current health and improve their future health. The concept of well-being encompasses multiple dimensions — happiness, life satisfaction, morale, self-esteem, and sense of coherence — and must be measured by subjective indicators (10).

2.2 Quality of life

Bowling (10) provides a thorough survey of the literature concerning the concept of quality of life (QOL). Quality of life can be seen as a grade of goodness, and its relation to health as being about the goodness of those aspects of life affected by
HEALTH AS AN OUTCOME

health. Health-related quality of life is only one dimension of wider quality of life. Both are multilevel and amorphous concepts, and both are increasingly popular as endpoints in the evaluation of public policy.

Variables related to quality of life can be divided into macro and micro perspectives. The macro perspective variables include income, employment, housing, education, and other living conditions and environmental circumstances, while the micro perspective variables include the perception of overall quality of life and individuals’ experiences and values. Quality of life thus appears to be a complex collection of interacting objective and subjective dimensions, and most investigators focus on this multidimensionality. However, it has been argued that quality of life should actually be considered as a unidimensional concept with multiple causes, and a unidimensional QOL rating such as “How do you feel about your life as a whole?” could be the consequence of global assessment of a range of diverse and complex factors. It thus seems reasonable that quality of life is influenced by causal variables, and that the level of quality of life manifests itself in indicator variables; this is in contrast to the traditional approach to measurement, which has implicitly assumed the presence of only indicator variables. In relation to this, the effects of personality on perception of well-being and quality of life are controversial, partly because of the debate about causal versus mediating variables. It has also been argued that there is a need for a model of quality of life which focuses on the potential link between the subjective evaluation of quality of life and psychological factors such as self-esteem or self-worth; self-efficacy, perceived control, and self-mastery; and autonomy.

Moving on from the basic definition, there are a number of theoretical models for quality of life. One of the main types comprises the need-based approaches based on Maslow’s (15, 16) hierarchy of human needs; the deficiency needs of hunger, thirst, loneliness, and security, and the growth needs of learning, mastery, and self-actualisation. Overlapping these are the social-psychological models, which emphasise autonomy and control, self-sufficiency, internal control, and self-assessed technical performance; the social competence models; and the classical models of subjective well-being (happiness, morale, and satisfaction). Another type consists of the expectation or gap models, which are based on the discrepancy between desired and actual circumstances. Finally, the phenomenological models are based on the concept that quality of life is dependent on the unique perceptions of the individual who experiences it, and should thus be measured using that individual’s own value system.

2.3 Health, oral health, and quality of life

The impact of health on an individual’s quality of life has been encapsulated by the term “health-related quality of life” (HRQOL). Although different studies have
used different definitions for HRQOL (17), the consensus emerging from the literature is that it has three main dimensions: physical symptoms, perception of well-being, and functional capacity.

Gift and Atchison (18) describe health-related quality of life as a multifaceted concept that offers an opportunity to address the trade-off between how long and how well people live. HRQOL is the value assigned to current or future health status and duration of life as modified by impairments, functional states, perception, and social opportunities, which in turn are influenced by disease, injury, medical treatment, and health care policy. It is a combination of one or more of absolute health, perception of actual health, perception of potential health, and any existing disability. It is a composite of clinical and socio-behavioural factors and is distinct from quality of life, which is a broad term that supersedes those elements which health influences.

Many oral health researchers (19, 20) have demonstrated the direct correlation between oral health and quality of life. There has been a growing interest in quantifying those consequences of disease which affect function, comfort, and ability to perform everyday activities ever since Cohen and Jargo (19) argued in 1976 that the greatest contribution of dentistry is the improvement of quality of life through the prevention and treatment of oral disease.

An international study performed by the WHO in collaboration with the University of Chicago, the ICSII, concluded that oral quality of life is the ultimate outcome (21). It is the cumulative result of the financing and organisation of the health care system, the socio-economic and socio-political environment, the predisposing and enabling characteristics of individuals, the oral health behaviour of individuals, and the dentition and periodontal status of individuals. The dimensions of oral quality of life considered in the ICSII were oral disease symptoms, well-being, and social and physical functioning, including problems with dentures.

Although oral disease affects many people throughout the world, it is rarely life-threatening (17), and so governments and health policy-makers tend to give oral health a relatively low priority. However, oral health researchers argue that the prevention and control of oral disease deserves greater attention because the adverse impact of poor oral health on the individual has been underestimated (22–24). Many consequences of oral disease affect not only physical but also social and psychological well-being. The broad impact of oral disorders on daily living was shown for example by Reisine (25) and Reisine et al. (26), who demonstrated how two typical physical oral symptoms affected quality of life, using different quality of life measures.
Few studies have incorporated all three HRQOL dimensions at once. One exception is a study by Chen and Hunter (17) which used dental symptoms, oral well-being, and oral functioning to investigate the relationship between oral health and quality of life. However, there are a number of studies which cover each of these dimensions individually, for example pain and impairment due to oral health problems (27, 28) and self-assessed satisfaction with oral health as indicators of oral well-being (29). Additionally, Hollister and Weintraub (30) strongly support the connections between oral health as an integral part of general health and thereby influencing quality of life.

The first major contribution towards a model for oral health-related quality of life (OHRQOL) was made by Locker (23), who abandoned the clinical focus and instead based his conceptual framework on the WHO’s International Classification of Impairments, Disabilities, and Handicaps (ICIDH) (31). He described the linkage of different concepts (disease, impairment, functional limitation, disability, discomfort, and handicap) in a linear function that moves from a biological to a behavioural and then social level of analysis.

Additional steps towards linking oral health into the context of quality of life were taken by Wilson and Cleary (32). Their model was based on the idea that different kinds of oral conditions can lead to symptoms, compromised physical and psychosocial functioning, and negative perception of health, all of which diminish an individual’s quality of life. However, they noted that disease, its functional and psychosocial outcomes, and its impact on quality of life are also influenced by both personal and environmental characteristics. Health is just one part of quality of life; non-medical factors also have an effect.

Building on this previous work, Williams et al. (33) developed a full OHRQOL model with the purpose of serving as a foundation for assessing, planning, implementing, and evaluating outcomes of dental hygiene care. This comprehensive framework makes a significant contribution to increased understanding of OHRQOL. It is based on three other models; that of Wilson and Cleary (32), the natural history of disease model (34), and the Neuman Systems Model for nursing (35). Wilson and Cleary’s model is described above. The natural history of disease model defines health and disease as a continuum, and describes disease as evolving, in the absence of intervention, from a state of health through prodromal disease into actual disease states. It can be used to provide guidance for primary, secondary, and tertiary prevention. The Neuman Systems Model is a dynamic model which considers the influence of environmental “stressors” on individuals, groups, and communities. Nursing actions (levels of prevention) are intended to assist individuals or populations in maintaining or regaining a state of equilibrium.
The OHRQOL model is based on the premise that a satisfactory level of oral health comfort and function, as defined by the individual or population, is an integral component of general health. Figure 2 illustrates the different domains and flows within the model. The domains of the model are:

- **Health and preclinical disease**: Levels of physical, psychological, social, and emotional well-being are in a state defined by the individual as ideal. The individual is experiencing neither impairment nor negative symptoms. Preclinical disease is part of this domain, and can be influenced by health promotion and disease prevention.

- **Biological and physiological clinical variables**: Clinically evident disease.

- **Symptom status, functional status, and health perception**: These domains encompass the interrelated concepts that define health-related quality of life. Symptoms such as xerostomia or pain will influence well-being and may provide motivation for seeking health care. Health perception, that is, the subjective opinion of physical, emotional and oral conditions, can have an impact on the effectiveness of intervention.

- **General quality of life**: Overall satisfaction with life as a whole. Quality of life is influenced by several components of life. Although intuitively it seems that health-related quality of life should be correlated with general quality of life, medical research has demonstrated that general quality of life is dynamic and difficult to measure. The relationship between HRQOL and general QOL may vary, and may not be as strong in some circumstances as might be anticipated.

- **Characteristics of the individual or population**: These include socio-cultural, economic, and environmental influences that impact modifiable and non-modifiable risk factors, values and preferences for treatment and health outcomes, self-efficacy and motivation, and symptom amplification or suppression. Collectively, these characteristics of individuals can indirectly or directly influence all domains in the model.
In health care, where clinical interventions are usually more specific and invasive, outcome assessment has a long tradition. However, the traditional outcome indices have a negative focus, being concerned with such things as survival periods, toxicity, biochemical indicators and symptom rates, various indicators of physical
and psychological morbidity, and easily-measured social variables such as hospital bed days or time taken off work or school. Treatment and care need to be evaluated in terms of how likely they are to lead to an outcome of a life worth living in social, psychological, and physical terms. The bio-psychosocial model of ill-health states that health is a consequence of the interaction of social, psychological, and biological events. Health status and health related quality of life are two distinct and overlapping conceptual terms. Health status is one aspect of HRQOL, encompassing such things as physical health, function, ability to perform, and social functioning. HRQOL broadens the outcome towards a consideration of the impact of the condition and its treatment on the patient’s emotional, physical and social functioning and lifestyle, providing a more subjective and patient-led baseline against which the effects of interventions can be evaluated.

In dentistry, oral health outcome has traditionally been measured using strictly clinical physical indicators. Dentists and dental hygienists have been trained to recognise and treat diseases such as caries and periodontal disease, and consequently various indices have been developed to describe these diseases within the population (36-42). Jönsson and Karlsson (43) state that the outcome measure is critical for evaluation of both health care and health economics. The outcome should be understandable by all involved, and should express benefits in terms of increased quality and utility. In general, the literature shows that clinical indicators of oral health are significant correlates of oral quality of life. Some studies found that poor oral health status was associated with a greater likelihood of experiencing oral pain. Cushing et.al. (29) reported that patients with more decayed teeth were more likely to experience oral disease symptoms, and Bailit (46) found that individuals with more decayed, missing, or filled teeth (DMFT) reported more oral pain. However, a study of older adults found no association between the number of DMFT and periodontal attachment on the one hand and oral pain and other oral symptoms on the other (24). With a few exceptions (24, 47), most studies found that the number of DMFT was negatively correlated to perceived oral health (47, 48). Greater number of missing teeth has also been related to impaired chewing ability or eating function (24, 48).

In the last few decades several health indicators, or instruments, have been developed to measure health-related quality of life. Bowling (10) provides a thorough survey of commonly used measures, including both disease-specific and broad-ranging instruments. These are further divided into different subject fields, for example, functional ability (basic mobility, self-care activities, activities of daily living such as bathing, using the toilet, and eating and drinking); broader health status (a focus on individuals’ perception of their health); psychological well-being (detecting common psychiatric disorders such as anxiety, depression, and dementia); social networks and social support (human relationships, social contexts, and social integration); subjective well-being/psychological well-being (satisfaction and balance.
between positive/negative affect and engagement with the existential challenges of life; and broader quality of life measures (generic measures spanning a broad range of topics and disciplines, thus increasing the need for valuation of several variables). Table 1 presents some examples of measures in different categories.

Table 1. Indicators for health-related quality of life.

<table>
<thead>
<tr>
<th>GENERAL HEALTH INSTRUMENT</th>
<th>HEALTH INDICATOR FIELD</th>
<th>DIMENSIONS/COMMENTS</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Stanford Arthritis Center’s Health Assessment Questionnaire (HAQ).</td>
<td>FUNCTIONAL ABILITY</td>
<td>The desire to be alive, free from pain, functioning normally, subject to minimal treatment toxicity, and financially solvent.</td>
<td>Fries et al. (49)</td>
</tr>
<tr>
<td>The Quality of Well-Being Scale (QWBS)</td>
<td></td>
<td>Developed in order to quantify wellness for a general health-policy model.</td>
<td>Kaplan et. al (50)</td>
</tr>
<tr>
<td>Sickness Impact Profile (SIP)</td>
<td>BROADER HEALTH STATUS</td>
<td>The impact of sickness on daily activities and behaviour, as opposed to feelings and clinical reports.</td>
<td>Deyo et al. (51,52) Bergner (53,54)</td>
</tr>
<tr>
<td>The Nottingham Health Profile (NHP)</td>
<td></td>
<td>Based on lay perception of health status.</td>
<td>Hunt et al. (55)</td>
</tr>
<tr>
<td>The Rand Health Insurance/Medical Outcomes Study Batteries</td>
<td></td>
<td>Based on a sample of 8000 adults. A study of health outcomes following allocation to different insurance plans. Contains several items aimed to detect changes in health status; physical, psychological, social, and mental health, together with perception of health.</td>
<td>Stewart and Ware (56)</td>
</tr>
<tr>
<td>Short Form-36 Health Survey Questionnaire (SF-36)</td>
<td></td>
<td>Developed for use in the previous study (56). A commonly used 36-item questionnaire.</td>
<td>Ware et al. (57,58)</td>
</tr>
<tr>
<td>EuroQol</td>
<td></td>
<td>Generic, multi-dimensional health profile giving a single value for each health state.</td>
<td>EuroQol Group (59)</td>
</tr>
<tr>
<td>Hamilton Depression Rating scale</td>
<td>PSYCHOLOGICAL WELL-BEING</td>
<td>Mostly used for assessment of depression. 17 items.</td>
<td>Hamilton (60) Freedland (61)</td>
</tr>
<tr>
<td>The Lubben Social Network Scale (LSNS)</td>
<td>MEASURING SOCIAL NETWORK AND SOCIAL SUPPORT</td>
<td>Composite measure consisting of ten items within three dimensions. Developed for use in the elderly.</td>
<td>Lubben (62)</td>
</tr>
<tr>
<td>Sense of Coherence Scale (SOC)</td>
<td>DIMENSIONS OF SUBJECTIVE WELL-BEING</td>
<td>Global in content. Designed to explain the maintenance or improvement of one’s position on a health-case/disease continuum. Short version is popular.</td>
<td>Antonovsky and Sagy (63) Pallant and Loe (64)</td>
</tr>
<tr>
<td>WHOQOL</td>
<td>BROADER QUALITY OF LIFE</td>
<td>THEORETICALLY DISTINCT FROM MEASURING OF BROADER HEALTH STATUS AND HRQOL MEASURES</td>
<td>WHOQOL Group (65,66)</td>
</tr>
</tbody>
</table>
2.5 **Oral Health-Related Quality of Life measures**

Prior to the theoretical framework proposed by Locker (24), Reisine (25) used the generic measure of Sickness Impact Profile (SIP). Since then, different methods have been used to develop measures specific to oral health. Table 2 presents the OHRQOL measures most frequently used to assess adults and children. Descriptive population studies have given an indication of the discriminant validity properties of many health status measures, but as Allen et al. summarise (67), there is a paucity of information regarding responsiveness to change, and the impact of therapeutic intervention on HRQOL still remains to be fully understood. Further, a greater understanding of the natural history of oral health-related quality of life is needed. Their suggested solution is to use a generic measure with core quality of life statements, and then add disease-specific statements to improve responsiveness.
**Table 2. Indicators for oral health-related quality of life.**

<table>
<thead>
<tr>
<th><strong>ORAL HEALTH-RELATED QUALITY OF LIFE MEASURE</strong></th>
<th><strong>DIMENSIONS/COMMENTS</strong></th>
<th><strong>REFERENCE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Geriatric Oral Health Assessment Index (GOHAI)</td>
<td>Contains 12 statements giving an overall score of 0-60 for the impact of oral disorders.</td>
<td>Atchison and Dolan (68)</td>
</tr>
<tr>
<td>Social Impacts of Dental Disease</td>
<td>14 items covering chewing, talking, smiling, laughing, pain, and appearance.</td>
<td>Cushing et al. (29)</td>
</tr>
<tr>
<td>Subjective Oral Health Status Indicators</td>
<td>42 items covering chewing, speaking, symptoms, eating, communication, and social relations.</td>
<td>Locker and Miller (69)</td>
</tr>
<tr>
<td>Subjective Well-Being Measure</td>
<td>Subjective well-being in the context of health. Three dimensions; happiness, energy (activity), and thinking.</td>
<td>Gill (70)</td>
</tr>
<tr>
<td>Dental Impact Profile (DIP)</td>
<td>25 statements/4 sub-scales (eating, health/well-being, social relations and romance).</td>
<td>Strauss and Hunt (71)</td>
</tr>
<tr>
<td>Oral Health Impact Profile (OHIP)</td>
<td>Social impact of oral disorders. 49 weighted statements for 7 domains (functional limitations, physical pain, psychological discomfort, physical, psychological, and social disability, and handicap.</td>
<td>Slade and Spencer (72)</td>
</tr>
<tr>
<td>OHIP-14</td>
<td>14-item questionnaire comprising a subset of the original OHIP-49.</td>
<td>Slade (73)</td>
</tr>
<tr>
<td>Dental Impact on Daily Living (DIDL)</td>
<td>36 items/5 sub-scales (comfort, appearance, pain, performance, and eating restriction).</td>
<td>Leao and Sheiham (74)</td>
</tr>
<tr>
<td>Oral Impact of Daily Performance (OIDP)</td>
<td>8 daily tasks: eating, speaking, cleaning teeth, sleeping, smiling, laughing, showing teeth, relation to others.</td>
<td>Adulyanon and Sheiham (75)</td>
</tr>
<tr>
<td>Oral Health Related Quality of Life – United Kingdom (weighted) OHQOL-UK(W)</td>
<td>16 questions incorporating both positive and negative dimensions for rating the impact of oral effects on quality of life</td>
<td>McGrath and Bedi (76,77)</td>
</tr>
<tr>
<td>Oral Health Related Quality of Life (OHRQOL) instrument-Dental Hygiene</td>
<td>56 items based on symptoms, health perception, and functional status. Included in the OHRQOL model and tested in the elderly.</td>
<td>Gadbury-Amyot et al. (78)</td>
</tr>
</tbody>
</table>

**MEASURES FOR USE IN CHILDREN**

| **Child Perception Questionnaire (CPQ11-14)** | 36 items organised into four health domains (oral symptoms, functional limitations, emotional well-being, and social well-being) for measuring oral health-related quality of life in children aged 11 to 14 years. | Jocovic et al. (79-81) |
| **CHILD-OIDP** | An index developed from the original OIDP (75), Oral Impact on Daily Performance. Within the OIDP index, oral consequences are divided into three levels: the impairment, the intermediate level (pain, discomfort, functional limitation, and dissatisfaction with appearance), and the ultimate impact. | Gherunpong et al (82) |
| **Child Oral Health-Related Quality of Life (COHRQOL)** | Children’s self-reported ratings of their oral health-related quality of life. Socio-demographic background; 25-item COHRQOL[8-10] questionnaire and the Coppermith Self-Esteem Inventory-School Form for 8-15 year olds. | Humphris et al. (83) |
3. AN ECONOMICAL FRAMEWORK FOR EVALUATION

A normative economic framework within the health care sector, based on the welfare theory has been described by Hurley (84). The welfare theory separates efficiency from equity, with an almost exclusive focus on efficiency. Economists generally distinguish three concepts of efficiency. The first two concern supply-side efficiency. Technical efficiency is achieved when production is organised in such a way as to minimise the input required to produce a given output and this depends solely on the physical production function. Cost-effectiveness efficiency is achieved when production is organised in such a way as to minimise the cost of producing a given output. Allocation efficiency, which incorporates the demand side, is achieved when resources are produced and allocated so as to produce the optimal level of each output and to distribute the outputs in line with the value consumers place on them. There is a hierarchical relationship between the three concepts of efficiency – technical efficiency is a necessary precondition to cost-effectiveness, and both technical efficiency and cost-effectiveness efficiency are necessary conditions for allocating efficiency. In welfare economics there are four concepts of particular importance: in utility maximisation individuals choose rationally and rank different options with consistency, while in individual sovereignty individuals are the best judges of their own welfare; in consequentialism any action must be judged exclusively in terms of the resulting, or consequent, effects; and by welfarism is meant that the resource allocation in any situation is judged solely on the basis of the utility levels attained by individuals in that situation.

When the assumption that utility is cardinally measurable and interpersonally comparable was dropped, the criterion of maximising the sum of utilities was replaced by the criterion of Pareto optimality. This means that if a change can increase the welfare of one person without decreasing that of another, the change ought to be implemented. The criterion compares the same individuals under different circumstances but cannot deal with interpersonal comparisons. Because nearly all policy changes are to the detriment of somebody, strict application of the Pareto criterion is therefore impossible to realise. To overcome this limitation, a modified version of the criterion has been used, the so-called “potential Pareto improvement”. The net change in welfare is the determining factor. If the increase in welfare is such that compensation for the losers of welfare is possible, then the criterion is met. The fact that compensation is possible is sufficient.

In applied welfare economics, utility (i.e. benefits) is normally measured in monetary terms. For valuation of non-marketed goods, which are common in the health sector, willingness to pay using contingent valuation methods is often assessed within cost-benefit analysis (CBA).
Welfare economics, including the assumption that individual sovereignty is violated in the health sector, have been criticised and alternative approaches prominent in the health sector have been discussed during the last decades. Consequently, there has been a major effort in health economics to develop benefit measures that do not directly depend on a person’s income and wealth. More fundamentally, extra-welfarists argue that health rather than utility is the most relevant outcome for conducting normative analyses in the health sector. The most relevant characteristic in evaluating alternative policies in the health sector is health which creates a need for health care. Two key concepts do not easily fit into a welfare framework: the concept of need (as opposed to demand), which depends on the ability to benefit from health care, and health (as opposed to utility) as a final outcome of concern.

More generally, rejection of the welfarist individualistic social welfare function has led to the development of a “decision-maker approach” to CBA and a call for a more communitarian approach to evaluation. In the decision-maker approach, the relevant arguments in the objective function are defined by the decision-maker. Extra-welfarists have argued that producing health is the primary objective. In the case of the communitarian perspective, individualism is rejected because it is argued that social welfare is more than the aggregation of individual preferences over individual programmes.

One argument of the Paretian approach is that a cost-benefit analysis should answer one question only: if those who would be affected by a project are divided into gainers and losers, by how much does the total sum that the gainers would be prepared to pay to ensure that the project goes ahead exceed the total sum that the losers from the project would be prepared to accept as compensation for putting up with it? The answer to this question does not amount to a statement about whether the project will increase or decrease social welfare, but is nevertheless a significant piece of information. This sets the Paretian approach apart from the decision-making approach. The welfare economist may legitimately declare that it is not possible to know which of two social states would produce more social welfare. Using the valuation of individuals to guide social choice may not be enough when choices have to be made about the supply of medical care; it is not difficult for an individual to undervalue effects that only have impact on others, for example, interpersonal external effects or merit goods. The benefits that a given good confers on society can be argued to be something different in principle from the benefits that individuals perceive themselves to receive from it. The decision-maker cannot refuse to express judgements about the relative importance of economic efficiency and merit good arguments, nor can he refuse to judge the social value of goods on the grounds of lack of information. It is his job to choose between alternatives. According to the decision-making approach, cost-benefit analysis exists to assist him in choosing; it may therefore, have to explore social objectives other than that of increasing economic efficiency. In this sense the decision-making approach is the more ambitious of the two approaches, since it permits a wider
range of the effects of a project to be taken into account in cost-benefit analysis. In a fairly centralised public decision-making system, the objective chosen will normally correspond to that implied by the potential Pareto improvement criterion. The key to this argument is the proportion that a national government, because of its control of the tax system, has control of the distribution between individuals of the community’s income.

Different principles have been discussed by Williams and Cookson (85) to assist allocation of resources: the utilitarian theory argues that health care should be distributed so as to maximise the utility of society. Redistribution is, then, bound to be a good thing on a utilitarian calculus, since the gain in happiness to the poor from one more unit of the good will be greater than the loss in happiness to the rich from one less unit of the good, assuming diminishing marginal utility of that good. The egalitarian theory is based on the concept that everyone has an equal claim to the health care resources; and the Rawls’ theory proposes first that basic liberties are to be distributed equally and at the maximum level that is compatible with the level for everyone else. Second, social and economic inequalities are to be arranged in such a way as to be of greatest benefit to the least advantaged members of society.

Equity involves fairness and justice, the idea of balancing legitimate, competing claims of individuals in society in a way that is seen as impartial or disinterested. Distribution equity, which concerns the fair distribution of some goods or services of interest, has been the dominant equity concern both of normative economic analysts and of health policy-makers. In determining priorities in any areas of public policy it is important to be clear about the objective of the policy. In general terms resources will be allocated to achieve both an efficient and an equitable outcome but since neither objective can always be fully satisfied, there will be a trade-off between them. It is important to define what is meant by efficiency and equity in the context of health, and health care. Sen (86) argues that economics ought to pay more attention to more ethical judgements and ethical considerations that shape human behaviour.

### 3.1 Health care as an economic commodity

According to Hurley (84), health care is different in ways that generate market failure and its distinctiveness is rooted in four characteristics: (a) demand for health care is a derived demand for health; (b) externalities; (c) informational asymmetries between providers and patients; and (d) uncertainty with respect to both the need for and the effectiveness of health care. No other commodity shares all of these features to the same extent as found in health sector.
(a) The derived nature of the demand for health care has profound implications for normative analysis in the health care sector. Efficiency in health care can apply to three levels: efficiency in the production of health care services; efficiency in the use, or consumption, of health care services; and efficiency in choosing an optimal level of health. At the first level only the supply-side notions of technical and cost-effectiveness efficiency are relevant. At the second level both supply- and demand-side efficiency concepts are relevant. To the extent that health care is consumed to produce health, technical and cost-effectiveness efficiency are relevant in assessing both the mix of health care services consumed and the use of health care versus other inputs to produce health. However, because health care also has direct effects on welfare, demand-side, or allocation efficiency, concerns also arise. A consumer may trade off efficiency in the production of health for direct utility effects by choosing a less effective treatment that also has fewer negative side effects. At the third level, allocation efficiency is relevant in choosing the optimal level of health care for the consumer, where health is traded off against other goods to maximise welfare.

(b) Externalities are goods with external effects and often call for collective action to ensure their provision at an efficient level. For example, externalities can arise from public interventions targeted at communicable diseases, or from an action taken by one person (e.g. ensuring clean, safe water; seeking treatment for a communicable disease) that generates direct health benefits for other individuals. Arguments regarding the nature of externalities for health care services are based on the broad public support for subsidies to increase citizens’ access to health care.

(c) The informational asymmetry between the patient and the provider regarding both the nature of the illness and the effectiveness of alternative treatments causes market failure. Supplier-induced demand is another example of informational asymmetries, where the provider violates the agency relationship out of financial self-interest by recommending services of questionable benefit to a patient.

(d) Two important types of uncertainty are associated with health care: uncertainty in the demand for health care (e.g. the unpredictability of getting ill) and uncertainty regarding the effectiveness of treatment. The economic efficiency of market arrangements therefore depends on the ability of a competitive system to create a full set of risk-bearing (i.e. insurance) markets. Moral hazard refers to the tendency for insurance coverage to induce behavioural responses that raise the expected losses that are insured, because it increases either the likelihood or the size of a loss. Individuals with health insurance coverage may take less care to avoid illness or injury. In the health sector moral hazard is associated with the fact than once an insurable event occurs the insured individual may incur higher total costs than in the absence of insurance because he or she does not have to pay for the full cost of treatment. The increased expenditure associated with such moral hazard
results from the behavioural responses of either the patient or the providers: patients whose care is subsidised may demand a greater quantity of services; providers, knowing that patients do not bear the full cost of services, may increase the quantity and price of treatments recommended.

3.2 Similarities and differences in dental health care and medical health care

It is evident, as summarised in Table 3, that dental health care and medical health care, as an economic commodity, share many characteristics; however, there are some differences, which have greater or lesser impact. In Sweden, medical health care is extensively subsidised by the Swedish taxation system, which naturally has an impact on the consumption of health care. Dental health care differs from medical health care in a number of ways. For youth dental care a capitation principle is used. For every child up to the age of 19, the dental health care system receives an annual amount of approximately 885 SEK from the county councils, varying between from 715 SEK to 1 000 SEK for the different Swedish counties (87).

In times of improving dental health, efforts have been made to reduce clinical “child time” in favour of increased dental care for adults, which generates more revenue for the clinic. This has influenced the risk for supplier-induced demand. For adults between 20 and 64 years old, only a small part of dental health services is subsidised by the national insurance system (88). This means that the majority of adults finance their dental care with out-of-pocket money. The private insurance market is quite negligible. Adults 65 years and older receive a potential subsidiary for prosthetic dentistry. This has obviously increased the demand for more exclusive treatment such as dental implants, both from the patients and from the supplier, since implants often involve different treatment options as well as a more profitable alternative for the dentist. The financing system holds risks for both supplier-induced demand and moral hazard. There ought to be fewer information asymmetries in dental care than in general medical care because of fewer dental diseases and often a closer and more frequent contact between the patient and the dental provider. However, there are reasons to believe that communicative problems do exist even in dental health care provision.

Allocation issues too are fewer in dentistry because of a more limited mix of diseases and treatment alternatives; however, where expensive treatments are available questions arise. Even though there has been a potential increase in health improvements for adolescents, a small group of children still suffer from dental
disease. The question of how many more resources should be spent on these children is of course an allocation problem.

Table 3. Health care as an economic commodity, giving the dental health care equivalent to medical health care.

<table>
<thead>
<tr>
<th>Characteristics of health care</th>
<th>Degree of correspondence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Derived demand</strong></td>
<td></td>
</tr>
<tr>
<td>- supply-side efficiency</td>
<td>Applicable for both medical- and dental health care X</td>
</tr>
<tr>
<td>- health consumption</td>
<td>Larger number of medical health care services X</td>
</tr>
<tr>
<td>- allocation of resources</td>
<td>Health is traded off against other goods to maximise welfare X</td>
</tr>
<tr>
<td><strong>Externalities</strong></td>
<td></td>
</tr>
<tr>
<td>- communicable diseases</td>
<td>Diseases impact on other individuals are more common in medical health care X</td>
</tr>
<tr>
<td>- impact of public finance</td>
<td>The financial system has high impact on health care consumption in both sectors X</td>
</tr>
<tr>
<td>- health-directed subsidiary</td>
<td>Such as preventive programmes in dental care X</td>
</tr>
<tr>
<td><strong>Information asymmetries</strong></td>
<td></td>
</tr>
<tr>
<td>- nature of illness</td>
<td>There are only a few diseases in dental care and those are well known X</td>
</tr>
<tr>
<td>- communication</td>
<td>Same communicative problems in both sectors X</td>
</tr>
<tr>
<td>- supplier-induced demand</td>
<td>“Dentists decide on treatment.” X</td>
</tr>
<tr>
<td><strong>Uncertainty</strong></td>
<td></td>
</tr>
<tr>
<td>- risk-bearing (insurance)</td>
<td>Most Swedish adults finance their own dental care X</td>
</tr>
<tr>
<td>- moral hazard</td>
<td>Increased expenditure due to irresponsible response of either the patient or the provider towards insurance X</td>
</tr>
<tr>
<td>- outcome uncertainty</td>
<td>In dental care the risk of getting ill is mostly unknown but the outcome of treatment is fairly predictable X</td>
</tr>
</tbody>
</table>

Sintonen and Linnosmaa (89) give seven main ways in which dental health care differs from general health care: (a) there are few dental diseases; (b) individuals learn about the quality of dental service from regular dental visits; (c) dental diseases are easier to diagnose; (d) there is a wider variety of alternative treatments available for treating a given disease; (e) there are extensive prevention possibilities in dental care; (f) except in emergency care and following accidents dental care is rarely “emergency” care and untreated dental illness rarely has dramatic consequences on an individual’s general health; and (g) some of the externalities
found in the general health care sector (e.g. communicable diseases) are not present in dental health care to the same extent and one would expect that market mechanisms perform better in dental care and insurance than in other health services. However, there are some implications for dental insurance that give undesired effects, such as the fact that insurance coverage induces people to make more use of dental services, and such as moral hazard, and supplier-induced demand for dental care. Birch (90) reports that an increase in dentists in a fee-for-service market leads to a higher total supply of services.

3.3 Different types of economic evaluation

Drummond et al. (5) emphasise two features that characterise economic analysis, regardless of the activities (including health services) to which it is applied. The first pertains to the linkage of costs and consequences, with one main objective to determine whether the value of health benefits exceeds costs of obtaining those benefits, which allows us to reach our decision. The second has to do with the fact that economic analysis concerns itself with choices. Resource scarcity, and our consequent inability to produce all desired outputs (even efficacious therapies) means that choices must, and will, be made in all areas of human activity. Pareto welfare economic theory provides the conceptual foundation to the methods of CBA for evaluation of health care programmes (84). This means that both costs and consequences are measured in monetary units and by ranking the allocation efficiency of these programmes and services on the basis of net benefit. In health care there are some difficulties (conceptual, ethical and practical) to assign monetary value to consequences. One example of difficulties embodied within a measurement technique is willingness to pay within CBA, which links the value of a health effect to the individual’s economic resources. Difficulties in transforming health effects into monetary values have led to development of other evaluation techniques.

Drummond et al. (5) describe different evaluation techniques and emphasise the importance of the viewpoint assumed for the study. A programme which looks unattractive from one viewpoint may look better when other viewpoints are considered. This results in different approaches to possible formulation of economic evaluation. The possible formulations and techniques are summarised in Table 4. Resources consumed, or costs, are divided into three sectors: the health sector, C1; patient and family resources, C2, such as out-of-pocket expenses, time, expenditure at home; other sectors, C3, where programmes rely on resources from elsewhere, such as the voluntary sector. With regard to patient and family resources, C2, the time factor merits some comments. Drummond et al. (5) discuss different ways of handling these costs since time has a value for individuals in paid employment, as well as for individuals not in paid employment. Calculation of production losses especially for short-term absences has been discussed to
sometimes overestimate the value of time since work could be compensated for by colleagues. The common calculation here is using gross wages as an estimation of time cost.

The consequences of health improvement can be measured in terms of effects (E) but can also be calculated in terms of health state preferences (U) in a cost-utility analysis (CUA), or in terms of willingness to pay (W) in a CBA. Other values (Vs), such as the value of information, could also be used in evaluation of health care programmes. Also, resources could be saved by providing efficacious health care programmes. These savings \((S_1, S_2\) and \(S_3\)) mirror the costs \((C_1, C_3\) and \(C_3\)) and are measured and valued in the same way and are the costs not spent on an alternative activity. Global willingness to pay \((W')\) could potentially include all the consequences identified in Table 4, depending on what the respondents to the willingness to pay perceived to be important.

Table 4. Formulations of economic evaluation in health care. (Source: Drummond et al. (5) ).

<table>
<thead>
<tr>
<th>Evaluation technique</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost minimisation analysis (CMA)</td>
<td>((C_1 - S_1)) ((C_1 + C_2 + C_3) - (S_1 + S_2 + S_3))</td>
</tr>
<tr>
<td>Cost-effectiveness analysis (CEA)</td>
<td>((C_1 - S_1)/E) ([C_1 + C_2 + C_3] - (S_1 + S_2 + S_3)]/E^*)</td>
</tr>
<tr>
<td>Cost-utility analysis (CUA)</td>
<td>((C_1 - S_1)/U) ([C_1 + C_2 + C_3] - (S_1 + S_2 + S_3)]/U^*)</td>
</tr>
<tr>
<td>Cost-benefit analysis (CBA)</td>
<td>((W') - (C_1 + C_2 + C_3)) ([W + V + S_1 + S_2 + S_3] - (C_1 + C_2 + C_3)])</td>
</tr>
</tbody>
</table>

\(E\) and \(U\) represent changes in effectiveness or health status, as compared with an alternative.

Cost minimisation analysis (CMA) is based on the assumption that the consequences of two or more activities are identical. It is only necessary to find the alternative with the lowest cost.

Cost-effectiveness analysis (CEA), along with cost-utility analysis (CUA), is used for assessment of both technical efficiency and cost-effectiveness. In CEA, costs are measured in monetary units and health effects are measured in the natural units relating to the objectives of the programme, for example, average blood pressure improvement in mmHg, cases found, cases of disease averted, patients showing
significant improvement, lives saved, and years of life gained. The results are often expressed as a cost per unit of effect.

**Cost-utility analysis** (CUA) facilitates comparison between different medical specialities. Quality-adjusted life-years (QALYs), where each year of life is multiplied by a weight reflecting quality of life, were developed for this purpose. QALYs are estimated by using one of three different techniques — rating scale, standard gamble, and time trade-off — to assign a weight between 0 (dead) and 1 (in full health). Healthy year equivalents (HYEs), a variant of QALYs, are defined as the number of years in full health that are considered equivalent to the lifetime health profile, that is, a succession of health states changing over time. The number of HYEs is the same as the number of healthy years in the time trade-off method.

**Cost-benefit analysis** (CBA) is based on individual preference regarding the value of increased or decreased health risk as a trade-off against other goods and services. There are three approaches to the monetary valuation of health outcomes (84, 91): *human capital*, where the value of a change in health is measured as increased earning power and decreased health care costs, *revealed preferences*, in which real market choices, i.e., actual purchases, of individuals are observed, and *stated preference of willingness to pay* (WTP), or *contingent valuation* — a hypothetical investigation of the willingness expressed by individuals to pay for improved health). The contingent valuation method (CVM), developed in the environmental field (92), is a commonly-used, survey-based, hypothetical, and direct method that makes it possible to elicit monetary values for individuals’ preferences and willingness to pay for various welfare changes and health care technologies (93, 94). The CVM has also been used to value traffic risk reductions (95-98). Respondents to CVM surveys may also be asked what level of compensation they would be willing to accept (WTA) for a loss (99).

Questions about WTP can be open-ended or binary. There are three main techniques found in the literature (92). The *bidding game* introduced by Randall et al. (100) resembles an auction. A first bid is made to the respondent, who accepts or rejects, and then the bid is raised or lowered, depending on the answer, until the respondent’s maximum WTP is reached. *Payment cards* are used to display a range of WTP values from which the respondent may choose. Development of these techniques was one of the reasons that researchers started experimenting with binary valuation questions. In a *binary* contingent valuation question, as described by Johannesson et al. (91), the respondent is asked to accept or reject a single bid for the amount which they would have to pay in exchange for a health-related programme or some improvement in health status. A respondent who accepts the bid in a binary contingent valuation question is assumed to have a maximum WTP in excess of the bid, while a respondent who rejects the bid is assumed to have a maximum WTP less than the bid. The population of respondents is stratified into
sub-samples, each offered a different bid. By analysing the various sub samples and making assumptions about the shape of the demand curve, it is possible to calculate the proportion of respondents who are willing to pay as a function of the bid (price). One advantage of this technique is its resemblance to an actual market situation; individuals are used to deciding whether or not to buy a good at a specific price. Binary valuation questions are now a commonly used elicitation technique.

### 3.4 Economic evaluations in the dental health care literature

Economic studies in dentistry can be grouped into three main categories: demand analyses, the effects of out-of-pocket payments and insurance systems on demand, for example Grytten and Holst (101) investigated the price-elasticity between income and demand; supply analyses, the study of production and remuneration systems (90); and the economic evaluation of specific treatments and care programmes (102). Many studies (103–107) have focused on supply analysis, analysing technical efficiency, and productivity issues. A common output in dentistry has therefore been measured by several intermediate measures, including number of patients, number of patients treated per hour, and number of procedures per hour/visit. However, ideally measurements ought to be measurements of change in oral health or of each dental provider’s contribution to oral health. Economic evaluations of health-related topics in dentistry have concentrated on preventive measures, particularly for caries. This is understandable because prevention has the potential to save money. Some of the reported evaluations within preventive dentistry, using different techniques, are listed in Table 5. However, there have been a few studies of other dental branches and one example is a very meticulous economic evaluation of dental implants by Karlsson (108).

#### 3.4.1 Costs

The real cost of any programme is not the number of dollars or crone appearing on the programme budget, but rather, the health outcomes achievable by some other programme which has been forfeited by committing the resources in question to the first programme. It is this opportunity cost which economic evaluation seeks to estimate and to compare with programme benefits (5). The first step in calculating cost is to identify the kind and number of resources a treatment requires (43). According to Yule et al. (102), there is a great potential for more detailed evaluation of costs (also considering the opportunity cost) in economic evaluations of dental health care. Doherty and Hussain (109) compared the costs of providing children’s dental services in three different practice settings. Holst and Brembo (110) in describing net costs for dental care and estimating treatment costs calculated cost
savings as time saved on fillings due to preventive efforts. Several authors (111-115) have used fees for services as an approximation of cost calculation. Drummond et al. (5), Weinstein (116) and Jönsson & Karlsson (43) advocate a more detailed cost evaluation since fees are more closely associated with revenue and it is not certain that fees in fact reflect the actual cost. Horowitz and Heifetz (117) and Klock (118) likewise used a more detailed cost evaluation technique.

3.4.2 Outcome measure in preventive dentistry

Cost-effectiveness assessments of preventive dental programmes have assumed that the goal is to reduce the number of decayed, missing or filled teeth or surfaces. The DMF index introduced by Klein and Palmer (36) has been frequently used in the literature as a common outcome measure, for example by Sköld (114), Horowitz and Heifetz (117), Stephen and Campbell (119) and Vehmanen (120). The DMF index has been criticised because one of its drawbacks is that it ignores changes in quality. Birch (121) improved the DMF index by developing a measure for the quality-adjusted tooth years (QATYs). The QATY measure is constructed by giving the Ds, Ms, and Fs different weights and introducing a time dimension for tooth quality. In an attempt to value the different components of the index Fyffe and Kay (122) introduced different tooth health utilities combined with the DMF index. Marcus et al. (123) constructed a multi-dimensional oral health index which reflected more detailed information of oral health status. Despite such attempts to develop a more suitable outcome measure the DMF index is still frequently being used.

3.4.3 Cost minimisation analysis

Arrow (124) used this evaluation technique in a fissure sealant study.

3.4.4 Cost-effectiveness analysis

Health economic evaluation in dentistry is dominated by cost-effectiveness analysis for caries-preventive measures. Different categories of CEA can be seen in the literature; it is sometimes connected to original caries-preventive programmes (118, 125-127) and sometimes to more theoretical models for caries-preventive CEA (117, 128-130). Some CEAs and their results are summarised in Table 5.

3.4.5 Cost-utility analysis

Cost-utility analyses are very rare in economic evaluation of preventive dental health care. Using a theoretical model for improvement of the DMF index in a water fluoridation programme, Birch (121) found that the outcome measure was useful and that the programme resulted in a cost per QATY of 10.43 pence. He
compared this with a restorative strategy that gave a cost per QATY of 90.11 pence. O'Keefe (131) studied water fluoridation using QATYs as outcome measure to compare two programmes, one non-fluoridated and one fluoridated; the results showed a cost saving for each QATY gained of $17.36 by using the fluoridated programme.

3.4.6 Cost-benefit analysis

Despite the increased interest in CBA among dental health researchers, only a few such analyses have been performed; a sample of them is presented in Table 5. Further, it has been noted that the monetary benefit of preventive programmes in dental health care is often calculated using the assumption that the cost of treating carious lesions is equal to the fee charged, which is not always the case, and also that this restorative cost is the sole determiner of the value of the saving made by preventive efforts (43). These measures do not take into account the effect of oral health on quality of life and utility. Two different types of CBA can be identified in the literature; studies that use future cost savings as an alternative to a real CBA (112, 118, 119, 132-134), and a recently published CBA in which the monetary value of the outcome was measured using the CVM (135-139).

Doessel (132) used the measure of cost savings made by averting future restorations in a water fluoridation programme to show a positive net effect. Cost savings were also used as a measure of achieved benefit in a successful NaF tablet programme in studies by Stephen and Campbell (119) and in a study by Petersson and Westerberg (133) who described a positive net benefit of a fluoride varnish programme. Leverett et al. (112) used treatment cost as a measure of benefit when calculating a benefit/cost ratio in a pit and fissure sealant programme. Klock (118) showed that traditional restorative dental care is less expensive than preventive care, while O'Rourke et al. (134) assessed both cost savings and intangible benefits (such as less anxiety and treatment) from a fluoride tablet programme.

Smith and Cunningham (135) used the payment card technique to elicit WTP for a public and patient group concerning their preferences for orthognathic treatment. The study found positive net benefit values. Cunningham and Hunt (136) studied the relation between utility values and WTP and thereby also the validity of the WTP measure. Using the payment card technique they found a WTP value of £6,833 for requesting orthognathic treatment for the correction of dentofacial deformity. van Steenberghe et al. (137) used the bidding game technique to study patients’ WTP for an anaesthetic gel, finding a median WTP of $10. Dixon and Shackley (138) used payment cards to investigate respondents’ preferences and WTP for water fluoridation. They emphasised the ability of the WTP technique to identify losers and their welfare loss. Matthews et al. (139) studied WTP for periodontal therapy using a bidding game to elicit the WTP for different therapy
options. The results favoured periodontal surgery. With support from other studies, (92, 140), they proclaimed that WTP is likely to be correlated with income. This result was also supported by Lindblom and Westerberg (141), who similarly used a bidding game to investigate individuals’ WTP for different dental interventions.
Table 5. Economic evaluations of different caries-preventive measures.

<table>
<thead>
<tr>
<th>Author</th>
<th>Preventive measure</th>
<th>Cost and consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CMA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrow (124)</td>
<td>Fissure sealant</td>
<td>Less cost in sealant group</td>
</tr>
<tr>
<td><strong>CEA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birch (129)</td>
<td>Water fluoridation</td>
<td>£1.60 and £6.50 per dmft person reduction per year in high- and low-caries areas, respectively</td>
</tr>
<tr>
<td>Manau et al. (142)</td>
<td>Water fluoridation</td>
<td>£0.39 per averted DMFS</td>
</tr>
<tr>
<td>Horowitz &amp; Heifetz (117)</td>
<td>Water fluoridation</td>
<td>£0.20–1.90 per averted DMFS</td>
</tr>
<tr>
<td>Klein et al. (126)</td>
<td>Water fluoridation</td>
<td>£0.036 and £0.48 using costs from Denver and Virginia, respectively</td>
</tr>
<tr>
<td>Klock (118)</td>
<td>Preventive mix*</td>
<td>SEK167–186 per saved tooth surface</td>
</tr>
<tr>
<td>Donaldson et al. (125)</td>
<td>Preventive mix*</td>
<td>£3.47 and £9.44 for children aged 4–6 and 7–10 years, respectively, per incremental improvement in DMFS</td>
</tr>
<tr>
<td>Manau et al. (142)</td>
<td>Fluoride mouth rinse</td>
<td>£2.26 per averted DMFS</td>
</tr>
<tr>
<td>Horowitz &amp; Heifetz (117)</td>
<td>Fluoride mouth rinse</td>
<td>£1.00 per averted DMFS</td>
</tr>
<tr>
<td>Googin et al. (143)</td>
<td>Mouth rinse + sealant</td>
<td>IR£0.66 per tooth surface saved</td>
</tr>
<tr>
<td>Horowitz &amp; Heifetz (117)</td>
<td>Topical fluor applications</td>
<td>$1.00–$21.30 per averted DMFS</td>
</tr>
<tr>
<td>Ramos-Gomez &amp; Shepard (144)</td>
<td>Fluoride varnish, three levels of frequency</td>
<td>$72.69, $65.74 and $66.28 per caries surface averted for levels 1, 2 and 3, respectively</td>
</tr>
<tr>
<td>Sköld et al. (114)</td>
<td>Fluoride varnish</td>
<td>SEK1 175 per averted DMFS</td>
</tr>
<tr>
<td>Klein et al. (126)</td>
<td>Fissure sealant</td>
<td>£40–£80 per saved tooth surface</td>
</tr>
<tr>
<td>Morgan et al. (127)</td>
<td>Fissure sealant</td>
<td>AU$11.80 per averted DMFS; C/E ratio = 1:41</td>
</tr>
<tr>
<td>Werner et al. (145)</td>
<td>Fissure sealant</td>
<td>£65 and $42, respectively, per saved tooth surface in a dental clinic and a school-based application</td>
</tr>
<tr>
<td><strong>CBA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Griffin et al. (115)</td>
<td>Fissure sealant</td>
<td>Range from cost savings up to a cost of £73.96 per child for three delivery strategies</td>
</tr>
<tr>
<td>Widenheim &amp; Birkhed (113)</td>
<td>Fluoride tablets</td>
<td>SEK167 per tooth surface saved</td>
</tr>
<tr>
<td><strong>CUA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birch (121)</td>
<td>Water fluoridation</td>
<td>10.43 pence per QATY gained</td>
</tr>
<tr>
<td>O’Keefe (131)</td>
<td>Water fluoridation</td>
<td>$17.36 cost saving for each QATY gained</td>
</tr>
</tbody>
</table>

*preventive mix = a combination of measures such as instructions in dental hygiene, as well as tooth cleaning, fluoride application, and sealants.

C = cost; B = benefit; C/B ratio = cost-benefit ratio; C/E ratio = cost-effectiveness ratio. QATY = quality-adjusted tooth year.
The results summarised in Table 5 indicate that community water fluoridation was the most cost-effective and cost-saving preventive measure, according to CEA and CBA studies. Fluoride varnish and sealant measures showed a higher cost per averted DMFS compared with other measures. In CBA studies (in which benefits are equalised with treatment cost) benefits of fluoride varnish exceeded cost and some fissure sealant studies have favoured restorative care. Many studies suffer from methodological problems and deficiencies, however, which makes comparisons between different health economic evaluations difficult and often impossible. In a review of the literature concerning evaluation of water fluoridation White et al. (149) report that the economic evaluations reviewed did not provide sufficient information about importance for public policy. The authors gave suggestions for improvements. Sintonen and Linnosmaa (89) concluded that even if there have been some improvements many challenges still remain. In a critical review and assessment of health economic evaluations of caries-preventive measures by the Swedish Council on Technology Assessment in Health Care, SBU, (150) guidelines are given for critical assessment of economic evaluation, as described by Drummond et al. (5). One of the conclusions was that assessment of health economic effects is difficult because of absence of well-grounded studies. Changed conditions since the period when most of the cited studies were performed, including a decrease in caries prevalence in many countries, also influence their usefulness to decision-makers. The report by the SBU (150) using more up-to-date figures of caries prevalence and calculation of costs, shows that in theory the cost-effectiveness ratio per averted DMFT was 199 SEK for water fluoridation, 982 SEK for fissure sealants and 1 877 SEK for fluoride varnish. With a cost-benefit approach the figures show a positive net benefit of 2 SEK for water fluoridation and a cost of 700 SEK for fissure sealants and of 1 562 SEK for fluoride varnish, per averted DMFT.
4. Dental caries and the Caries–preventive project

Like most of the chronic infectious diseases, dental caries is influenced by several interdependent factors. The local manifestation in the oral cavity with lowered pH is due to saccharose fermentation of bacteria. Frequent intake of saccharose, high occurrence of bacteria in the mouth, and certain defensive factors and their characteristics present in the saliva are all important risk factors for development of the disease. Besides this oral medical explanation of the disease, epidemiological studies of the distribution of dental caries such as the one by Winther (151) have shown that social factors are often responsible for variations across the population while Faresjö et al. (152) report that social factors have an impact on the effects of preventive care.

The use of fluoridated toothpaste and fluoridated water has been considered to be an important explanatory factor for the decrease in caries during the past decades (153). Marthaler (154) claims, however, that the reduction in caries cannot be ascribed to one factor only. Other explanatory variables include decreased virulence of the caries microbiological environment, societal changes, and changes in the way that the disease is measured (154).

4.1 Prevention of dental caries

Preventive measures have long been of interest to dental health care practitioners. Prevention can be divided into three types of interventions; primary prevention, which aims to prevent the onset of disease or injury, secondary prevention, which encompasses measures designed to stop or minimise the progression of early disease while the individual is still generally asymptotic, and tertiary prevention, which has the goal of preventing further deterioration and disability while attempting to improve or restore residual function. In Sweden, preventive efforts are directed towards the main oral health diseases — caries, gingivitis, and periodontitis — with a focus for children and adolescents on caries prevention. A mixture of preventive strategies is used.

Burt (155) discusses the necessity of new prevention strategies due to the changed distribution of caries. The most generously funded programmes to control dental caries are to be found in Scandinavian countries where caries was a major problem for school children in the 1970s. The caries decline is of course good news but it is not an unmixed blessing in dentistry. For example, it raises questions of whether caries is the same public health problem it used to be, whether we should continue our preventive efforts in caries control and, therefore, whether caries control merits the same allocation of public resources. The reduced severity of caries means that further reductions in disease levels require greater commitment of resources to
make an impact. One response to the altered caries distribution is the targeted programmes aimed at specific groups at high risk of caries disease.

In Sweden several authors have confirmed the reduction in caries. Källéstål et al. (156) in their study on caries in 13-year-olds in the Swedish county of Västerbotten showed a 75% decrease in caries between 1967 and 1987. Sundberg (157) showed a decrease from 3.1 to 1.5 DFTs in 12-year-olds across Sweden during the period 1985–1994. During the same period the percentage of caries-free 12-year-old children increased from 22% to 48% and the number of children with high DFT values likewise decreased.

The prevention efforts have been focused on fluoride application, improved oral hygiene, and diet counselling. The fluoride effect is not fully understood but there is a consensus that fluoride works locally on the tooth during the process of demineralisation and remineralisation by diminishing the mineral losses on the crystal surfaces of the tooth enamel and increasing remineralisation. This occurs at low concentrations of fluoride (158). This may explain why fluoridated toothpaste, fluoridated mouth rinse, and water fluoridation have been effective. Fluoride rinsing was reported to be effective (159) in the early clinical trials where also the caries distribution was different. Fluoride varnish is another way of administering fluoride. Varnish has a high fluoride content and is applied by a professional dental provider (a nurse, dental hygienist or dentist). The varnish serves as a fluoride deposit which releases fluoride upon need (160). Varnish has been reported to be effective in several studies (161, 162), especially when applied more intensively, that is, three times a week once or twice a year (114, 163). Historically, the preventive work in Sweden is based on individual instructions in oral hygiene, and application of fluoride. The positive oral health effect of improved oral hygiene was studied by Axelsson et al. (164). Dental sealant has been reported to be both effective (165) and expensive, and is recommended for targeted strategies in certain geographic areas with high caries experience, for first and second molars at risk (166). Fluoride tablets are another fluoride application that has been reported to be effective in school children (118). Its effect has been said to be comparable to that of mouth rinsing (167).

The SBU (150) in their review of the dental literature (900 studies) on effectiveness of different caries-preventive measures produced strong scientific evidence for the effectiveness of fluoridated toothpaste, and some scientific evidence for the effectiveness of fluoridated mouth rinse for children, adolescents, and root-surface caries for the elderly, and for the effectiveness of application of fluoride varnish at least twice a year, as well as some support for the effectiveness of fissure sealant. For strong evidence, certain criteria were required, including randomised controlled studies, a representative selection of individuals, at least 3 years’ follow-up for permanent teeth, and independent persons evaluating the results. The scarcity of
well-accomplished studies based on strong evidence is obvious. This scarcity causes uncertainty and makes future recommendations for the best preventive strategy difficult.

4.2 The caries-preventive project

The shift in Swedish dental care from population-based prevention to a more individualised high-risk strategy has caused considerable local variations at the dental clinics with regard to both preventive measures and time intervals between health check-ups. Källestål and Holm (168) showed that caries-preventive measures aimed at high-risk individuals were often carried out in an unstructured manner and were not always directed at those in greatest need. It was obvious that there was a need for more systemised guidelines for clinical preventive work. The planning of the project “Evaluation of caries-preventive measures” (169) took place in the early 1990s, where also the health economic perspective was included.

The project started in 1995, when the children were 12 years old, and they were to be followed to the age of 18. The project is described in detail by Källestål et al. (169). The 26 dental clinics that had agreed to participate in the study are distributed throughout the country. The project was approved by all medical ethics committees in Sweden. Of the 4 355 12-year-olds invited to participate in the study, 3 373 participated in 1995, at the study start. At the screening session the study group were divided into a low-risk and a high-risk group. The distribution of social strata in the study group was similar to that for the general Swedish population (170). The so-called “DMFS value”, giving decayed (D), missing (M) or filled (F) teeth or surfaces (S), for the individuals who did not participate in the study was similar (mean 1.7) to that of the study group. The design of the study and the numbers of individuals who participated at study start are shown in Figure 3.

Figure 3. Study design of the study titled “Evaluation of caries-preventive measures” (169).
High-risk individuals were identified by deducting previous caries experience from present dental health status. Children with more than one decayed approximal surface, enamel (E) or dentine caries, or in whom a filled approximal surface was present or a tooth was missing due to caries (D_eMFS_a>1) were allocated to the high-risk group. Subjects who, according to the examining dentist, ran a high risk of caries because of mental or physical disability or chronic disease were likewise assigned to the high-risk group. In the rest of the subjects, after restoration of any caries lesions the amount of lactobacillus in saliva was examined by using what is termed a “dip-slide test” (Dentocult®, Orion Diagnostica, Helsinki, Finland). Individuals with CFU>10^5 were allocated to the high-risk group. The individuals in the high-risk group (1 134) were called in for a dental examination every year, and preventive measures were carried out in accordance with one of four randomly distributed alternatives (a–d), as listed in Figure 4. The low-risk group were examined every other year. All dental examinations were carried out by dentists, whereas the preventive measures were performed by dental hygienists and by dental nurses specially trained in prophylactic work.

Figure 4. Description of the different preventive methods a–d.
The high-risk group was subdivided into four groups, each one randomly assigned to one of the four preventive programmes. The preventive methods (a–d), randomly tested in the experimental group, were designed to be similar to the methods used in the clinical setting with different fluoride content and represent a step-wise increase in contact with dental personnel, and cost (see Figure 5). Subjects from the high-risk group were examined every year. The low-risk subjects were examined every other year and received no specific preventive treatment. At these biannual examinations of the whole cohort an extensive questionnaire was filled in by all subjects.

Figure 5. Intervention model showing preventive methods a–d and a step-wise increase, from a to d, in dental care and cost.

The drop-out rate was 8% every 2 years, altogether 527 individuals (16%) over 4 years. The total number of examined participants in the high-risk group was 1 134 at study start, and 1 118, 1 061, 1 018 and 968 over the 4 years. The total number out of 3 373 participants who were examined every second year was 3 107 and 2 846, respectively. The loss of responses within the questionnaire was low, at the most 10%, for subjects both in the high- and low-risk group.

To ensure examination reliability a re-examination of 5–9% of the adolescents was performed each study year. Twice yearly a set of bite-wing tests was read by all examiners. Although congruence towards the “gold standard” decreased over time the reproducibility was fair to good (mean intra- and inter-examiner reproducibility $\kappa = 0.82$ and $\kappa = 0.74$, respectively) so that the results may be considered reliable with regard to both inter- and intra-examiner reproducibility.
4.3  *Economic evaluation in “health care enterprises”*

Evaluation methods, including economics, are of potential interest to decision-makers. The role of evaluation is to give the decision-maker a theoretically-correct answer to the question at hand; the particular role of health economics is to identify, measure, and (where possible) value a wide range of costs and consequences in order to improve the basis for decision-making (5). Mason and Drummond (172) indicated as early as 1995 that economic evaluations have grown considerably in importance, noting that there has been an exponential rise in the number of published studies over the last few years as health care decision-makers begin to seek data that will assist them in allocating scarce resources. However, as previously mentioned, there are often methodological weaknesses and inconsistencies in the way that both costs and consequences are measured, reducing their usefulness in the decision-making process.

The significant decline in caries incidence, and its skewed distribution, have moved the focus of preventive strategies from the general population to specific high-risk groups. As noted in the introduction to this thesis, lack of resources in the Swedish public health care sector has led to a reorganisation of activities within clinics that has not been proved to be to the benefit of such groups. In times of resource scarcity, whether the resource be finances or personnel, it is important that decision-makers are adequately informed regarding the increased need for improvements in technical efficiency, and the best strategy for distribution of health measures. Even though caries incidence has declined, other oral health problems such as gingivitis and periodontitis must not be ignored. The organisation of a health care enterprise with an appropriate personnel mix to ensure an optimal health outcome presents a considerable challenge. Health economics has the potential to make a sound contribution to a more comprehensive basis for the decisions that will need to be made.
5. AIMS

The overall aim of this thesis was to evaluate caries preventive measures from a societal perspective, and thus develop effective health economic analytical methods.

5.1 Its specific aims were:

- to investigate the use of resources in preventive dentistry and calculate the related costs;
- to demonstrate techniques suitable for evaluating dental care costs in the Swedish public dental health care sector and establish whether and how the real costs differ from the fees charged;
- to evaluate and develop outcome measures suitable for preventive dental care; and
- to test costs and consequences within a health economic decision model adapted to preventive dental care.
6. SUBJECTS AND METHODS

All research reports in this thesis were approved by the Human Research Ethics Committee of Umeå University.

Professional dental care in Sweden is organised as follows: activities such as diagnostics, intervention (treatments) and prevention of disease are carried out by dentists, dental hygienists and specially trained dental nurses. Diagnostics and intervention dominate the dentist’s work, which is performed with the assistance of dental nurses. The dental hygienist treats both children and adults. The dental hygienist’s role is to help prevent, and treat periodontal disease and dental caries. Specially trained dental nurses work mainly with prevention of dental caries in children and adolescents. They may also perform other tasks that have been delegated by the dentist. Both dental hygienists and specially trained dental nurses mostly work independently, with no assistance. These three labour categories are the direct distributors of dental care in public dental clinics. Other tasks, such as central administration and other work not directly related to the health care process, such as cleaning and laundry, are shared, as are facilities for sterilisation, and the rest and waiting-rooms. Resources used in the clinics are: labour (divided into dentists, dental hygienists, dental nurses and other workers); capital (buildings and equipment); materials and supplies; and services (laundry, telephone, post, education of personnel, etc).

6.1 Use of resources for prevention of dental caries

The starting point of the present economic evaluation was an analysis of one dental clinic, with focus on resources (i.e. costs) used for prevention of dental caries (Paper I). The major part of the working hours (80%) for the clinic concerned was devoted to children and adolescents, while only 20% of the clinic’s time was spent on adults. The study gave special emphasis to the following three aspects: the distribution of time spent on different activities at the clinic; the caries progression in 92 adolescents during the 4 study years; and costs based on treatment time allocated to prevention and related to different caries progression in these adolescents. To investigate the distribution of treatment time spent on different activities a special account was made of all services provided at the clinic. The account was made for 1 week, and was taken to be representative for the year. As previously described by Källestål & Holm (168), caries progression in 13–17-year-old children (1987–1991) was analysed by using radiographs, with a focus both on new proximal caries and on progression of lesions that were present at baseline. A progression score was calculated for each surface. Costs were calculated by using the clinic accounts. The total annual cost for the clinic was calculated to be 7 436 000 SEK (£693 172). All costs were calculated in Swedish crone (SEK) as well as in pound sterling (£).
1992 prices and the exchange rate of 1 July 1992. Costs had to be covered by incomes directly associated with service time. Service time (i.e. time available for dental service) was calculated from statistics collected from the employer, Västerbotten county council. The total service time was 8 647 hours, which gave a hourly cost for dental service of 860 SEK /hour (£80/hour) calculated by dividing total clinic cost by service time. The analysis of costs was based on the assumption that the provision of dental services in a clinic is designed to provide a mix of services with the ultimate aim of promoting oral health, making the various activities indivisible. Total time allocated to prevention was calculated by using notes on prophylactic treatments from the patient records, as well as on the time used for treatment.

### 6.2 Evaluation of dental care costs

To overcome methodological deficiencies and make the cost analysis more explicit and useful for further economic evaluation we needed to take another approach (Paper II). As charges (i.e. fees for services) have been used in several studies as a measure equalised with costs, a comparison of the two measures was also made. Twenty-six public dental clinics from across Sweden participating in the intervention study titled “Evaluation of caries-preventive measures” (169) were analysed with a focus on costs. The clinics had expressed an interest in participating in the study on having been invited to participate and were therefore not chosen at random. All 26 clinics except one, which was run co-operatively, were run by the local county. Accountancy data for the year 1994 were collected using financial records from the clinics and with the assistance of economists from the local councils. A questionnaire was designed including questions on all financial data, treatment time and other clinic characteristics. Treatment time was the crucial measure of the basic resource used during the care rendered by dentists, hygienists and dental nurses.

Costing has two elements: the measurement of the quantity of the resource used \( (q) \) and the assignment of a unit cost or price \( (p) \). In this study \( q \) stands for number of minutes used for treatment. A key issue that was investigated in this study was how the resources and costs were related to the basic measure of the dental care process, treatment time. In this study three different methods were used for calculating unit cost and with all of them the costing procedure implies that the cost of treatment time adds up to the total cost for the clinic. The first, average treatment cost, does not distinguish between who is performing the treatment: dentist, hygienist or nurse. Average treatment cost is calculated by taking the ratio of the total cost to the total number of treatment minutes. The other two methods take into account the fact that treatment time cost differs for dentists, dental hygienists and dental nurses. In both these methods a base cost, based on salary cost for each practitioner, is calculated. Costs for overheads are added by two alternative
principles: a *percentage mark-up* to the base cost for method 2 and an *additive mark-up* for method 3. Method 2 uses a percentage mark-up to the base cost by calculating an overhead factor, \( \text{OH}(x) \), which is equal for all three practitioners (dentist \( d \), dental hygienist \( h \), and dental nurse \( n \)). This quota or overhead factor (equal for all) multiplied by the base cost for the three practitioners gives the unit cost for each one.

\[
\text{OH}(x) = \frac{\text{total clinic cost}}{\text{base (d) } \times T_t(d) + \text{base (h) } \times T_t(h) + \text{base (n) } \times T_t(n)}
\]

This means that dentists who have higher wages bear a higher share of total overhead costs than do the dental hygienists and nurses. Method 3, using an additive mark-up, makes it possible to calculate how much of the overhead cost should be allocated to the dentist compared with the other dental care providers. The formula that allocates the overhead costs is \(-\frac{\text{total OH cost}}{(T_t(d)\times X + T_t(h) + T_t(n))}\), where \( X \) is the factor that shows how much overhead cost per treatment time is allocated to the dentist.

A practical example of the cost calculations is presented in the Appendix A.

### 6.3 Cost-effectiveness of caries-preventive measures

The next step in the study was to compare, using a CEA, the costs and consequences of the caries-preventive measures accomplished in the intervention study “Evaluation of caries-preventive measures” (169) (Paper III). The appropriate way of evaluating cost-effectiveness is by using an incremental cost-effectiveness ratio. To the direct dental health care costs (Paper II) costs contributed by the patient and the patient’s family are added. The patient- and family-related costs consist of time, travelling expenses for the persons accompanying the children to the clinic, and out-of-pocket expenses. Data on these costs were collected by means of a questionnaire given on three occasions to the children and once to the accompanying person. As the outcome measure the 4-year caries increment was used, as assessed by Fjelldahl (173). Increment was calculated by subtracting the caries experience score at the last examination from the baseline score. Caries experience was calculated by using the indices decayed, missed due to caries, and filled surfaces (DMFSs) and \( D_e\text{MFSs} \) (including enamel caries). The increment was computed as net DMFS and \( D_e\text{MFS} \) increments by deducting previous caries experience from present dental health status.

The incremental cost-effectiveness ratio is calculated by comparing the additional costs and additional effects a new programme provides in relation to the effects the other programme offers. The outcome measure effect, \( E \), in this study was expressed as incremental change in \( D_e\text{MFSs} \) in permanent teeth for the different
 intervention programmes a–d (see Figure 4). The incremental cost-effectiveness formula could be expressed as follows:

\[
[\text{Costs (C}_1 + \text{C}_2)_{\text{programme}, x} - \text{Costs (C}_1 + \text{C}_2)_{\text{programme}, y}] - \text{cost savings (S}_1 + \text{S}_2) / (E_{\text{programme}, x} - E_{\text{programme}, y})
\]

where \(C_1\) = dental health care costs, \(C_2\) = patient- and family-related costs, and savings means cost savings of averted disease where \(S_1\) = cost savings in the dental health care sector by preventive programmes, \(S_2\) = savings in patient- and family-related resources and \(E\) = effects or outcome measures.

### 6.4 Oral health-related quality of life measures in caries preventive care

An outcome measure should express benefits in terms of increased quality and utility (43). The composite DMF index introduced by Klein and Palmer (36) has been widely used as an outcome measure in caries-preventive research. However, it has the disadvantage of ignoring changes in quality. Over the last few decades, different and more individually-adapted indicators have been developed to supplement clinical indicators with measurements of functional and psychosocial outcomes. The next step was therefore to analyse whether OHRQOL measures can be useful in health economic evaluation (Paper IV).

#### 6.4.1 Subjects and data collection:

**High-risk group:** An epidemiological database was used to identify all inhabitants of a given Swedish county who were 19 years old, were born in 1986, and had a DMFT score > 8 including at least three teeth with proximal lesions or fillings. The patient records of these individuals were then used to exclude those who had in the past year either undergone orthodontic treatment or demonstrated symptoms of jaw or oral disease other than caries. After exclusion, thirty-seven subjects remained.

**Low-risk group:** The same methods were used to identify those individuals born in 1986 who had a DMFT score of 0, were classified by dentists as having an extremely low caries risk, and who, like those chosen for the high-risk group, had not experienced either orthodontic treatment or oral symptoms within the past year. From among the 614 individuals thus identified, 63 subjects were randomly selected using a computerised randomising technique.

Between both groups, 100 adolescents were invited to participate in the study. The total falling-off rate was 18% (seven subjects from the high-risk group and eleven from the low-risk group). Nine individuals did not accept the invitation to participate; the main reasons given were vacations and preoccupation with senior
high school examinations. The other nine were excluded because they had just begun dental treatment (mainly involving fixed orthodontic appliances), and so no longer fulfilled the inclusion criteria. Thus 82 subjects eventually participated, 30 in the high-risk group and 52 in the low-risk group. The internal loss, i.e., the failure rate for completion of all questions, was very low, with the only missing data being from two individuals who failed to complete questions related to parental occupation and type of housing.

The questionnaires completed by the subjects were divided into three sections: a) demographics and socio-economics b) self-estimation of caries risk, and willingness to pay, and c) a test of two OHRQOL measures: CPQ11-14 (79) and OHIP-14 (73).

6.5 Valuation of caries preventive care

Although cost-benefit analysis is the evaluation method with the strongest foundation in welfare economics, it is seldom found in the dental literature. The study described in paper V used the contingent valuation method to investigate 19-year-olds’ willingness to pay for a caries prevention programme. CVM includes three stages. Firstly, information on respondent characteristics is collected. Secondly, the respondents receive a fair and detailed description of the good or service to be valued and the conditions under which it is available. Finally, valuation of the benefit is carried out.

The study sample and the data collection procedure were the same as the study described in the previous section. The WTP scenario was read out by the data collector/interviewer, and precautions were taken to avoid misunderstanding of the question (see Appendix B). The 19-year-olds’ WTP was used both as an outcome measure for cost-benefit analysis and in the introduction of a new outcome measure, Value of Statistical Oral Health (VOSOH).

The CBA was performed according to the benefit-cost function described by Drummond et al. (3) for calculating the net social benefit of a project in terms of costs and derived benefits, adjusted for time by a discounting factor. This function can be expressed as follows:

\[
\text{NSB}_i = \sum_{t=1}^{n} \frac{b_i(t) - c_i(t)}{(1 + r)^{t-1}}
\]

- \(b_i(t)\) = benefits (in monetary terms) derived in year \(t\)
- \(c_i(t)\) = costs (in monetary terms) in year \(t\)
- \(r\) = discount factor at annual interest rate
- \(n\) = lifetime of project

\[
\text{NSB}_i = \text{net social benefit of project } i \text{ (discounted)}
\]
The function calculates the net benefit and costs adjusted for time by discounting. Evaluation was performed from both a broad societal perspective and a dental health care perspective, since although the societal perspective is the one more commonly used in evaluation of health care (5), it can also be argued that the narrower perspective of dental health care is the one that the individuals will have in mind when considering WTP. Thus net social benefit, NSB, was calculated for both the societal perspective and the dental health care perspective.

Estimates for participation cost were taken from the study by Oscarson et al. (174). From the dental health care perspective, this cost is solely the treatment cost ($C_1$), while from the societal perspective it includes both treatment cost ($C_1$) and patient and family-related costs ($C_2$) such as travel, time, and out-of-pocket expenses. Total cost ($C$) is calculated by subtracting the cost savings ($S$) of averted disease from the participation costs; again the two perspectives result in two variables, $S_1$ and $S_2$, which mirror the cost variables $C_1$ and $C_2$. In both cases the derived benefits, $B$, represent the monetary value of the expected outcome and were defined as the mean yearly WTP for reducing the risk of a decayed tooth surface.

The WTP data was also used to determine a new supplemental outcome measure for CBA studies, the value of statistical oral health, or VOSOH. The concept of a statistical life is used widely in the literature (5, 92, 95-98). An individual’s marginal rate of substitution (MRS) is defined as WTP to reduce the risk of a certain outcome divided by the reduction in risk ($\Delta p$): $MRS = \frac{WTP}{\Delta p}$. The hypothetical VOSOH is motivated by this measure. Oral health comprises a full scale of health conditions, from the worst-case scenario of tooth mortality and loss of function, to minor problems involving a single tooth surface. By using the tooth as an example, this method enables the calculation of different statistical values for different dental health conditions: from the statistical value of a tooth in perfect health, function and surrounding tissues (tooth life), to the statistical value of an intact tooth surface. VOSOH is the overall expression implying perfect oral/dental health; the value studied is made explicit by creating subcategories of VOSOH, for example, intact tooth surface (ITS). The present study calculated the statistical value of an intact tooth surface (VOSOH$\_\text{ITS}$), i.e., a tooth with a healthy enamel surface, free of dental caries and fillings.

6.6 Sensitivity analysis

To test for uncertainty, sensitivity analyses were performed for the cost calculation methods and the incremental CEA of Papers II and III. Since the incidence of dental caries has shown a remarkable decline during the past few decades, the caries risk is likely to be lower in the general population compared to a population with higher risk. To test for uncertainty for the outcome measure VOSOH$\_\text{ITS}$,
sensitivity analyses were accomplished both for caries risk estimation methods and the WTP measure of Paper V.

6.6.1 Incremental CEA in the five-year follow-up

Källestål (175) has described the effect of five years’ implementation of caries-preventive methods used in the Swedish caries-preventive project (169). By using the five-year data, the sensitivity of the incremental CEA model was further tested. The outcome, caries increment, was computed as net dentine DMFS and dentine and enamel (DₐMFS) increments by deducting previous caries experience from present dental health status. The mean DMFS and DₐMFS for the study group was as follows: for group a, 4.06 (SD 4.83) and 7.00 (SD 6.86); for group b, 4.21 (SD 4.38) and 7.10 (SD 6.34); for group c, 3.93 (SD 5.67) and 6.49 (SD 6.77); for group d, 3.64 (SD 4.04) and 5.95 (5.77).

The incremental cost-effectiveness ratio is calculated as described above (see section 7.3.). The outcome measure, or effect (E) was expressed as incremental change in DₐMFS in permanent teeth for the intervention programmes a-d (described previously in Figure 4). Dental health care cost (C₁) for the fifth year, 2000, was estimated using the treatment cost for the fourth year, then discounted five years to 1995 and added to total treatment cost. Patient- and family-related cost, PFC, (C₂) for the fifth year was calculated by adding this year to period 3. Period 3 consists of 1.3 years. The contribution from the fifth year to period 3 was calculated as follows: 1/1.3 multiplied by cost for period 3, discounted five years to 1995 and added to total PFC. The cost savings were calculated as described earlier (Paper III) with use of the outcome from the five-year follow-up and discounted five years. Costs, cost savings, and outcome are shown in their discounted form using a discount rate of 3% for presenting the results of the CEA.

6.7 Differential timing of costs and consequences

Since comparison of programmes or services must be made at one point in time (usually the present), the timing of programme costs and consequences which are spread over a period of time must be taken into account. Even in a world of no inflation and no bank interest, it would be an advantage to receive a benefit earlier and to incur a cost later — it gives you more options (32). In the present study both costs and consequences (effects) were discounted to the base year of the study using a discount factor \((1 + r)^{−n}\), where \(n = \) period in years and \(r = \) discount rate. Dental health care costs (C₁) for 1999 were discounted four years to 1995, costs for 1998 were discounted three years, and so on. Since data for patient- and family-related costs (C₂) were collected three times during the study period, period 1 was equalised with year 1 and 2, and period 1 was discounted for \(n = 2\), period 2 for \(n = 3\), and period 3 for \(n = 4\). All costs and savings were calculated at the price level
of 1994. The assumption was made that health outcomes develop linearly over time and therefore the obtained effect was discounted to the base year, \( n = 4 \). A discount rate of 3\% was used to present the results of the CEA. However, the analyses were also done to show data in their undiscounted form and for a discount rate of 5\%.

In the WTP study of Paper V, allowances must be made for the different timing of costs and consequences. Both costs and effects described in Oscarson et al. (174) were discounted to the study start time, 1995. However, the benefit measure, yearly WTP, was obtained in 2005. Therefore, for comparison purposes the calculated yearly costs from 1995 were adjusted for inflation to 2005 prices.

6.8 Statistical methods

The statistical methods used by Fjelldahl (173) for comparing effects of the different preventive programmes were analysis of variance (ANOVA) to establish differences in four-year increments between the preventive programmes, and Poisson regression with overdispersion for analysis of the incidence rate ratios. Statistical significance was considered to be present at the 5\% level (Paper III). In the OHRQOL and WTP studies of Papers IV and V, all data from the questionnaires were collected and transferred to a computer. The statistical package used was SPSS 12.0.1 for Windows. Descriptive statistics were generated for the outcome variables and used to characterise the individuals in the studies. Differences between the high-risk and low-risk groups were tested with respect to perceived oral health-related quality of life, measured as CPQ_{11-14}, OHIP-14, and global rating scores. Both the overall sums and sub-scale scores were analysed as outcome variables for the OHRQOL instruments and for the global rating score. The overall sums and sub-scale scores were dichotomised after analysing the frequency distribution of the data; for the overall sum scores of OHIP-14 the split was \( 0 = 0 \) and \( \geq 1 = 1 \); for CPQ_{11-14}, \( 3–15 = 0 \) and \( \geq 16 = 1 \); and for global rating, \( 0–1 = 0 \) and \( 2–4 = 1 \). A median split was used for dichotomising the different sub-scale scores of the CPQ_{11-14} instrument. Pearson’s Chi-square test was used to perform bivariate analysis of the association of these variables with each other and with other variables such as gender and socio-economic background. Statistical significance was considered to be present at the 5\% level (Paper IV). Determinants for the individuals’ WTP (Paper V) were analysed in a linear multiple regression model using WTP as the dependent variable, with the independent variables being gender, socio-economic level, type of housing, and caries risk (i.e., belonging to the low-risk or the high-risk study group). Statistical significance was considered to be present at the 5\% level.
7. **RESULTS**

7.1 *Use of resources for prevention of dental caries – cost calculation*

The distribution of time spent on different activities at the single clinic studied showed that 17% of time was used for preventive work. Another 31% was used for restorative work and 19% for diagnostics. The remaining time was used for emergency treatment or administrative work, plus there was a substantial loss of time due to adolescents not showing up (17%). During the 4-year study all children were given treatment, both preventive and restorative, by dentists, dental hygienists or specially trained dental nurses after referral from the dentist. No special criteria had been used for referral. The most common indicators for preventive treatment were high number of initial caries lesions and/or signs of gingival inflammation and/or poor oral hygiene.

A total time of 46.7 hours had been allocated to preventive treatment for the 92 adolescents during the 4 years of the study. By using the hourly cost in the clinic, 860 SEK (£80), the total cost for prevention for the 92 children was 40 162 SEK (£3 744). When ≥20 “progression steps” were used to define high caries active individuals, four of the 92 adolescents were included in the high caries active group. Using notes in the records on the hours of preventive treatment received by this group, the costs for prevention, calculated in the same way as used for calculation of the total cost for dental services, were found to be 1 020 SEK (£95) per subject. For the rest of the group (<20 “progression steps”), the average cost for prevention was 410 SEK (£38). Table 6 summarises the costs for individuals with different caries progression.

<table>
<thead>
<tr>
<th>Progression steps</th>
<th>Subjects</th>
<th>Prevention time (minutes)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>mean</td>
<td>median</td>
</tr>
<tr>
<td>≤5</td>
<td>44</td>
<td>34.4</td>
<td>10</td>
</tr>
<tr>
<td>6–10</td>
<td>23</td>
<td>16.7</td>
<td>15</td>
</tr>
<tr>
<td>11–15</td>
<td>15</td>
<td>17.0</td>
<td>15</td>
</tr>
<tr>
<td>16–20</td>
<td>6</td>
<td>62.7</td>
<td>15</td>
</tr>
<tr>
<td>21–34</td>
<td>4</td>
<td>71.2</td>
<td>52.5</td>
</tr>
</tbody>
</table>
7.2 Evaluation of dental care costs

7.2.1 Distribution of treatment time and cost elements

The distribution of treatment time within the 26 clinics participating in the intervention study “Evaluation of caries-preventive measures” (169) is given in Figure 6. The dentists’ services make up most of the total treatment time, with a mean value of 72%.

Figure 6. Treatment time as a percentage of total working time for dentists, dental hygienists and dental nurses.

Total costs were divided into four major cost categories: labour, capital and material costs, and services. Out of these four elements, labour formed the major part of the total clinic cost, with a mean of 67%. The way in which the different cost elements formed the total cost is shown in Table 7.

Table 7. The cost element as a share of total cost.

<table>
<thead>
<tr>
<th>Cost element/ total cost</th>
<th>Mean</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
<th>25th percentile</th>
<th>75th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour cost</td>
<td>0.67</td>
<td>0.67</td>
<td>0.58</td>
<td>0.78</td>
<td>0.61</td>
<td>0.71</td>
</tr>
<tr>
<td>Capital cost</td>
<td>0.13</td>
<td>0.14</td>
<td>0.06</td>
<td>0.23</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>Material cost</td>
<td>0.08</td>
<td>0.08</td>
<td>0.05</td>
<td>0.11</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>Services</td>
<td>0.12</td>
<td>0.11</td>
<td>0.02</td>
<td>0.24</td>
<td>0.06</td>
<td>0.18</td>
</tr>
<tr>
<td>Total</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.2.2 Unit cost calculation

Method 1
Average treatment time cost (Table 8) is calculated as cost per minute of professional dental care regardless of who the practitioner is. The exchange rate used was US$1 = 7.15 SEK (the exchange rate in September 1995). The average treatment cost per minute varied from 8.50 SEK (US$1.16) to 14.87 SEK (US$2.03).

Methods 2 and 3
Important differences were seen in unit cost depending on the method used for allocation of overhead costs. Table 8 summarises unit cost (methods 2 and 3) for all three professional groups. Nurse and hygienist costs were more sensitive to the method which was being used, compared with the dentist cost. The mean values for dentist cost per minute ranged from 12.82 SEK (US$1.79) to 14.06 SEK (US$1.97). For hygienists and trained nurses, the mean value costs per minute varied from 6.67 SEK (US$0.93) to 9.13 SEK (US$1.28) and from 4.36 SEK (US$0.61) to 8.09 SEK (US$1.13), respectively, depending on the method used.

Table 8. Unit cost (SEK/min), according to methods 1, 2 and 3 using data from 1994.

<table>
<thead>
<tr>
<th>Method</th>
<th>Practitioner</th>
<th>Mean</th>
<th>Median</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average treatment cost</td>
<td>Nurse</td>
<td>8.09</td>
<td>8.31</td>
<td>5.25</td>
<td>10.58</td>
</tr>
<tr>
<td></td>
<td>Hygienist</td>
<td>9.13</td>
<td>9.16</td>
<td>5.09</td>
<td>12.19</td>
</tr>
<tr>
<td></td>
<td>Dentist</td>
<td>12.82</td>
<td>12.97</td>
<td>9.32</td>
<td>15.37</td>
</tr>
<tr>
<td>Method 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead factor</td>
<td>Nurse</td>
<td>4.36</td>
<td>4.35</td>
<td>3.19</td>
<td>5.32</td>
</tr>
<tr>
<td></td>
<td>Hygienist</td>
<td>6.67</td>
<td>6.30</td>
<td>2.81</td>
<td>10.45</td>
</tr>
<tr>
<td></td>
<td>Dentist</td>
<td>14.06</td>
<td>14.39</td>
<td>9.95</td>
<td>17.11</td>
</tr>
<tr>
<td>Method 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Same overhead cost per treatment minute for all (x = 1)</td>
<td>Nurse</td>
<td>6.31</td>
<td>6.47</td>
<td>4.32</td>
<td>8.37</td>
</tr>
<tr>
<td></td>
<td>Hygienist</td>
<td>7.38</td>
<td>7.28</td>
<td>4.10</td>
<td>11.99</td>
</tr>
<tr>
<td></td>
<td>Dentist</td>
<td>13.54</td>
<td>13.86</td>
<td>9.38</td>
<td>16.24</td>
</tr>
</tbody>
</table>
7.2.3 Sensitivity analysis for cost calculation

The unit costs used in the cost function are highly sensitive to changes in treatment time and salaries. Decreasing the treatment time by 10% increases the unit cost for both nurses and hygienists by 10%, while increasing the treatment time by 10% will decrease the unit cost by 7%. Changing the salary when calculating the base cost for each practitioner strongly influences the unit cost, but not as much as does a change in calculated treatment time. A change in salary of ±10% will alter the unit cost by ±7% for nurses, ±10% for hygienists, and ±4% for dentists.

7.2.4 Comparison of costs and charges

In 1994 the hourly rate set by Swedish health insurance was 657 SEK (US$91.89) for dentists, 399 SEK (US$55.80) for hygienists and 239 SEK (US$33.43) for nurses. Charges per minute for dentists were 10.95 SEK (US$1.53), for hygienists, 6.65 SEK (US$0.93) and for nurses, 3.98 SEK (US$0.56). These figures compared with the figures in Table 8 show that all three methods show higher mean costs compared with charges, which means that charges do not match costs. There are fewer differences as a result of using method 1 than there are as a result of more detailed costing in methods 2 and 3.

7.3 Cost-effectiveness of caries-preventive measures

7.3.1 Outcome

The distribution of caries increment in the high-risk group was skewed, as reported in Fjelldahl (173). About 200 (21%) subjects had no dentine caries increment during the 4-year period. In 21% of subjects there were one or two new cavities. In other words, 42% of the subjects in the high-risk group had no or at the most two dentine cavities in 4 years. When enamel caries was included, 152 (16%) did not have a cavity in 4 years. There was a dentine increment of ten or more surfaces in 4% of the group, and when enamel caries was included, 17% had an increase of ten new surfaces or more. The mean DMFS and D\textsubscript{2}MFS caries increment in each preventive group between 1995 and 1999 is given in Table 9. The low-risk group showed a mean caries increment for DMFS and D\textsubscript{2}MFS of 1.52 and 3.39, respectively. The preventive programmes in the high-risk group represent an increase in preventive efforts in terms of contact with dental personnel and fluoride treatment. Programme (a) consisted of tooth-brushing/toothpaste technique information (171) and represents the minimum preventive programme comparable to the prevention exercised by the low-risk group since most adolescents brush their teeth. Concerning dentine caries, including also enamel caries, there was a tendency that the increment in caries was lower with more applications of fluoride and with more contact with dental personnel so that 1.1 more surfaces were saved.
in the fluoride-varnishing group (c) than in the tooth-brushing group (a). The differences between the preventive groups (a–d) were not significant when using ANOVA, but when calculating rate ratios (RRs), a significantly lower risk was shown for subjects taking part in preventive programme (c), the fluoride-varnishing group.


<table>
<thead>
<tr>
<th>Group</th>
<th>Intervention programmes</th>
<th>N</th>
<th>DMFS (SD)</th>
<th>DeMFS (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Tooth-brushing</td>
<td>248</td>
<td>3.5 (4.9)</td>
<td>6.1 (6.4)</td>
</tr>
<tr>
<td>B</td>
<td>Fluoride tablets</td>
<td>225</td>
<td>3.0 (3.4)</td>
<td>5.4 (5.1)</td>
</tr>
<tr>
<td>C</td>
<td>Fluoride varnish</td>
<td>247</td>
<td>3.0 (4.3)</td>
<td>5.0 (5.7)</td>
</tr>
<tr>
<td>D</td>
<td>Individual prevention</td>
<td>248</td>
<td>2.9 (3.6)</td>
<td>5.2 (5.2)</td>
</tr>
</tbody>
</table>

DeMFS = decayed enamel and dentine missing and filled surface.
DMFS = decayed dentine missing and filled surface.
SD = standard deviation; N = number of subjects at the end of the study period.
7.3.2 Costs

Dental health care costs
Treatment cost is the product of unit cost and treatment time (Tt) in minutes. Table 10 shows mean treatment time spent on the individuals in the different preventive programmes. The Tt ranged from approximately 35 minutes, for the programme using the fewest resources, to 386 minutes, for the programme with the most resources used. Note that the number of participants in the high-risk groups a–d over the 4 years decreased by 12–15%.

Table 10. Mean treatment time in minutes for the years 1995–1999 for individuals in intervention programmes a–d.

<table>
<thead>
<tr>
<th>Group</th>
<th>Year</th>
<th>Number</th>
<th>Mean (minutes)</th>
<th>SD (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1</td>
<td>292</td>
<td>12.19</td>
<td>6.17</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>274</td>
<td>8.12</td>
<td>5.43</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>261</td>
<td>7.18</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>248</td>
<td>7.17</td>
<td>7.14</td>
</tr>
<tr>
<td>b</td>
<td>1</td>
<td>257</td>
<td>12.24</td>
<td>7.42</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>246</td>
<td>8.63</td>
<td>5.80</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>229</td>
<td>7.54</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>225</td>
<td>7.46</td>
<td>8.87</td>
</tr>
<tr>
<td>c</td>
<td>1</td>
<td>284</td>
<td>100.53</td>
<td>44.68</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>270</td>
<td>91.26</td>
<td>39.11</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>261</td>
<td>83.07</td>
<td>43.07</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>247</td>
<td>89.34</td>
<td>49.51</td>
</tr>
<tr>
<td>d</td>
<td>1</td>
<td>281</td>
<td>100.35</td>
<td>40.14</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>274</td>
<td>96.92</td>
<td>42.55</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>260</td>
<td>95.39</td>
<td>48.52</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>248</td>
<td>93.47</td>
<td>44.29</td>
</tr>
</tbody>
</table>

SD = standard deviation.
The mean treatment costs for all 4 years and total treatment costs using different discount rates are shown in Table 11. Depending on the caregiver category to perform the preventive treatment, the total treatment cost at a discount rate of 3% varied for programmes (a) and (d) from approximately 141 SEK and 1 566 SEK for a nurse, to about 456 SEK and 5 049 SEK for a dentist.

Table 11. Mean treatment cost, and total treatment cost using a discount rate of 0%, 3% and 5% for individuals in interventive programmes a–d.

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>53.15</td>
<td>81.31</td>
<td>171.39</td>
<td>53.37</td>
</tr>
<tr>
<td>Year 2</td>
<td>35.40</td>
<td>54.16</td>
<td>114.17</td>
<td>37.62</td>
</tr>
<tr>
<td>Year 3</td>
<td>31.31</td>
<td>47.89</td>
<td>100.95</td>
<td>32.87</td>
</tr>
<tr>
<td>Year 4</td>
<td>31.26</td>
<td>47.82</td>
<td>100.81</td>
<td>32.53</td>
</tr>
<tr>
<td>∑ 0%</td>
<td>151.12</td>
<td>231.18</td>
<td>487.32</td>
<td>156.39</td>
</tr>
<tr>
<td>∑ 3%</td>
<td>141.39</td>
<td>216.31</td>
<td>455.97</td>
<td>146.26</td>
</tr>
<tr>
<td>∑ 5%</td>
<td>135.49</td>
<td>207.27</td>
<td>436.92</td>
<td>140.11</td>
</tr>
</tbody>
</table>

Costs are given in SEK, where in December 1999 SEK8.54 = US$1.

Σ 0%, 3% and 5% = total treatment cost (C_i) using a discount rate of 0%, 3% and 5%, respectively.

dent = dentist; hyg = hygienist; nu = nurse.

Costs contributed by the patient and the patient’s family
A total of 3 370 out of 3 373 children answered the first questionnaire, 3 090 out of 3 107 answered the second and 2 819 out of 2 849 responded to the third, while 2 288 out of 2 499 accompanying persons (parent or other) answered their questionnaires. At the first examination, 2 499 (74%) of the 12-year-old children had someone accompany them to the clinic, in 91% cases the children’s parent(s). In 1997 and 1999, 29% and 16% of the subjects came to the clinic accompanied by an adult, mostly a parent.

It was expected that the costs contributed by the accompanying person would decrease over time and therefore, costs were investigated at three different time points, although they were allocated over the study period of 4 years. Costs were also influenced by the number of visits to the clinic. For the four groups a–d, there were a total of 4, 4, 24 and 16 visits, respectively (see Figure 4 for the programme details).
Summary of costs contributed by the patient and the patient’s family
The sum of the costs contributed by the patient and the patient’s family (PFCs), in other words, out-of-pocket expenses, transportation costs and time costs for the groups a–d for the whole study period, was 199 SEK, 412 SEK, 1 297 SEK and 1 014 SEK using a discount rate of 3%. Table 12 shows all costs per individual summarised for each period and for each group.

Table 12. Summary of total patient and family-related costs (PFCs) for groups a–d allocated to three periods using a discount rate of 0%, 3% and 5%.

<table>
<thead>
<tr>
<th>Group</th>
<th>A 0%</th>
<th>3%</th>
<th>5%</th>
<th>B 0%</th>
<th>3%</th>
<th>5%</th>
<th>C 0%</th>
<th>3%</th>
<th>5%</th>
<th>D 0%</th>
<th>3%</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>121</td>
<td>114.06</td>
<td>109.75</td>
<td>198</td>
<td>186.63</td>
<td>179.59</td>
<td>795</td>
<td>749.37</td>
<td>721.06</td>
<td>628</td>
<td>591.95</td>
<td>569.60</td>
</tr>
<tr>
<td>Period 2</td>
<td>56</td>
<td>51.24</td>
<td>48.37</td>
<td>134</td>
<td>122.62</td>
<td>115.75</td>
<td>365</td>
<td>334.01</td>
<td>315.29</td>
<td>283</td>
<td>258.97</td>
<td>244.45</td>
</tr>
<tr>
<td>Period 3</td>
<td>38</td>
<td>33.76</td>
<td>31.26</td>
<td>116</td>
<td>103.07</td>
<td>95.43</td>
<td>240</td>
<td>213.24</td>
<td>197.45</td>
<td>183</td>
<td>162.60</td>
<td>150.55</td>
</tr>
<tr>
<td>Total PFCs</td>
<td>215</td>
<td>199.06</td>
<td>189.38</td>
<td>448</td>
<td>412.32</td>
<td>390.77</td>
<td>1400</td>
<td>1296.62</td>
<td>1233.80</td>
<td>1094</td>
<td>1013.52</td>
<td>964.60</td>
</tr>
</tbody>
</table>

Cost savings of averted disease
In this study cost savings in the dental health care sector are the saving of the cost for restoration of a mean outcome of 1.1 tooth surfaces. The only programme that showed a significantly lower caries increment was prevention programme (c), with 1.1 saved tooth surfaces in comparison with programme (a) (79). Using the unit cost for dentists gave a cost saving of 344 SEK with a discount rate of 3% and n = 4. By contrast, cost savings in patient and family-related resources were 89 SEK using a discount rate of 3% and n = 4. The S2 included adolescent time cost (10 SEK), out-of-pocket expenses (0.83 SEK), accompanying persons time cost (accompanying persons = 0.6 in the formula), so that –

\[
\text{[((25 min*1.1) + 30 min)*2.41)*0.6] + \text{transportation cost} \text{[((6 km*2.5)*0.75(use of cars))*0.6]}\]

All costs were thereafter multiplied by 0.8885, the discount factor for 3%, n = 4, and summarised. The total cost savings, S1 + S2, were 433 SEK.

7.3.3 Cost-effectiveness analysis
As previously mentioned, out of the four intervention programmes, programme c showed the lowest caries increment, with 1.1 saved tooth surfaces in comparison with programme a (173). Using the unit cost for dental nurses for providing preventive care, and the incremental cost-effectiveness formula given previously,
this gave an incremental cost-effectiveness ratio between programmes c and a of 2,043 SEK per averted D_MFS. This means a yearly cost of 511 SEK. Of this cost, treatment cost represents 334 SEK. A summary of cost, outcome, and incremental cost-effectiveness ratio is given in Table 13.

Table 13. Incremental cost-effectiveness analysis for intervention programmes a and c using the unit cost for nurses.

<table>
<thead>
<tr>
<th>Group</th>
<th>Incremental cost-effectiveness analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>(D_MFS)</td>
</tr>
<tr>
<td>Disc. 0%</td>
<td>6.10</td>
</tr>
<tr>
<td>Disc. 3%</td>
<td>5.42</td>
</tr>
<tr>
<td>Disc. 5%</td>
<td>5.02</td>
</tr>
</tbody>
</table>

E = outcome measure effect; C = cost; ΔC = incremental costs between programmes a and c; Ctot = incremental cost-cost savings; ΔE = incremental effectiveness between programmes a and c; S = total cost savings, i.e. S1 + S2; and Disc. 0%, 3% and 5% = discount rate 0%, 3% and 5%. Costs are given in SEK, where in December 1999 8.54 SEK = US$1.

Figure 7 shows the total costs and sensitivity of the method used for calculating PFCs over time.

Figure 7. Total costs allocated over the study period. The interval between the values for total costs and treatment costs represents costs contributed by the patient and the patient’s family. Costs are given in SEK, where in December 1999 8.54 SEK = US$1.
7.3.4 Sensitivity analysis for the CEA

Outcome was tested for intervention programme c. Varying the size of the outcome measure D₇MFS in the incremental CEA by adding one or more extra averted units will improve the cost-effectiveness ratio from the base case of 2 043 SEK. Figure 8 shows the impact of how a better health outcome could change the cost function towards a positive net effect. It should be noted however that cost savings in the formula are calculated with the assumption that all averted D₇MFSs should have been restored, probably an overestimation. The break-even point, when savings exceed costs, will be 4.3 and 6.1 D₇MFSs depending on the perspective used (the dental health care or the societal perspective) for cost calculation (see Figure 8). The CEA ratio is not very sensitive to the choice of discount rate; assuming a rate of 0% will decrease the ratio by only about 5%. The effect of discounting is shown in Tables 11–13.

![Graph showing sensitivity of method for calculating costs for averted DeMFSs](image)

Figure 8. Sensitivity of the method used for calculating costs for one or more averted D₇MFS, both from a societal and from a dental health care perspective.

Incremental CEA in the five-year follow-up

Källéstål (175) showed that when enamel caries was included, the difference between the group with the least caries increment (d) and one with the most (b) was 1.15 surfaces. Elevated risk for caries increment was present for both dentine and enamel + dentine caries for adolescents living in working-class households, for those who reported frequent sweet-eating, and for those who reported not always brushing their teeth twice a day. Lower risk was found for those belonging to the fluoride varnish group (c). Cost, outcome, and incremental cost-effectiveness ratio
RESULTS

are shown in Table 14. All data are presented in their discounted form with a discount rate of 3%.

Table 14. Incremental cost-effectiveness for intervention programs at five-year follow-up.

<table>
<thead>
<tr>
<th>Group</th>
<th>b (C₁ + C₂)</th>
<th>d (C₁ + C₂)</th>
<th>Incremental cost-effectiveness analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C₁ + C₂)</td>
<td>163 + 463</td>
<td>(C₁ + C₂)</td>
<td>1830 + 1065</td>
</tr>
<tr>
<td>∆E</td>
<td>Eb – Ed</td>
<td>C_c – C_a</td>
<td>∆C – S</td>
</tr>
<tr>
<td>∆C</td>
<td>S</td>
<td>Ctot</td>
<td>Cost savings</td>
</tr>
<tr>
<td>626</td>
<td>2 895</td>
<td>0.99</td>
<td>2 269</td>
</tr>
</tbody>
</table>

E = outcome measure effect; C = cost (C₁ + C₂); ∆C = incremental costs between programmes b and d; Ctot = incremental cost-cost savings; ∆E = incremental effectiveness between programmes b and d; S = total cost savings (S₁ + S₂); Discount rate 3%. Costs are given in SEK, where in December 1999 SEK8.54 = US$1.

Using the unit cost for dental nurses for providing preventive care, and the incremental cost-effectiveness formula given previously, this gave an incremental cost-effectiveness ratio between programmes d and b of 1 851 SEK per averted DₑMFS, or a yearly cost of 463 SEK.
RESULTS

7.4 OHRQOL measures in caries preventive care

The frequency distribution of values for demographic and socio-economic variables in the two groups is shown in table 15. Both groups contained more girls than boys. The socio-economic variable (parents’ occupation) indicated that workers were more common in the high-risk group than in the low-risk group. The most common type of housing in the high-risk group was a rented flat, while for the low-risk group it was an owned house.

Table 15. Frequency distribution for demographic and social background variables.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test (n=30) (%)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>- boys</td>
<td>13 (43.3)</td>
</tr>
<tr>
<td>- girls</td>
<td>17 (56.7)</td>
</tr>
<tr>
<td>Housing</td>
<td></td>
</tr>
<tr>
<td>- rented flat</td>
<td>11 (36.7)</td>
</tr>
<tr>
<td>- condominium</td>
<td>6 (20.0)</td>
</tr>
<tr>
<td>- house</td>
<td>13 (43.3)</td>
</tr>
<tr>
<td>Socio-economics</td>
<td></td>
</tr>
<tr>
<td>- worker</td>
<td>10 (33.3)</td>
</tr>
<tr>
<td>- civil servant</td>
<td>17 (56.7)</td>
</tr>
<tr>
<td>- businessman or farmer</td>
<td>3 (10.0)</td>
</tr>
</tbody>
</table>

7.4.1 CPQ_{11-14} and OHIP-14

The overall and sub-scale scores for the OHRQOL measures, CPQ_{11-14} and OHIP-14, are summarised in table 16. The individuals in the high-risk group reported a higher mean total score than the low-risk group for both instruments; however, the differences were not statistically significant ($p = 0.465$ and $p = 0.332$ respectively). The high-risk group also generally showed higher sub-scale scores but there were no statistically significant differences except for the domain of oral symptoms in CPQ_{11-14} ($p = 0.034$).
Table 16. Mean CPQ<sub>11-14</sub> and OHIP-14 overall and sub-scale scores for the high-risk and low-risk groups.

<table>
<thead>
<tr>
<th>OHRQOL measure</th>
<th>Group</th>
<th></th>
<th></th>
<th>p-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High risk (n = 30)</td>
<td>Low risk (n = 52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td>Mean</td>
<td>Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPQ&lt;sub&gt;11-14&lt;/sub&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total scale</td>
<td>17.2 (9.0)</td>
<td>14.1 (8.5)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- oral symptoms</td>
<td>6.2 (3.2)</td>
<td>5.0 (3.1)</td>
<td>0.034&lt;sup&gt;*&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>- functional limitation</td>
<td>5.2 (3.2)</td>
<td>4.3 (3.5)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- emotional well-being</td>
<td>3.4 (4.6)</td>
<td>3.3 (3.5)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- social well-being</td>
<td>2.5 (2.5)</td>
<td>1.5 (1.9)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>OHIP-14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total scale</td>
<td>3.7 (5.2)</td>
<td>2.2 (3.3)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- pain and discomfort</td>
<td>0.9 (1.2)</td>
<td>0.6 (1.0)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- functional limitation</td>
<td>0.5 (0.8)</td>
<td>0.3 (0.5)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- psychological impact</td>
<td>1.5 (2.4)</td>
<td>1.1 (1.8)</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td>- behavioural impact</td>
<td>0.8 (1.7)</td>
<td>0.3 (0.7)</td>
<td>n.s.</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> p-values from Pearson’s Chi-square test. Significance level p< 0.05.
(SD) standard deviation
n.s. not significant
7.4.2 Global rating of overall well-being

Eight individuals (26.6%) in the high-risk group reported that their overall oral well-being was “Not at all/Very little” affected by their oral conditions compared to 17 individuals (32.7%) in the low-risk group (see Table 17). The difference in global rating between high-risk and low-risk group was not statistically significant ($p=0.568$).

Table 17. Global rating of effect of oral conditions on overall well-being for the high-risk and low-risk groups.

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High risk (n=30)</td>
</tr>
<tr>
<td>Global rating</td>
<td>n</td>
</tr>
<tr>
<td>Not at all</td>
<td>4</td>
</tr>
<tr>
<td>Very little</td>
<td>4</td>
</tr>
<tr>
<td>Some</td>
<td>8</td>
</tr>
<tr>
<td>Much</td>
<td>11</td>
</tr>
<tr>
<td>Very much</td>
<td>3</td>
</tr>
</tbody>
</table>

7.5 Valuation of caries preventive care

Twenty-one individuals (70%) in the high-risk group estimated their own caries risk as high compared to 7 individuals (13%) in the low-risk group. Forty-five individuals (87%) in the low-risk group estimated their risk as low compared to 9 (30%) in the high-risk group (see Figure 9).

Figure 9. Individuals’ own estimation of their risk for caries progression.
7.5.1 Elicitation of willingness to pay (WTP) and Cost-Benefit Analysis (CBA)

The independent variables tested were gender, caries risk (i.e. study group designation), socio-economics, housing, self-esteem, and attitudes. When all variables were analysed, the only two that were found to significantly influence WTP were caries risk (i.e. group belonging) and housing (see Table 18). Girls were willing to pay 18.12 SEK less than boys, but this difference was not statistically-significant. The individuals in the high-risk group were willing to pay 26.54 SEK more than the individuals in the low-risk group, with the mean monthly WTP being 117.12 SEK (US$15.21) and 90.58 SEK (US$11.76) respectively, i.e., a yearly WTP of 1405.44 SEK (US$182.52) and 1086.96 SEK (US$141.16) respectively. Individuals living in rented flats and condominiums were willing to pay 39.93 SEK (US$5.19) and 15.26 SEK (US$1.98) more than individuals living in owned houses.

Table 18. Willingness to pay (WTP) per month in SEK for different scenarios within a caries preventive strategy.

<table>
<thead>
<tr>
<th>Parameter estimate</th>
<th>Std. Error</th>
<th>p-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERCEPT</td>
<td>90.58</td>
<td>17.79</td>
</tr>
<tr>
<td>SEX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- male</td>
<td>-18.12</td>
<td>12.18</td>
</tr>
<tr>
<td>- female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RISK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- low-risk group</td>
<td>26.54</td>
<td>12.22</td>
</tr>
<tr>
<td>- high-risk group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOUSING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- own house</td>
<td>15.26</td>
<td>15.93</td>
</tr>
<tr>
<td>- condominium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- rented flat</td>
<td>39.93</td>
<td>12.18</td>
</tr>
</tbody>
</table>

a p-values from linear multiple regression (significance level p < 0.05).

Table 19 presents results calculated using the yearly benefit-to-cost function. The NSB has a positive values for both the high-risk and the low-risk group, independently of whether total cost or just dental treatment cost was used. From a dental health care perspective, NSB1 was 1039 SEK (US$134.94) for the high-risk group and 721 SEK (US$93.64) for the low-risk group. From a societal perspective, NSB2 was 844 SEK (US$109.61) for the high-risk group and 527 SEK (US$68.44) for the low-risk group. Thus the goal of finding a project with NSB > 0 was fulfilled, providing evidence for the success of the preventive approach.

Table 19. Willingness to pay (WTP) per month in SEK for different scenarios within a caries preventive strategy.
Table 19. Net Social Benefit (NSB) for the high-risk and low-risk groups.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>B (SEK)</th>
<th>C1 (SEK)</th>
<th>C (SEK)</th>
<th>NSB1 (SEK)</th>
<th>NSB2 (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High risk</td>
<td>1 405</td>
<td>366</td>
<td>560</td>
<td>1 039</td>
<td>844</td>
</tr>
<tr>
<td>Low risk</td>
<td>1 087</td>
<td>366</td>
<td>560</td>
<td>721</td>
<td>527</td>
</tr>
</tbody>
</table>


7.5.2 VOSOH-ITS (Value Of Statistical Oral Health-intact tooth surface)

Table 20 presents values of statistical oral health, referred to an intact tooth surface, for both high-risk and low-risk groups. Estimated risks of 1/1 and 1/6 resulted in values of a statistical healthy tooth equal to 2810 SEK (US$364.94) and 16860 SEK (US$2189.61) for the high-risk group, and 2174 SEK (US$282.34) and 13044 SEK (US$1694.03) for the low-risk group. Table 20 makes evident the sensitivity of the estimated risk (1/1 to 1/10) and of different WTP (+ 30%).

Table 20. VOSOH-ITS (Value Of a Statistical Healthy Tooth-intact tooth surface) in Swedish krona, SEK.

<table>
<thead>
<tr>
<th>Estimated Risk</th>
<th>(Δp) Risk reduction (50 %)</th>
<th>Mean yearly WTP (SEK)</th>
<th>VOSOH-ITS WTP/Δp (SEK)</th>
<th>VOSOH-ITS WTP + 30% (SEK)</th>
<th>Mean yearly WTP (SEK)</th>
<th>VOSOH-ITS WTP/Δp (SEK)</th>
<th>VOSOH-ITS WTP + 30% (SEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-risk group (n=30)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/1</td>
<td>1/2</td>
<td>1 405</td>
<td>2 810</td>
<td>1 967 / 3 653</td>
<td>1 087</td>
<td>2 174</td>
<td>1 522 / 2 826</td>
</tr>
<tr>
<td>1/2</td>
<td>1/4</td>
<td>1 405</td>
<td>5 620</td>
<td>3 934 / 7 306</td>
<td>1 087</td>
<td>4 348</td>
<td>3 044 / 5 652</td>
</tr>
<tr>
<td>1/3</td>
<td>1/6</td>
<td>1 405</td>
<td>8 430</td>
<td>5 901 / 10 959</td>
<td>1 087</td>
<td>6 522</td>
<td>4 565 / 8 479</td>
</tr>
<tr>
<td>1/4</td>
<td>1/8</td>
<td>1 405</td>
<td>11 240</td>
<td>7 868 / 14 612</td>
<td>1 087</td>
<td>8 696</td>
<td>6 087 / 11 305</td>
</tr>
<tr>
<td>1/6</td>
<td>1/12</td>
<td>1 405</td>
<td>16 860</td>
<td>11 802 / 21 918</td>
<td>1 087</td>
<td>13 044</td>
<td>9 131 / 16 957</td>
</tr>
<tr>
<td>1/10</td>
<td>1/20</td>
<td>1 405</td>
<td>28 100</td>
<td>19 670 / 36 530</td>
<td>1 087</td>
<td>21 739</td>
<td>15 217 / 28 261</td>
</tr>
</tbody>
</table>

Low-risk group (n=52) |                           |                       |                        |                          |                       |                        |                          |

SEK Swedish krona. 7.70 SEK = US$1 (July 2005).
8. DISCUSSION

In public health care, including dental health care, the decision-maker has many, often conflicting, objectives to pursue. Accurate evaluation methods are necessary to create a sound basis for this process. Economic analysis has the potential to assist in the complex context of decision-making; this thesis focuses on the applicability of economic evaluation methods to the decision-making process.

The first specific aim was to investigate the use of resources in preventive dentistry and calculate the related costs; this was discussed in Paper I. Paper II dealt with the second aim, that of demonstrating techniques suitable for evaluating dental care costs in the Swedish public dental health care sector, and establishing whether the real costs differ from the fees charged. The third aim, to evaluate and develop outcome measures suitable for preventive dentistry, was partially fulfilled by Papers IV and V. Finally, Papers III and V fulfilled the fourth aim of describing the linkage of costs and consequences for preventive dental health care in a health economic decision model.

In a four-year study of a single clinic, it was found that a total of 46.7 hours was used for preventive treatment in 92 adolescents tracked between 13 and 17 years of age. By using treatment time in minutes as an intermediate measure to translate resource inputs and calculate costs, the total cost for the four-year period was found to be 40 162 SEK, half of which was spent on the highly caries-active subjects (Paper I).

In the intervention project entitled “Evaluation of caries-preventive measures” (169), three methods of evaluating dental care costs were discussed. The first, average treatment time cost, was found to be the preferred analysis method in the case where only the treatment times are known and there is limited data on which dental professionals provided the care. The other two analytical methods reflect both the differences in treatment costs depending on the practitioner’s level of skill and competence (i.e., the practitioner’s salary) and the differences in handling overhead cost allocation. All three methods seem useful for evaluating costs with CEA and CBA. Charges alone were not found to be sufficient as an alternative to a more detailed cost evaluation, at least not in Swedish public dental care, since charges in the Swedish health care system do not cover costs (Paper II).

A CEA performed from a societal perspective, taking into account patient and family-related costs and savings as well as treatment costs, showed an incremental cost-effectiveness ratio of 2 043 SEK per averted D MFS, using a dental nurse as the professional responsible for the preventive treatment. This means a yearly cost of approximately 511 SEK to achieve one averted D MFS during the years 1995–
1999 through a preventive strategy with extensive administration of fluoride as opposed to a low-fluoride programme. On the other hand, from a health care perspective, in which the only concern is treatment cost, there was an incremental cost-effectiveness ratio of 1.337 SEK per averted DMFS, a yearly cost of approximately 334 SEK using the same professional (Paper III).

The concept of oral health-related quality of life (OHRQOL) offers one possibility for moving from the bio-medical paradigm towards a perspective which also considers the social and psychological impact of oral health on the individual, OHRQOL measures were tested for use as an supplemental outcome in caries preventive dentistry in a pilot study among adolescents. Two groups of 19-year-olds, one low-risk for caries and one high-risk, were tested for perceived OHRQOL using two measures, OHIP-14, and CPQ11-14. Neither measure was able to distinguish between the groups (Paper IV).

The main objective in any health economic analysis is to determine whether the value of the derived health benefits exceeds the costs of obtaining those benefits. Cost-benefit analysis (CBA) measures both costs and consequences in monetary terms. It has been considered to be a normative tool of applied welfare economics, and it also appeals to decision-makers. By using the contingent valuation method, the willingness of 19-year-olds to pay for a caries-preventive strategy was elicited. Individuals in the high-risk group were prepared to pay 318.49 SEK (US$41.36) more than individuals in the low-risk group. The WTP data was also used to calculate a new outcome measure, value of statistical oral health (VOSOH), which could potentially be used as an additional supplement to CBA in health economic analysis for assisting decision-making (Paper V).

8.1 Reliability and validity

8.1.1 Treatment time
As described previously, costing has two elements: measurement of the quantities of resource used (q) (here the same as treatment time in minutes), and the assignment of unit costs, or prices (p). One crucial measure is therefore the use of minutes as an intermediate measure for translating resource inputs into monetary values for dental care costs (Papers I and II). Minutes have been used in other studies, for example by Holst and Brembo (110). Since cost calculation is strongly influenced by treatment time, as shown in the sensitivity analysis of Paper II, it is necessary to assess the validity of the reported treatment times.

Some estimation was necessary in the first study, since not all data were available. This fact motivated a more comprehensive analysis, described in Paper II. For instance, did all 26 clinics in Papers II and III use the same criteria for measuring
treatment time? A questionnaire completed by the clinic managers confirmed that treatment time for all clinics meant time spent with the patient.

Also, did the dentists, hygienists and dental nurses in fact report accurate time? Dentists are generally already used to reporting treatment time, for remuneration and statistical purposes, so there is no reason to believe that their reports were invalid. Interviews with clinic managers verified that this data appeared to be accurate. Since dental nurses have less experience in reporting treatment time, an extra questionnaire was sent out explicitly addressed to nurses giving their own treatment. The purpose of this was to compare the data with the official reports. The results were found to correspond well at all but three clinics; the differences in these cases necessitated making some adjustments.

Finally, does the treatment time seem accurate and comparable to that found by other studies? Svedberg et al. (176) performed an in-depth analysis of how dental clinics use their working day by measuring time for every activity performed. Total patient-related time (“treatment time” in our study) for dentists at our 26 dental clinics varied from 70% to approximately 84% of total time. This does not differ much from Svedberg et al.’s results, indicating that the reported treatment time was correct.

The main contribution to cost comes from staff time (salary) and the amount of time (minutes) that the dental practitioner uses. Also important are the differences between the skills of the three types of dental practitioner, which are reflected in different salaries. Dental treatment rooms with similar facilities look the same no matter who the treating professional is and the cost of the dental materials used for routine work is generally of minor importance. Therefore it is possible to simplify the calculation of resource input by using treatment time in the same way. Treatment costs differed considerably between the clinics analysed in Paper II; this may have been related to the number of employees and how the clinics organised their staff. Since labour forms the major part of total costs it could be of interest to establish whether an increase in the number of staff employed is proportionate to an increase in treatment time, which would of course influence treatment cost. It is, however, beyond the scope of this thesis to further discuss these differences.

8.1.2 Cost calculations

In the single-clinic study (Paper I), treatment cost was calculated regardless of whether care was provided by dentist, dental hygienist, or nurse, with the assumption that all dental professionals were working with the same objectives. No consideration was given to how resources were allocated within the clinic or to the opportunity cost of the use of the different care providers. It is of course important to consider both how scarce resources are allocated and how clinics use their
DISCUSSION

personnel resources for best efficiency. Using staff in one way means that other alternatives are denied. This could have an impact on both health outcome and cost-effectiveness. It is necessary in this context to consider the different viewpoints, or perspectives, that economic analysis can be performed under.

When economic evaluation is used as an aid to decision-making it is important to report which perspective was taken in the analysis and to ensure that input data are correct (5, 116). Weinstein (116) prefers a societal perspective unless there is a good reason for using another perspective. However, even if the societal perspective is the theoretically-correct perspective for drawing normative conclusions about resource allocation, Weinstein (177) claims that actual health resource decisions are usually made from more limited perspectives, ranging from the perspective of national health care systems (e.g. the dental health clinic) to that of a third-party payer to that of individual health care providers. Each of these types of decision-maker can benefit from cost-effectiveness analysis from the appropriate perspective.

Three methods are proposed for evaluation of costs, in the hope that they will be useful for future economic evaluation of both preventive strategies and dental care in general (Paper II). In each of these methods the costing procedure assumes that the cost of treatment time adds up to the total cost for the clinic. Choosing the right method is thus more a question of purpose and availability of data, as well as of the perspective from which the study is undertaken and how the resources are measured. If only treatment time is known and there are no accurate data on which professional provided the dental care, the preferred method is that of calculating average treatment time cost. If the economic evaluation includes data on treatment time and the provider of dental care, this must be taken into consideration when choosing unit cost. The choice of method for allocating overhead costs is more a matter of preference but should ensure consistency. The differences between the two methods per treatment minute are fairly small for the dentist. The method with a percentage mark-up to the base cost is easy to use and lets the dentists bear a greater part of overhead costs because they have higher salaries and perform more treatments compared with the other staff. With the additive mark-up method it is possible to alter the proportions of overhead costs borne by the dentist, hygienist and nurse.

This study also revealed the deficiencies of using charges as an approximation of costs instead of calculating real costs. Using charges as a measure equal to cost, which is a common strategy for many studies, one minute of treatment by a dentist should cost 10.95 SEK, i.e., one hour should cost 657 SEK (US$1.53 and US$91.89, respectively), calculated using 1994 prices. This sum would not be sufficient and would have meant an underestimation of about 15–22% of unit costs for the clinics included in this study since all the clinics but one had a much higher
cost per minute/hour. For dental hygienists and nurses too, charges did not cover costs, although the difference was smaller. In the dental literature, costs are estimated very differently in CEA and CBA. Downer et al. (178) advocated a general service fee scale to estimate treatment cost while Drummond et al. (5), Weinstein (116) and Jönsson and Karlsson (43) argued in favour of a more detailed cost evaluation since fees are associated more with clinic revenue than with cost and it is not certain that fees in fact reflect the actual cost. Although some authors (117, 118) have used such a detailed evaluation, there are still several studies (111-115) which use the fee charged for services as an approximation of cost calculation.

The incremental cost-effectiveness function (Paper III), which is sensitive to a change in both costs and outcome, needs further consideration. Resources can be saved by preventive programmes, but it is possible that the savings made in reduced costs for restorative care could be partly overestimated by the cost function. The caries increment includes both enamel and dentine lesions and it is not always certain that all new caries lesions, in particular small ones, in actual fact need to be restored. However, I have opted to calculate all lesions in the same way rather than taking an unreliable guess. The patient- and family-related costs have also potentially been overestimated. Data concerning the presence of a person accompanying the children were collected on three occasions during the study. It is not certain, however, that these data were representative for the whole study period — the children may not have needed someone to accompany them on some of the visits — and so total costs could actually have been less, resulting in a more favourable cost function.

8.1.3 Caries increment in the CEA study

The differences in caries increment between the preventive groups studied in Paper III were small, with the greatest difference being between groups (c) and (a). Even though the differences calculated using ANOVA were not significant, the rate ratio analysis showed a significantly better outcome for the more intensive fluoride application in group (c) than for group (a). It must however be asked whether these results are reliable.

The study was not blind, so the examiner was able to check which preventive group the adolescents belonged to. It is difficult to determine whether this may have influenced the examination or the analysis of the radiographs. Additionally, the fact that 28 dentists were used as examiners puts a strain on reproducibility. As seen in previous studies (179, 180), dentists show great variation in diagnosis in terms of both intra- and inter-individual agreement. For this reason every effort was made to calibrate the examiners’ methods of examining approximal surfaces using bite-wing radiographs as a diagnostic tool. Although congruence with the
“gold standard” decreased over time, the reproducibility was fair to good, so the results may be considered to be reliable.

The difference in caries increment between the treatment group with the smallest increment and the group with the highest was only about one surface if enamel caries was included. The preventive treatment in the group with the highest increment, group (a), was comparable to that of the low-risk group as they only received written instructions about tooth-brushing/toothpaste technique (171), an activity already performed by most of the adolescents. Still, group (a) were better off with the preventive treatment they received than had they been given none.

The results can be considered to be representative of Swedish 12–16-year-olds since both the social strata and the distribution of living area in the study group were representative of the general population (170). The drop-out rate was 16% (527 individuals), which must be considered low. Participation in the project interfered with the daily work of the dental professionals, particularly the clinicians, to such an extent that participation had to be voluntary. This ruled out the possibility for cluster or random sampling. An effort was made, however, to include clinics with different demographic, social, and geographic realities since it was recognised that convenience sampling often leads to bias. Few studies have been published with a comparable design, but the results were found to be in accordance with findings reported in two Finnish studies (181, 182) with a two-year and three-year follow-up; although the Finnish studies show a higher caries increment than seen in the present study, the success rate of the prevention programmes was equally low.

8.1.4 Measurement of oral health-related quality of life (OHRQOL) and elicitation of willingness to pay (WTP)

The data of Papers IV and V relating to OHRQOL and WTP were collected using a questionnaire administered face to face by a personal data collector. It is known that the reliability and validity of instruments designed for health outcome measurement can be threatened by many factors (10, 183). Table 21 summarises some of the dangers relevant to the studies described here.
Table 21. Validity and threats to validity.

<table>
<thead>
<tr>
<th>VALIDITY</th>
<th>EXPLANATION / COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face validity</td>
<td>This refers to investigators’ assessment of the presentation and relevance of the questionnaire; whether the questions appear to be relevant, reasonable, unambiguous, and clear.</td>
</tr>
<tr>
<td>Content validity</td>
<td>More systematic than face validity, this refers to judgements (usually made by a panel) about the extent to which the content of the instrument appears logically to examine and comprehensively include, in a balanced way, the full scope of the characteristic or domain it is intended to measure.</td>
</tr>
<tr>
<td>Criterion validity</td>
<td>Correlation of the measure with another criterion measure which is already accepted as valid.</td>
</tr>
<tr>
<td>Construct validity</td>
<td>Provides corroboration that the instrument is measuring the underlying concept it purports to measure. Two subtypes: convergent validity requires that the scale should correlate with related variables, while discriminant validity requires that it should not correlate with dissimilar variables.</td>
</tr>
<tr>
<td>Bias</td>
<td></td>
</tr>
<tr>
<td>Social desirability bias</td>
<td>This may exert a small but pervasive effect (people present themselves at what they consider to be their best) and lead to a particular response set (the wish to give a preferred image and answer questions accordingly).</td>
</tr>
<tr>
<td>Interviewer bias</td>
<td>The interviewer can subconsciously bias respondents towards answering in a certain way by asking “leading questions”.</td>
</tr>
<tr>
<td>Sampling bias</td>
<td>Possible unless the sampling method ensures that all members of the population of interest have a calculable chance of being selected.</td>
</tr>
<tr>
<td>Probability preference bias</td>
<td>The tendency for individuals to weight probabilities non-linearly, such that they place great value on events that have probabilities that are near certainty (0 or 1).</td>
</tr>
<tr>
<td>Non-response bias</td>
<td>Results from differences in characteristics between the responders and non-responders.</td>
</tr>
<tr>
<td>Protest (zero) bias</td>
<td>Protest zero bias, bids that obviously differ from the mean (outliers).</td>
</tr>
<tr>
<td>Anchor-point bias</td>
<td>Otherwise known as starting point bias, commonly found in the contingent valuation method when the first value offered (bid) influences the answer of the respondent.</td>
</tr>
<tr>
<td>Hypothesis bias</td>
<td>Respondents provide answers that give higher values than they would pay in a real market situation.</td>
</tr>
</tbody>
</table>
The reliability and validity of the OHRQOL measures used in Paper IV, CPQ\textsubscript{11-14} and OHIP-14, have already been thoroughly tested and described. Several studies support high internal consistency and content validity for OHIP-14 as a measure especially constructed for use in adults (67, 72, 73, 184, 185), while Jocovic et al. (79, 186) confirm good reliability and validity for the CPQ\textsubscript{11-14}. However, the subjects of the present study were 19 years old, an age somewhere between child and adult. One reason for the use of both CPQ\textsubscript{11-14}, which is intended for adolescents around the age of puberty, and the OHIP, which is often used for adults and the elderly (185, 187), was that there are no measures especially constructed for this particular age group. It was assumed that the CPQ\textsubscript{11-14} would be easy for the 19-year-olds to understand and complete, due to their increased knowledge and life experience over the age group that the questions were intended for; however this was less certain to be the case for the OHIP-14 measure. This use of measures that have not been directly tested for the actual age group at hand could perhaps jeopardise content validity, but hopefully the use of both measures together can overcome this deficiency.

Bias, as well as validity, must be considered. The interviewers were two highly educated academic women, recruited as interviewers/survey administrators from an employment agency. Both had training relating to personnel and behaviour. They had no professional dental background and were not associated with the research project, thus decreasing the risk of their influencing respondents with potential preferences relating to the research objectives.

The interviewers gave information about the questionnaire and read the starting instructions of every new domain for the OHRQOL measure and the hypothetical scenario for the WTP study (Paper V), but otherwise acted as neutral observers. The interviews and questionnaires were also completed in a neutral meeting place, away from dental clinics. These precautions must be considered valuable for reducing the risk of both interviewer bias and social desirability bias.

The interviews required participants to commit time and effort to travelling. They were therefore offered a small compensation as encouragement; this, of course, could have had the effect of increasing participation. The risk that this compensation influenced the answers is not plausible. Although the frequency of demographic and socio-economic variables showed some skewed distribution within the groups, with girls being more frequently represented and an unequal distribution of housing and socio-economics within the groups being apparent, analysis of the impact of these variables on the OHRQOL scores (Paper IV) did not change the outcome or conclusions.

Probability preference bias is the tendency for individuals to weight probabilities non-linearly, such that they place great value in events that have probabilities of near certainty. Since there was just one risk scenario presented for both study groups
(Paper V), it is possible that respondents calculated their own estimated risk when giving their WTP values, which could have had an effect on WTP. The interviewers read the WTP question thoroughly according to the interview guide, and repeated the question if something was unclear to the respondent. If the respondents wrote a zero value for the WTP, the interviewer asked if that corresponded with their true value, in order to avoid non-response or protest zero bias. Outliers, or bids that obviously differ from the mean, can also be considered to be protest bias; however, no such outliers were found in the present study.

A number of guidelines for the use of the contingent valuation method in eliciting WTP were developed in 1993 by a panel of economists (188). The panel particularly recommended the use of a binary approach with one bid, a personal interviewer, a general population with a high participation rate, and a thorough description of the risk estimation and the WTP scenario. Some, but not all, of these criteria were fulfilled by the pilot study described in Paper V). Johannesson et al. (91) have argued for the use of a binary technique when eliciting WTP. The study of Paper V used a binary question followed by an open-ended question. Several studies (5, 91, 92, 189) discuss the risk of anchor-point (starting point) bias. In a traditional binary contingent valuation approach, respondents are only asked to accept or reject a single bid in order to model a market situation where individuals decide whether to buy or not to buy a good at a specific price. The sample size in our study was too small to divide and stratify the individuals into sub samples (91) and offer each a different bid. Instead, the individuals were asked a second open-ended question to make it possible to calculate the mean willingness to pay. While this scenario does carry the risk of starting-point bias, it was considered that without the initial binary question, the risk of non-response would have been larger. Further, the wide variance of the distribution of the respondents’ WTP results, both above and below the bid presented in the initial question, suggests that the respondents truly were making an active choice.

One question of particular interest regarding content validity and the risk of hypothesis bias was the question of whether it is realistic to expect 19-year-olds, still occupied with school studies and not financially self-sufficient, to engage in hypothetical monetary exercises. The interviewers were instructed to thoroughly elucidate the hypothetical scenario in the WTP questionnaire, and to ensure that respondents understood that their own budget situation must be considered when expressing their WTP (see Appendix B). In 2006, as 20-year-olds, these individuals will have to make an active choice to pay with their own money for their dental health care. Even if Swedish adolescents have limited economic resources, most do have their own (small) budgets, for example for their mobile telephone accounts, leisure activities, and clothing. Hence they are quite familiar with economic thinking and decision-making.
DISCUSSION

WTP has often been connected with ability to pay (84, 92). Variables that were associated with WTP were caries risk (i.e., risk group designation) and housing. The individuals with high caries experience also estimated their own risk as high, thus it is plausible that they showed higher preferences for preventive efforts than did the non-caries group. Though housing can be seen as a partially socio-economic variable, the association in this study implies some relationship with wealth. However, the individuals who lived in owned houses gave lower WTP scores compared to those who lived in rented flats. This finding may have been influenced by the fact that more caries-free individuals lived in owned houses, which implies that caries also has a socio-economic component. As shown earlier (92, 137, 140, 141), WTP is likely to be related to income. However, not all studies support this hypothesis; Cunningham and Hunt (136), for example, did not find such a correlation in a study involving a number of students. Even though the mean WTP was lower in the low-risk group compared to the high-risk group, their valuation of the preventive strategy must be considered positive. This could perhaps be explained by their earlier positive experiences of preventive care, by the possibility that they actually rank healthy teeth highly, or that they estimated their own caries risk to be higher than their actual risk, a fact that the results of their own estimated risk implied for a couple of individuals. Nevertheless, the participants appeared to understand the hypothetical scenario presented, which could be of use in future CVM studies (189, 190).

There have been indications of a decreasing demand for dental health care among young adults. Grytten and Holst (101) reported this trend in a study of the price elasticity among different age groups between income and the demand for dental health care. In Norway, 67% of young adults of 18 and older pay their own bills and use dental health care at least once a year. The total expenditure in this age group (1995) was just half of that of the group aged 60 and over, almost certainly due to better oral health, although the price elasticity was low in the younger age group. The lower demand for dental health care was also discussed in a report from the Swedish National Institute for Public Health (191). This report emphasised that the reason for less demand was the decreased ability of individuals to afford dental health care. This might be seen to contradict the findings of positive preferences for preventive dental health care in the WTP study of Paper V; however, it should be borne in mind that this kind of preventive scenario is seldom described to individuals in real-world dental health care situations, making comparison rather difficult. Furthermore, specific directed preventive programs are rarely offered to young adults. Nevertheless, the WTP approach calls for more testing. An increase in validity could be managed, for example, by examining its convergence with other health state preferences and measures, or by using revealed preferences, that is, the observation of the actual decisions made by individuals in a market situation.
The studies of Papers IV and V were conducted in a single Swedish county. Since the incidence and prevalence of caries are low, all individuals who fulfilled the criteria for the test group were invited to participate. The individuals in the low-risk group were not matched controls but were selected randomly from 614 caries-healthy individuals who also fulfilled the criteria. These facts, in combination with the small sample size, could certainly have affected the differences in the demographic variables. The small sample size, presenting potential sampling bias, must be considered in discussion of the external validity. It is possible that a larger sample could have generated different results. Nevertheless, both studies must be seen primarily as pilot studies, and the results discussed in Paper IV still indicate that the differences between the groups are too small to be useful in fulfilling the study objectives; they imply that the caries situation of the individuals with the highest caries experience among Swedish 19-year-olds does not affect their quality of life in a manner that makes it possible to distinguish them from their caries-free counterparts.

8.2 Health economic analysis in caries-preventive research

The question of whether health improvements are worth the cost or not is beyond the scope of a CEA alone; the addition of CBA helps to produce a more comprehensive analysis.

8.2.1 Cost-effectiveness of caries-preventive measures

CEAs are considered to be an aid to decision-making, and in preventive dentistry they assist in choosing between alternative preventive strategies. It is not possible, however, to directly compare our results (Paper III) with those of other studies on caries prevention, since many papers merely discuss the theoretical considerations inherent in making an accurate CEA of caries-preventive programmes (128, 192). Others use data inputs from other studies and test cost-effectiveness based on hypothetical assumptions (115). Few reports, however, are based on a controlled, randomised CEA. Apart from the fact that these studies were performed at different times, reported costs vary considerably depending on the preventive measures considered, the quality of data collection, and the evaluation techniques used. Using cost per averted DMFS for different caries-preventive measures, the cost-effectiveness for water fluoridation ranged from US$0.036 to US$1.90 (117, 125, 131), for fluoride mouth rinsing from $1.00 to $2.26 (117, 142), for fluoride varnish from $65.74 to $72.69 (144) and 1 175 SEK (114), for fluoride tablets from 167 SEK (113) to £6.75 per averted DMFT (134), for a preventive mix (i.e. instruction, cleaning, and fluoride application) from 167 SEK to 186 SEK (118), and for fissure sealant from AU$11.80 (127) to US$40 and US$80 (123, 145). Griffin et al. (115) reported the costs for three different deliveries of fissure sealant. The costs ranged from one strategy that was described as cost saving to a cost of $73.80 per averted decayed
DISCUSSION

surface for the other two. Water fluoridation generally has the lowest costs, while preventive measures that use more resources (e.g. fluoride varnish programmes and fissure sealants) have higher costs. In the present study, when using a dental nurse to provide the preventive treatment, the incremental cost-effectiveness ratio was 2 043 SEK (i.e. a yearly cost of 511 SEK) per averted DcMFS (Paper III). From a dental health care perspective (i.e. where the only concern is treatment cost), there was an incremental cost-effectiveness ratio of 1 337 SEK (i.e. a yearly cost of approximately 334 SEK) per averted DcMFS. A comparison with a study from the USA also using the dental health care perspective, with fluoride varnish as preventive measure, reveals a CEA ratio of 561–621 SEK (144), using an exchange rate of 8.54 SEK = US$1. The analysis in the five-year follow-up (175) showed an even more favourable incremental cost-effectiveness ratio; 1 851 SEK per averted DcMFS (i.e. a yearly cost of 463 SEK) compared to the results described earlier (Paper III). The differences in caries increment between the preventive groups were still small. The difference between the group with the least caries increment (d) and one with the most (b) was 1.15 surfaces when enamel caries was included. The main reason for the lower CEA ratio, even though the follow-up includes one extra year of treatment with the same low effect, can be explained by the lower use of patient- and family-related costs in group d compared to c, and the fact that out-of-pocket expenses were higher in group b.

If a hygienist or dentist is used for the preventive programmes the incremental cost-effectiveness ratio will increase to 2 045 SEK and 4 311 SEK, respectively, per averted DcMFS. From a societal perspective (i.e., if all costs are included) the total costs per averted DcMFS will be 2 765 SEK for treatment provided by a hygienist and 5 077 SEK for treatment provided by a dentist (Paper III). If strictly dental health care aspects are considered (i.e., if the only concern is treatment costs for the preventive programmes) it is important that treatment be performed at the right competence level. Our experience is that the majority of preventive strategies are performed by dental nurses, which is why we mainly used nurse data for our calculations. However, it is possible that individuals at higher risk of developing caries disease or individuals already suffering from disease would be better off if they were treated by a dental hygienist. Since dental hygienists, with their higher competence directed towards prevention and health promotion and their better knowledge and interest about patient behavioural concerns, will be better suited to response for different preventive strategies. Using these prerequisites for increasing their own competence and contribute to research within this subject field and thereby contribute to the overall development of more effective strategies for caries prevention, gives opportunities for an even more favourable outcome.

Sensitivity analyses show that an improvement in health outcome in terms of averted DcMFSs has a potential impact on the cost-effectiveness function. This means that an even more favourable cost-effectiveness ratio could be achieved by
using an accurate preventive measure in communities or selected smaller areas with high caries incidence. The skewed distribution of caries suggests that the small group of individuals at higher risk of developing disease may benefit from a different preventive approach. The results of the CEA show that there is a need for efficiency both in the production process and in the dimension of best possible outcome. The CEA ratio can be adjusted in terms of both costs and outcomes and it is important to consider this when organising youth dental care. The important questions are: what preventive measure should be used in the different individual groups for best possible outcome, and which competence level is most suitable for each group?

8.2.2 Cost-benefit analysis of caries-preventive measures

There was a significant difference between the mean WTP for the two risk groups. Individuals in the high-risk group were prepared to pay 318.49 SEK (US$41.36) more for a caries-preventive strategy than individuals in the low-risk group (Paper V). The WTP technique has the advantage of being able to present a hypothetical market situation when the traditional market fails, although its use has been controversial (92).

Although a number of studies in the dental literature use the term “cost-benefit analysis”, there is significant mislabelling. The lack of full and complete CBA studies in preventive dentistry makes proper comparison with the study of Paper V impossible. Two different types of CBA studies can currently be found in the dental literature; studies that use future cost savings as an alternative to a real CBA (112, 118, 119, 132-134), and the recently-published CBA in which the monetary value of the outcome was measured using the contingent valuation method (135-139). Other than the water fluoridation study by Dixon (138) there is to our knowledge no CBA in the literature that has analysed individuals’ WTP using the CVM.

Since one of the primary goals of CBA is to find projects which give a positive net social benefit, both the differences in NSB between the two groups studied in Paper V and the overall positive NSB values are of interest. NSB was calculated using unit cost for prophylactic nurse as the cost of the preventive measure, since nurses were the professionals responsible for the intervention (169).

Calculations were also performed using the same calculation technique and total treatment time, but with the unit costs that would be incurred if treatment was provided by either dental hygienists or dentists. The unit cost data were collected from Oscarson et al. (174). Use of dental hygienists again resulted in positive NSB values; for the high-risk group, NSB was 648 SEK (US$84.16) from the societal perspective and 845 SEK (US$109.74) from the dental care perspective. Use of
dentists resulted in small but positive NSB for the high-risk group; 15 SEK (US$1.95) from the societal perspective and 214 SEK (US$27.79) from the dental care perspective. For the low-risk group, both NSB values were positive using dental hygienists to provide treatment and negative using dentists.

8.3 Outcome

Outcome is one of the key issues in economic evaluation (91). Depending on the type of comparison, a distinction is often made between cost-effectiveness, cost-utility and cost-benefit analyses. In CEA, the use of real endpoints (e.g., number of heart attacks prevented, lives saved, events that occur or do not occur) is recommended over the use of surrogate endpoints such as reduction in mmHg or, in dentistry, DMF values. If the relationship between the surrogate endpoint and the actual endpoint is known, then it is better to use the reduction in the latter as the effectiveness measure. Further, if endpoints are used then their definition must be clearly stated. Cost utility measures such as quality-adjusted life-years (QALYs) were developed to overcome deficiencies and make possible a comparison between different medical specialities. The idea of QALYs is that each year of life is multiplied by a weight reflecting quality of life; weights are estimated by one of three different techniques and take a value between 0 (equivalent to dead) and 1 (full health). Birch and Ismail (193), reviewing the concept of utilities and their use and benefits in economic evaluations (CEAs and CUAs), concluded that before utility measurement is accepted as a standard component in dental health research, there must be guarantees that the right things are measured, in the right way, and in the right group.

In cost-effectiveness analysis it has been more common to incorporate both general and disease-specific quality of life measures. The use of general quality of life instruments enables comparison of quality of life between different diseases. The disadvantage is that many of the items may not be relevant for some diseases, and they may not be sensitive enough for small changes. They can, however, be useful as a supplement to more specific measures. Cost-benefit analysis, on the other hand, offers a direct comparison between costs and outcomes, since both are expressed in monetary terms (91).

Most outcome measures in dental health care have been associated with the clinical approach to oral health, since they equate health with absence of disease. Several indices and outcome measures have, during the last few decades, been constructed and used in dental health care for describing health conditions, for example in periodontics (39, 41, 194) and orthodontics (42). For caries disease, the composite DMF index (36) was introduced as early as 1937 and has been widely used as the major outcome measure of dental health. For an outcome measure to be appropriate for health care evaluation, it should be understandable by all involved,
and should express benefits in terms of increased quality of life and utility (43). The DMF index ignores changes in quality of life. Rosenberg et al. (195) discuss the importance of patient perspective, arguing that if a patient’s functioning and dental care expectations are not taken into consideration in the formulation of a treatment plan, then, as is common in medical care, compliance and outcome may be negatively affected. Coulter et al. (196) discuss a shift from instruments focused on the provider and based on the bio-medical paradigm towards instruments focused on the patient and based on more subjective measures of oral health. Dentistry must draw on the social sciences in order to articulate more clearly the social and psychological factors that must be included within such a patient-focused index.

Attempts have been made to incorporate changes in quality into clinical measures. Birch (121) improved the DMF index by developing a measure for quality-adjusted tooth years (QATYs). The QATY measure is constructed by giving the Ds, Ms, and Fs different weights and introducing a time dimension for tooth health quality. In an attempt to value the different components of the index, Fyffe and Kay (122) introduced different tooth health utilities to combine with the DMF index. Another attempt at developing the DMF index was described by Sheihama et al. (197). These authors constructed the following two indicators: number of functioning teeth, defined as the aggregate of filled and sound teeth; and number of sound-equivalent teeth, defined as a weighted average of sound teeth, filled (but otherwise sound) teeth, and teeth with some decay. The weights were, in principle, intended to represent the relative amounts of sound tissue in these three categories of teeth. They found this system to be more reliable than the DMF index as an indicator of dental health. In studying cranio-mandibular disorders there have been several attempts to show the impact of disease on patients’ daily life, for example by List and Helkimo (198). QATYs have also been used in periodontics (199). Marcus et al. (200) constructed a multi-dimensional oral health index which reflected more detailed information on oral health status.

Despite such attempts to develop a more suitable outcome measure, and although many years have passed since the first discussions on the use of the DMF index, it is still frequently used in preventive dentistry research. However, although the DMF index is understandable, persuasive, and sensitive to the effects of the intervention in a study, it is neither sufficient in a complete economic evaluation nor entirely useful for comparison of a diverse set of health interventions. Furthermore, despite claims to the contrary, it will only rarely capture all the potential benefits and harms of an intervention, or give an outcome that is possible to evaluate in CBA. Further development of these crucial outcome measures still has high priority in evaluation research.
8.3.1 OHRQOL as a supplemental measure in economic analysis

In recent years there has been broad acceptance of the use of measures that can supplement clinical outcomes by making patient-oriented improvements in quality of life and well-being more explicit. This increasing interest has contributed to the development of several measures, both generic measures like the SF36 (58) and EuroQol (201), and those more specific to oral health, such as the Oral Health Impact Profile (OHIP) (72), the OHIP-14 (73), the Geriatric Oral Health Assessment Index (GOHAI) (68), the Dental Impact Profile (71), and the Oral Impact on Daily Performance (OIDP) (75). In dentistry, the commonly-used measures are GOHAI, OHIP, and OHIP-14. The age-dependency of these measures has been discussed by, for example, John et al. (202), and particularly by Jocovic et al. (79) and Gherunpong et al. (82). Children and adolescents go through a physical and psycho-social development which must be taken into account in the use and development of OHRQOL measures. Jocovic et al. (79) and Gherunpong et al. (82) presented two useful measures aimed at children, the CPQ (Child Perception Questionnaire) for different age-categories, and the child-OIDP. Humphris et al. (83) used a variant of the measure described by Jocovic et al. (79), with a 25-item questionnaire developed for 8-10 year-olds.

The study described in Paper IV found that OHRQOL measures were not able to discriminate young adults with high risk of caries from those with no caries experience with respect to perceived oral health related quality of life. It is instructive to compare the mean CPQ11–14 scores of these groups — 17 for the high-risk group and 14 for the low-risk group — with those collected by Jocovic et al. (79), who found a substantial impact of oral and oro-facial conditions on function and psychosocial well-being for three different study populations; pedodontic (mainly caries problems), orthodontic, and oro-facial. Using the CPQ11–14 measure, they found overall mean scores of 23.3 for the pedodontic group, 24.3 for the orthodontic group, and 31.4 for the oro-facial group. The oral conditions of the pedodontic group are the most suitable for comparison to the individuals in the present study, especially for the high-risk group. For the four different health domains (oral symptoms, functional limitations, emotional well-being, and social well-being) Jocovic et al. (79) reported sub-scale scores of 6.2, 5.8, 6.3, and 4.9 for the 11–14-year-old children in the pedodontic group; these scores, like the overall scores, were higher than those of the 19-year-olds in the present study. Furthermore, they also found a positive correlation between overall scores and the number of decayed tooth surfaces, a finding not mirrored among the 19-year-olds of our study. It should be noted however that the study by Jocovic et al. (79) lacked a control group and had a sample size of only 32.

Åström and Okullo (203) studied the OIDP measure in combination with a clinical examination. The study investigated dental caries (DMFT index) in a population of
372 Ugandan adolescents aged 13–19. Sixty-two per cent of the individuals reported experiencing an oral impact that affected their daily life in the past six months. A floor effect of 32% indicates that the OIDP impacts are of relatively high severity in this population. Overall DMFT scores in the Ugandan study ranged from 0.0 to 14.0 with a mean of 2.9. None of the OIDP frequency items discriminated statistically significantly between adolescents with decayed teeth (DT>0) and those without (DT=0); however, statistically significant differences were observed between students with missing teeth (MT>0) and those without (MT=0).

The OHIP-14 has mostly been used among the elderly, and often to functional outcomes. In a study of elderly populations, Locker et al. (184) reported that 27.1% reported one or more impacts, with a mean overall score of 5.9. The high-risk and low-risk groups in the present study gave overall OHIP-14 scores of 3.7 and 2.2 respectively. In a study comparing the OHIP-14 and EuroQol-5D+ in a general adult patient population, Brennan and Spencer (186) reported an overall score of 8.94 for the OHIP-14 measure.

The correlation between clinical indicators and subjectively perceived OHRQOL measures has been discussed for example by Allen (183). Atchison and Dolan (68) and Locker and Slade (204) reported weak correlation between clinical indices (e.g. caries or periodontal pocketing) and summary scores derived from GOHAI and OHIP respectively. However, these studies involved an elderly adult population, leaving open the question of whether the same circumstances apply to children and adolescents. In a population including both children (12-13 years old) and adults in New Zealand, Chen and Hunter (17) attempted to find different predictors and their impacts on OHRQOL (socio-economic status, oral health behaviour, and oral health status). They showed that decayed teeth, whether treated or untreated, may have a negative impact on children’s oral well-being.

Jocovic et al. (185) have discussed the benefits of global rating, a useful single-question measure that can be used instead of the more traditional multi-item measures. Global rating saves time for both respondents and investigators and has been seen as measures that could provide with information about how people perceive their health, predictors for health services, functional decline and survival. Two global rating questions (185) were presented, both positively correlated with the CPQ11-14 measure: “Would you say that your health of your teeth, lips, jaws or mouth is...” and “How much does the condition of your teeth affect your life overall?” The latter question was included in the study described in Paper IV, but no significant differences in answering were found between the high-risk and low-risk individuals. Jocovic et al. (183) reported that 30.1% of individuals said that their overall well-being was “some/a lot/very much” affected by their oral or oro-facial conditions. This is in contrast to the results of our study; 73.4% of the individuals in the high-
risk group and 67.3 % in the low-risk group reported that their well-being was some/a lot/very much affected. It is difficult to interpret these differences. Jocovic et al. (185) noted that the global rating of well-being was age-dependent and indicated that the older children experienced more impact on their lives as a whole. It is unclear, however, whether this can explain the high impact of oral health impact reported by the subjects of the present study.

The objective of the present study was to investigate the usefulness of OHRQOL measures to supplement health economic evaluations, a possibility that has potential support from other studies (1, 79, 91). Johannesson et al. (91) note that because of their structure, quality of life instruments are still not feasible for direct use in economic evaluation. These instruments typically consist of different dimensions, the scores of which are frequently collapsed into a single composite score though simple addition. There is no reason to believe that this score can be interpreted as a suitable weight for the construction of quality-adjusted life-years. Instead, the usefulness of OHRQOL measures lies in their use as a complementary measure for describing states of health and for revealing in which dimensions the quality of life changes with different treatments. They can also be useful together with measurement of willingness to pay in cost-benefit analysis and to supplement clinical indicators in order to provide a comprehensive account of the health of individuals and populations.

However, our work indicates that the prevalence and incidence of caries in Sweden is too low to have major influence on young adults’ perceived OHRQOL and well-being. We must also bear in mind that older adolescents, such as the 19-year-olds in our study, are capable of handling situations differently from the younger children previously studied, at least regarding dental health care. This may partly explain the difference between the results of our study and the results of others. Use of the same study design with younger and less mature subjects may have yielded results more in line with those of Jocovic et al. (79).

8.3.2 VOSOH\textsubscript{ITS} \textit{(Value Of Statistical Oral Health\textsuperscript{intact tooth surface})}

The WTP data elicited for Paper V was also used to develop a new outcome measure. The idea of a statistical life is widespread in the literature, with a large range of reported values. Persson et al. (10) reported in a Swedish study that the value of a statistical life is approximately 20 million SEK (US$2.4 million) at 1999 prices. Similar calculations for the statistical value of a healthy tooth or dentition are to our knowledge not covered in the dental literature. Our new outcome measure, VOSOH, can potentially be used as a supplement to CBA studies, and seems especially feasible for interventions in preventive dentistry both in dental caries prevention and periodontal health care. Given the expression of the formula, the estimation of risk is important. Two different study groups were included in
Paper V, each with different prerequisites with respect to caries risk. According to the formula, lower estimated risk for the same WTP value results in a higher value of the statistical measure under study, which seems logical. If the risk is estimated to be very low, and individuals still have a high willingness to pay for a preventive programme, that results in increased individual preferences and high values of the statistical object under study.

Unqualified VOSOH is a comprehensive overall term encompassing the entirety of oral health. A potential first step on the staircase, the value of an intact tooth surface, was the value elicited in our study.

We can also consider a hypothetical worst-case scenario (not previously described), the loss of all teeth in the upper jaw due to periodontal disease, in order to estimate a value for VOSOH-Upper Jaw Dentition. The high-risk individuals were presented with the following scenario: “Given your history, your risk of losing all teeth in the upper jaw within the next 10 years is about 1/10. An extensive periodontal treatment and maintenance programme provided by a dental hygienist can reduce this risk by 60%. How much are you prepared to pay per month to reduce your risk by 60%?” Assuming a WTP of 325 SEK ($42.21), i.e., a yearly WTP of 3900 SEK ($506.49), the formula VOSOH-UJD = WTP / Δp (where Δp is the reduction in risk), gives the value of preservation of healthy upper dentition as 65000 SEK ($8441.56). VOSOH enables comparison of the costs of preventive treatment and maintenance programmes with, for example, a treatment that uses a complete upper jaw implant supported bridge. It is important however to emphasise that for calculations to be valid, knowledge about the initial risk and the capacity of risk reduction must be relevant. Nevertheless, VOSOH has the potential to serve as a supplement to the net social benefit calculations in cost-benefit analysis for an even more comprehensive understanding of individual preferences.

8.4 What is the scope for the dental health care decision-maker?

Decision-making in health care must take into account several priority issues. Health economics can assist in providing a sound basis for this, but given the multiple characteristics of different diseases and health problems, a single measure may be insufficient. The best approach to take may be a combination of clinical and effectiveness measures with patient-oriented measures such as quality of life, information about individual preferences, and appreciation of the net social benefit (1).

There are a number of objectives for a decision-maker to consider when managing dental health care administration among Swedish county councils. As the main person responsible for a public health care enterprise, the decision-maker should be concerned with the growth of the company, for example in terms of increased skill...
and knowledge. Explicit incorporation of health objectives into the accounting procedure is of importance, not least in order to strengthen the health profile of the company.

Health economic evaluations in dentistry are still at the development stage. Despite this, and despite the fact that public dental health care might not yet be prepared for the immediate implementation of such evaluation techniques, there is still no reason not to begin the process and thus contribute to further development of suitable methods. By broadening the decision-making basis to include different perspectives and analyses such as CEA, OHRQOL measures, and CBA (Papers III, IV and V), contributions to further progress can be made. It should be remembered that different outcome measures give different information, and these new techniques are complements rather than substitutes (91).

The following method of opening the health economic perspective to the decision-maker in preventive dentistry is suggested: Firstly, make an inventory to identify and establish actual baseline data in terms of both finance and health. Secondly, stipulate clear and well-defined overall health objectives from both clinical and patient-oriented perspectives. Thirdly, establish treatment objectives for different patient categories with well defined outcome measures consistent with the overall health objectives, beginning with the two main oral diseases, caries and gingivitis/periodontitis. Health promotion, maintenance care, and treatment of disease must all be considered, and both costs and consequences should be explicit in the budget. Fourthly, implement a CBA prior to the planning process to discover the preferences and WTP for preventive dentistry among the adult population. Fifthly, implement different preventive strategies. Before implementation, analyses of individual preferences, health objectives, expected result of preventive measures, resource accessibility, and allocation policy must be undertaken in order to create the best health outcome. Sixthly, perform continuous follow-ups (centralised or local) to compare health outcomes with costs (CEA, CBA, OHRQOL). Health organisations should be obliged to consider these perspectives in the recurrent budget process.

8.4.1 Organisation of dental clinics

Clinic organisation is not just a matter of economic efficiency or job satisfaction but is also and above all an opportunity to create an optimal mix of resources for ensuring the best possible health outcome.

There are varying estimates of the total clinic time used for preventive work. The analysis described in Paper I of the services provided by a single clinic showed that 17% of the time during the week studied was used for preventive work. Edward et al. (205) found that approximately 6% of total clinic time was used for individual
prevention in children aged 6–19. A report by the SBU (150) used data from Gothenburg county to estimate the working time used on prevention by dentists (8.1%), dental hygienists (43.9%), and nurses (25.7%). Regardless of the exact estimate that one chooses to rely on, it is clearly essential that these resources be used properly.

As shown in Figure 6, treatment by dentists makes up most of the total treatment time; those figures, from 1994, give a mean value of 72%, which is still reflected in the way dental work is organised today (Paper II). Dentist time naturally includes diagnostic and intervention activity, and while for some clinics this emphasis on such activities might be appropriate, the majority of children and adolescents and even adults visiting a dental clinic will be in fairly good health. The sensitivity analysis of Papers II and III showed that in terms of cost-effectiveness efficiency, both salary cost and outcome have an impact on the CEA ratio. This could be an incentive for dental clinics to reorganise their personnel and work procedures in order to achieve optimum efficiency in terms of both costs and outcome measures. The objectives of dental health care are to preserve health in healthy people, to prevent diseases, and, for the small group of individuals at higher risk of developing disease or already suffering from disease, to offer an efficient treatment strategy. Care should be organised in such a way as to accomplish these objectives. There may be some advantages to organising clinics from the health-promotion perspective.

Hannertz and Westerberg (206) have described yet another approach, with a study designed to test an alternative model relating to competence and mix of personnel. A public dental clinic was set up in a Swedish town with personnel consisting of one dentist and five dental hygienists, in contrast to the conventional setup of two dentists and four dental nurses. Thus the input of the dentist was reduced by half, while the dental nurses were replaced with more clinically-competent dental hygienists. In Sweden dental hygienists are entitled to make independent decisions regarding examination and preventive and treatment measures within the scope of their professional skills. Moreover, the emphasis of their skillset is predominantly directed towards disease prevention and the promotion of health. The outcome of the study was that the new way of organisation produced better results. A positive benefit/cost relation was also demonstrated, in line with that described by Wang (207) and Jokela and Pienihäkkinen (208), who discussed reduced personnel expenditures in children’s dental care.

It seems clear that clinics should aim for a health-promoting profile rather than continue taking a restorative approach. For this reason, when organising the dental clinics the decision-makers must keep in mind the objective of oral health, and determine the best mix of personnel categories to accomplish it.
Fjelddahl (173) presents some recommendations based on risk indicators found in the intervention study “Evaluation of caries-preventive measures” (169). The population-based recommendations were: brush your teeth twice a day, eat sweets no more than once a week, receive a fluoride varnish at examinations, and, for high-risk individuals, use an intensified varnishing programme. Burt (155) has emphasised the need for three categories of future prevention strategies. The motivation for the first type, population strategies, is that since public dental health has an obligation towards the whole population there will always be room for programmes such as water fluoridation (where feasible), fluoridated toothpaste, and education regarding good oral health habits. Geographically based strategies, on the other hand, would be targeted at selected areas and would include public health fluoride rinses or fluoride supplements in areas with high incidence of caries. Thirdly, targeted strategies for individual patients would include fluoride gels, varnishes, chlorhexidine, sealants, and other intervention such as dietary restrictions. The targeted strategy would seem immediately attractive, due to the small group of people who suffer from caries disease or are at high risk for developing disease. However, a strategy that involves selecting individuals from a classroom is likely to become expensive once the costs of testing and administration are added. The best way may therefore be to use a targeted, geographically based strategy aimed at a seriously disease-affected group in a particular district, for example, or a particular school. Even though the trend in prevention is towards following a high-risk strategy, it is also important not to forget the population-based strategies. Regular individual contact with dental health care providers as well as health promotion may certainly contribute to good health education and result in positive health behaviour, which in turn may have positive effects on prohibiting other oral diseases such as gingivitis and periodontitis (209, 210), as well as promoting general well-being in the future.

Even though preventive programmes c and d did have some positive effect, and resulted in the lowest caries increment, it seems that the preventive measures tested were insufficient to have an impact on a high-risk group, since individuals in the high-risk group developed far more caries than did those in the low-risk group. It is possible however that the individuals in the high-risk group were too heterogeneous to all respond in the same way to a relatively standardised programme. Because of the many possible interdependent factors that impact negatively on the risk of dental caries — for example, undesirable social situations, dietary factors, compliance, and defence factors — it is possible that a more targeted and individualised preventive strategy is the only way to maximise a positive health outcome for such individuals.

Thus it seems that dental health care decision-makers must consider not only finding better individually adapted preventive measures for targeted risk groups, but also organising dental clinics with a more suitable mix of providers and an
optimal distribution of services between those providers for a better health outcome. Since the cost-effectiveness ratio can be modified by altering both costs and outcome, efficiency is necessary not only in the production process but also in the outcome of best possible oral health. In other words, it is not only a matter of where the cheapest dental service can be provided, but also of what preventive measures are used and which competence level is best suited for handling different patient groups within the clinic. One practical suggestion is that *dentist* time is best used for consultation, therapy planning, and rehabilitation of the minority of individuals with increased health care demands, while *dental nurses* can be used for more standardised population-based strategies. *Dental hygienists*, with their preventive and health promoting profile, are best suited for handling oral health controls as well as working with the dentist on therapy planning and evaluation of treatment for the small group at high risk. However, it must be remembered that proper allocation of resources is not just a matter of calculating costs and outcomes but also has an inherent dilemma of equity. The distribution of disease and links to factors such as ethnicity and socio-economic background must be taken into account by decision-makers when consider how prevention and resources should be allocated to all individuals in a just and equitable way.

### 8.5 Conclusions

- Preventive dentistry has a central role in Swedish public dental health care. Prevention as a dental clinic activity consumes resources, and it is essential that these resources be used properly.
- The total cost for preventive treatment given to 92 adolescents at a single clinic during a four-year study was 40 200 SEK. The amount spent on prevention in the low and average caries-active group was less than half the sum spent on the high caries-active group.
- Methods for evaluating costs have been proposed, useful for CEA and CBA.
- The choice between the use of average treatment time cost or unit cost time cost depends on the data that are available and the perspective of the analysis.
- Within Swedish public dental health care, charges are not sufficient as an alternative to a more detailed cost evaluation since they do not cover costs.
- The economic evaluation of the caries-preventive measures analysed in the four-year intervention study, “Evaluation of caries-preventive measures”, showed an incremental cost-effectiveness of 2 043 SEK per averted DₐMFS when unit costs were calculated under the assumption that nurses were responsible for preventive treatment. Of this amount, treatment costs comprises 1 337 SEK. This result corresponds to a yearly treatment cost of approximately 334 SEK. Evaluation of the five-year follow-up, again using nurses to establish the unit
DISCUSSION

cost, showed an incremental cost-effectiveness ratio of 1,851 SEK per averted D<sub>e</sub>MFS, that is, a yearly cost of 463 SEK.

- It is important to consider the perspective from which a study is carried out. Costs contributed by the patient and the patient’s family have a high impact on total costs for children and younger adolescents but decrease with time as the adolescents get older.

- The usefulness of OHRQOL measures to supplement outcome measurement in health economic evaluations, particularly as directed toward caries preventive interventions, cannot be supported by this study, at least not for Swedish 19-year-olds; the OHRQOL indicators were not able to discriminate between individuals with no caries experience and those with high caries experience.

- The contingent valuation method was used to elicit 19-year-olds’ willingness to pay (WTP) for caries preventive measures. The net social benefit calculated using these data was >0, meaning that the benefits of prevention exceeded the costs. The individuals with high caries experience had a higher mean yearly WTP than the individuals with no caries experience; 1,405.44 SEK (US$182.52) as compared with 1,086.96 SEK (US$141.16).

- A new outcome measure, Value Of Statistical Oral Health (VOSOH) was also presented, and its potential use as an additional supplement to CBA in health economics was discussed. Even though the sample size was small and the subjects were localised in one Swedish county, the results of the contingent valuation method used indicate the applicability of the methods and suggest that further testing and analysis would be worthwhile.

- The proposed and tested methods for health economic evaluation seem useful for improving the basis for the decision-making process.

There is still scope for finding an even more useful outcome measure in order to make changes in caries disease (and other oral diseases) more explicit and thus improve the quality of information available to patients and decision-makers alike. Even though the CBA of Paper V may be best considered as a pilot study, the overall impact of the intervention was positive, and therefore is certainly of interest for further testing. Another considerable challenge for future research is to test and increase the validity of CBA analyses. One way of doing this would be to examine its convergence with other health state preferences and measures, for example, quality of life (136, 211). Another way (5, 91) would be the use of revealed preferences, that is, the observation of the decisions that individuals actually make in real market situations. Since the majority of Swedish adults pay for their own dental care, the Swedish dental health care system is rather convenient for this kind of test. It is suggested that when planning for a preventive intervention programme among adults, the programme itself should be preceded by an elicitation of the individuals’ WTP, in order to aid analysis of the respondents’ actual purchases in the health market. Another line that further research could take would be to investigate how the effectiveness of different preventive measures could be improved, and
how increased benefits could be achieved for individuals already suffering from disease or at high risk of developing disease. Additional study of the optimum competence levels and personnel mix within dental clinics could also be fruitful.

Improvement in preventive care is not just a matter of increased efficacy of preventive measures (for example, fluorides). If the social context in which individuals’ lives are organised in a way that makes it impossible for traditional preventive efforts to have any effect, then the focus of our preventive strategies must change. It is time to leave the strictly bio-medical paradigm behind in favour of the biopsychosocial perspective.

Scarcity in both finances and personnel often leads to discussion of changing the way that dental hygienists are employed, usually with the implication that they should begin to take over some of the dentist's restorative work — “drilling and filling”. I believe that such a development would be devastating to the profession and a great waste of their specific proficiency. As recently stated in two systematic reviews by the Swedish Council on Technology Assessment in Health Care (SBU) (150, 212), there has been relatively little evaluation within dentistry of topics relating to patient behaviour, patient communication, patient education and theoretical grounds for increasing patient adherence. Work conducted for this thesis suggests that this deficiency in knowledge about the best way of achieving success in daily work is one reason why each local dental clinic has its own preventive strategy. More far-sighted and thorough analysis and planning is necessary if Sweden is to remain on the front line of advocacy for preventive dental care. The creation of conditions to facilitate controlled clinical trials in these patient-centred subject fields presents a major challenge. Since such fields are encompassed by the traditional profession of the dental hygienist, it seems obvious that this challenge must be undertaken by the hygienists themselves.

This also implies that those who make decisions for and about the Swedish dental health care system must carefully consider which long-term strategy will result in the best health outcome. There is still scope for making a national, uniform, and coherent plan to create guidelines and prerequisites for preventive dental care and evaluation. The establishment of a national centre for preventive dentistry and dental evaluation could be a major first step in such a strategy. Working closely with the general public dental health clinics and the counties that administer them, this could result in an organisation with improved opportunities for the creation of a better general health outcome. Such a national and health-oriented move could also help legitimise the future existence and maintenance of a public dental health care system. The cost of the resources used on one hand, and the value and importance of prevention on the other, are elements too important to be handled incautiously.
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11. Appendix

Appendix A. Cost calculation for proposed methods (a practical example)

### CLINIC DATA

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<th>Treatment Time (Tt)</th>
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<td><strong>Capital</strong></td>
<td>2,125,000</td>
</tr>
<tr>
<td>C - Nurses</td>
<td>4,542,400</td>
<td></td>
<td>221,880</td>
<td><strong>Material</strong></td>
<td>1,150,000</td>
</tr>
<tr>
<td><strong>D - Other</strong></td>
<td>758,880</td>
<td></td>
<td>942,420</td>
<td><strong>Overhead</strong></td>
<td>1,347,300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13,097,000</td>
<td>207,000 / (1,600*60)</td>
<td></td>
<td><strong>Total OH/total</strong></td>
<td>6,264,478</td>
</tr>
</tbody>
</table>

### CALCULATION

#### Method 1

\[
P_{\text{BASE}} \times \text{OH-FACTOR} = \text{UNIT TIME COST/Min.} \times \text{MINUTES TOTAL UNIT TIME COST}
\]

- **Dentist**
  \[
  N \times R = N \times R \times J = 11,168,582
  \]
- **Hygienist**
  \[
  O \times R = O \times R \times K = 1,011,336
  \]
- **Nurse**
  \[
  P \times R = P \times R \times L = 917,082
  \]

**Total Clinic Cost**

13,097,000

#### Method 2 A

\[
P_{\text{BASE}} + \frac{\text{OH/total}}{\text{TT/total}} = \text{UNIT TIME COST/Min.} \times \text{MINUTES TOTAL UNIT TIME COST}
\]

- **Dentist**
  \[
  N + \frac{Q}{M} = N + \frac{Q}{M} \times J = 10,208,419
  \]
- **Hygienist**
  \[
  O + \frac{Q}{M} = O + \frac{Q}{M} \times K = 1,378,487
  \]
- **Nurse**
  \[
  P + \frac{Q}{M} = P + \frac{Q}{M} \times L = 1,510,094
  \]

**Total Clinic Cost**

13,097,000

#### Method 2 B

\[
P_{\text{BASE}} + \times 1.3 = \text{UNIT TIME COST/Min.} \times \text{MINUTES TOTAL UNIT TIME COST}
\]

- **Dentist**
  \[
  N + S \frac{Q}{(J \times X + K + L)} = N + \frac{S \times 1.3}{J} = 10,534,946
  \]
- **Hygienist**
  \[
  O + S \frac{Q}{(J \times X + K + L)} = O + \frac{S}{K} = 1,230,901
  \]
- **Nurse**
  \[
  P + S \frac{Q}{(J \times X + K + L)} = P + \frac{S}{L} = 1,331,153
  \]

**Total Clinic Cost**

13,097,000
### Appendix B. Willingness-to-pay questionnaire. (SEK7.70 = US$1, July 2005.)

In about a year, you will have to pay for your dental care yourself. It will then cost you money to have your teeth examined and fixed. In this county, the filling of one tooth or two teeth will cost about 600 or 1100SEK* respectively. By preventive care, you will reduce the risk for needing fillings and you will increase the chance to keep your teeth and gums healthy. More preventive efforts will decrease the risk for subsequent damage. Preventive care means that dental staff, often a dental hygienist, will advice you on how you should look after your mouth in the best way and will clean and fluoridize your teeth. A preventive care programme may involve about 3 times a year. Preventive dental care will also cost you money.

These questions will help us assess your interest and the interest of other young people in preventive care. Therefore, we would like to ask you how much you would be willing to pay for preventive dental care. Your willingness to pay will measure your interest in this kind of care. We would now like you to answer some questions on how much you would be willing to pay per month for decreasing the risk of tooth cavities by preventive dental care, considering what you think you could afford.

Would you be willing to pay SEK 75 per month to decrease your risk for a tooth filling by at least half (50%) within the next two years?

- Yes
- No

If yes, what is the maximum you would be willing to pay for this? SEK ..........

If no, what is the maximum you would be willing to pay for this? SEK ..........

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*SEK: Swedish Krona