

Caries – Diagnosis, Risk Assessment and Non-Invasive Treatment

A Systematic Review

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Summary and Conclusions of the SBU Report:

Caries – Diagnosis, Risk Assessment and Non-Invasive Treatment

A Systematic Review

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Project Group:

Ingegerd Mejåre (Chair)
Susanna Axelsson
(Project Leader)
Gunnar Dahlén
Ivar Espelid

Anders Norlund
Åsa Svensson
(Project Assistant)
Sofia Tranæus
Svante Twetman

Scientific Reviewers:

Kim Ekstrand
Kajsa H Abrahamsson

Nils Oscarson
Madeleine Rohlin

English Translation:

Ken Schubert

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SBU's Conclusions

Main Conclusions

- ❑ Past caries experience is the single best factor for prediction of future caries (Evidence Grade 1).

It is possible to identify children and adolescents at very low risk of developing caries during the next 2–3 years (Evidence Grade 1). However, it is difficult to determine accurately which individuals are at risk of developing caries.

- ❑ For caries diagnosis, a combination of visual-tactile and radiographic examination is more reliable than either method used separately (Evidence Grade 3). In general, accuracy in excluding the presence of caries is greater than in confirming its presence (Evidence Grade 3). The likelihood that radiation-induced cancer will develop because of exposure to dental radiography is considered to be very small, but greater than zero. There is inadequate scientific support for complementary diagnostic methods. There are no studies of the cost-effectiveness of the various diagnostic methods.
- ❑ There is insufficient scientific support for any conclusion as to whether early caries lesions can be treated effectively by non-invasive methods.

Fact box 1 Study Quality and Relevance, Evidence Grade.

Study quality and relevance refers to the scientific quality of a particular study and its ability to reliably address a specific question.

Evidence Grade refers to the total scientific evidence for a conclusion.

Evidence Grade 1 – Strong Scientific Evidence

A conclusion assigned Evidence Grade 1 is supported by at least two studies with high study quality and relevance among the total scientific evidence. If some studies are at variance with the conclusion, the Evidence Grade may be lower.

Evidence Grade 2 – Moderately Strong Scientific Evidence

A conclusion assigned Evidence Grade 2 is supported by at least one study with high study quality and relevance, as well as two studies with medium study quality and relevance, among the total scientific evidence. If some studies are at variance with the conclusion, the Evidence Grade may be lower.

Evidence Grade 3 – Limited Scientific Evidence

A conclusion assigned Evidence Grade 3 is supported by at least two studies with medium study quality and relevance among the total scientific evidence. If some studies are at variance with the conclusion, the Evidence Grade may be insufficient or contradictory.

Insufficient Scientific Evidence

If no studies meet the study quality and relevance criteria, the scientific evidence is rated as insufficient to draw any conclusions.

Contradictory Scientific Evidence

If different studies are characterized by equal study quality and relevance but generate conflicting results, the scientific evidence is rated as contradictory and no conclusions can be drawn.

SBU's Summary

Background

Caries is a chronic disease which can affect us at any age. Untreated, it can lead to pain in the mouth and loss of teeth. Caries is one of the most common diseases of childhood. In most cases, caries develops slowly and the process may arrest without professional intervention. However, the disease is not usually self-limiting and without adequate treatment the process can continue until the tooth is destroyed. The development of a caries lesion is the result of a complicated interplay of many factors. The term "caries" is used to embrace both the disease process and its consequences, ie the damage caused by the disease process.

A large component of the daily work of dental personnel comprises caries diagnosis, risk assessment (identifying tooth surfaces, individuals or populations groups at risk of developing caries) and early treatment of caries lesions, particularly in children and adolescents. These tasks are so closely related that a caries diagnosis is followed by risk assessment, which in turns forms the basis of treatment decisions.

When a caries lesion is detected, three courses of action are available to the clinician:

- Monitor the condition
- Choose non-invasive (early) intervention, the aim of which is to prevent progression of the lesion

- Choose operative intervention, ie remove the carious tooth substance and restore it with a filling.

There is increasing emphasis on the importance of effective early intervention. A prerequisite for early intervention, however, is reliable diagnosis of the lesion at an early stage of the disease process. The purpose of the present systematic review of the literature was to assess the scientific evidence with reference to the following questions:

- How effective are different methods of disclosing the presence of a caries lesion, compared with a reference method? Are there side effects and risks associated with the methods reviewed? Which diagnostic method is the most cost-effective?
- How well can caries be predicted?
- Are there effective, non-invasive methods (no removal of tooth substance) for treatment of early caries lesions on the crown or the root surface of the teeth?

Method

Literature Search

A search of the literature was conducted primarily via the electronic data bases dating back to 1966. Relevant papers were also identified in the reference lists of the retrieved articles. Other complementary sources were documents from consensus meetings and the reference lists of review articles.

Inclusion Criteria

To be included in the systematic review, all articles were required to meet predetermined criteria: the results of the studies should be relevant to the questions posed by the project, ie have appropriate outcome measures and an appropriate follow-up period

and study design. With respect to diagnosis, the efficacy of the various methods was compared with reference methods which included studies of extracted teeth. For prediction, the material comprised mainly prospective studies, where the reliability of risk assessment could be evaluated. With respect to treatment of early caries lesions, it was a requirement for inclusion that the study had a control group.

Reviewing and Grading the Quality of an Included Study

The articles which fulfilled the inclusion criteria were further reviewed by at least two reviewers, according to an assessment protocol. The protocol was a basis on which to compile information on the study design and results and to rate the quality of the study, ie how well the study had been conducted and how reliable the results were considered to be. The quality of each study was assessed separately by at least two reviewers and rated as high, medium or low.

Grading the Evidence Supporting the Report's Conclusions

Conclusions were drawn with respect to each of the questions posed in this project. The conclusions were based on the strength of the supporting evidence which was in turn derived from the quality ratings of the studies selected for inclusion under the respective topics. The strength of the evidence supporting the conclusions was graded as strong, moderately strong, limited or insufficient, as shown in Fact Box 1. It should be noted that although the effect of an intervention may be assessed as lacking adequate scientific backing, this does not necessarily mean that the intervention is ineffective. Lack of an unambiguous, scientifically supported result can be interpreted as an indication that the method warrants further investigation in clinical studies.

Investigation of Established Practice

Because there is no up-to-date information about how often the most common radiographic examination, the bitewing radiograph, is used on children and adolescents, the project began with an investigation of established practice. Bitewing radiography is a method in which the radiographic film is placed in a holder with a tab for the patient to bite on. The method allows the crowns of both the upper and lower teeth to be viewed on the same film. Those county council health departments which had a computerized patient record system in the year 2000 were asked whether it would be permissible to retrieve data on the frequency of bitewing examinations of children and adolescents. Comparable regions in Norway were also included in the investigation. The results disclosed that bitewing radiographs were used as an aid to caries diagnosis in 20–40% of examinations of 5 year-old children. The corresponding figures for Norway were 10–25%. In both Sweden and Norway, regular dental checkups from 11 years of age almost always include bitewing examination for caries diagnosis.

Results of Literature Search

How Effective are the Various Methods for Diagnosing Caries?

Background

In current practice, caries is diagnosed mainly by visual-tactile and radiographic examination. Often the methods are combined in an established clinical routine. To avoid unnecessary exposure to radiation and for other reasons there should be clear indications for radiographic examination of a patient. Visual-tactile examination means that the teeth are examined using a mouth mirror and probe: each tooth is systematically inspected, surface by surface. For optimal visual examination it is necessary to have good lighting, the teeth should be cleaned prior to examination and

kept dry with the aid of cotton rolls or a blast of compressed air. Visual examination of caries lesions is often used when screening patients, eg determining a patient's priority for treatment and in risk assessment.

Radiographic examination in which the radiographic film is placed in a holder, so-called bitewing examination, was introduced as early as 1924. Today either conventional or digital techniques may be used for radiographic examination. The digital technique has many advantages, eg it saves time, no chemicals are used, the radiation dose is lower, storage of films is less complicated and information from digital radiographs can more readily be shared. The digital technique also offers greater versatility, eg brightness and contrast can be adjusted to enhance radiographic characteristics relevant to the diagnostic question.

Radiographic Diagnosis

On the basis of two studies of moderate quality it may be stated that radiographic diagnosis of approximal caries (caries on the surfaces between the teeth) in dentine (tooth bone) has high specificity (correctly identifies sound surfaces) but that sensitivity (correctly identifies surfaces damaged by caries) is highly dependent on the extent of carious damage to the dentine. This is not unexpected: the greater the mineral loss, the more obvious the contrast on the radiograph between sound and carious tissue. For enamel caries, the values for sensitivity in these two studies were 22 and 46% respectively. The corresponding values for specificity were 97 and 76% respectively. This illustrates the inverse relationship between sensitivity and specificity.

In contrast to the approximal surfaces, the chewing surfaces can be inspected directly. For radiographic diagnosis of caries lesions on chewing surfaces, it is common in many studies to use a selection of extracted teeth where the clinical findings are uncertain and the diagnosis will be determined from the radiographic

appearance. Thus the study material often includes lesions located adjacent to the junction of enamel and dentine. Such a sample gives low values for sensitivity. The potential to extrapolate such research results is determined by the selection of carious lesions and the severity of the lesions.

Visual-tactile Diagnosis

Studies of visual-tactile diagnosis are based on both selected samples of extracted teeth and clinical examinations. Studies on extracted teeth predominate.

Studies Based on Extracted Teeth

Evaluation of visual-tactile examination of the chewing surfaces of permanent teeth was based on nine studies of moderate to high quality. Despite considerable similarities in design and method, the studies showed widely discrepant results and remarkably high ranges of sensitivity (10–95%) and specificity (39–98%). The pronounced variation is attributable mainly to the fact that the selected material varied markedly between the studies and that there is a difference in the depth of lesions involving dentine. A further factor contributing to the wide range of results is variation in methods of validation (macroscopic methods were used in some studies and microscopic methods in others).

In general, these publications indicate low sensitivity and high specificity for diagnosis of dentine caries. This implies that in practice, overdiagnosis of dentine caries using visual-tactile examination is negligible, but some caries lesions are overlooked. In the case of early diagnosis of enamel caries lesions on the chewing surfaces, sensitivity is generally higher, but specificity is significantly lower. This means that the diagnosis “no dentine caries” is more reliable than the diagnosis “no enamel caries”.

The diagnostic potential of visual examination of the approximal surfaces of the teeth was investigated particularly in three studies. As in the above studies, these studies reported low sensitivity (median 21%) and high specificity (median 97%) for diagnosis of dentine caries.

Clinical Studies

In the clinical studies of dentine caries on the chewing surfaces, sensitivity was 72% and specificity 84%. The corresponding values for the approximal surfaces were 34 and 98% respectively. Because of the limited number of studies, no firm conclusions can be drawn with respect to the potential of the visual method to diagnose caries lesions on chewing and approximal surfaces.

Combined Visual and Radiographic Examination

With respect to combined visual and radiographic diagnosis of caries on chewing surfaces, two studies were included: one of high and one of moderate quality. The values for sensitivity and specificity varied between the two studies: sensitivity 49 and 65% and specificity 73 and 87%, respectively. The variance was probably attributable to the diagnostic strategy and/or differences in the severity of the caries lesions.

Caries Diagnosis in Baby Teeth (Deciduous Dentition)

With respect to the deciduous dentition, the literature review disclosed no studies which assessed the value of radiographic examination. For visual-tactile examination as the caries diagnostic method, there are no studies of the approximal surfaces. In the studies identified as evaluating visual-tactile examination of the chewing surfaces of the deciduous teeth, the results do not differ from those of studies on the permanent teeth.

Diagnostic Aids/Complementary Methods

Some of the diagnostic methods which may become available for general clinical application in the future are based on a variety of technical solutions and physical explanatory models such as fluorescence, heat, ultrasound or electrical impedance. FOTI (fibre optic transillumination), DiFOTI (digital fibre optic transillumination), DIAGNOdent, QLF (quantitative light-induced fluorescence) are optical methods. ECM (electronic caries measurement) is based on electrical impedance

Studies of ECM on extracted teeth provide limited scientific support for high specificity (85%) for diagnosis of dentine caries on the chewing surface, which implies a moderate risk of over-diagnosis. With respect to other recent methods for caries diagnosis, there is to date insufficient scientific support to allow evidenced conclusions.

How can Caries be Predicted on the Basis of Various Risk Factors and/or Risk Indicators (Predictors)?

Background

Official statistics on children and adolescents in Sweden show a gradual improvement in dental health up to the year 2000, but no appreciable improvement since. From age 7 to 14–15 years, lesions on the chewing surfaces of the permanent teeth predominate. Thereafter there is an increase in the incidence of lesions on the approximal surfaces. Lesions on the front teeth and on the buccal and lingual surfaces (surfaces facing the cheeks and the tongue) are today relatively uncommon.

Epidemiological and demographic studies show an increase in the number of elderly people in the population. The number of dentate elderly (those with their own teeth) is also increasing. As a result of periodontal disease and as part of the aging process the gums recede, exposing the root surfaces. The risk for root caries is relatively high because the root surface is less resistant to acid attack than enamel.

A correlation between various factors and the development of caries has been shown in a large number of cross-sectional studies. Such studies are valuable for identifying potential risk factors for caries, but they are inadequate for correctly identifying individuals at risk for caries, which is the determining characteristic of a prediction model. For this, longitudinal, preferably prospective studies are required.

Most of the studies of caries prediction use models with one or more risk factors/risk indicators. To be applicable in practice, a good model for risk assessment should also be simple and inexpensive and most importantly, it should function as a useful aid in decision-making. Risk assessment is used not only to decide what form of treatment the patient should have, but also to determine an appropriate interval for patient recall.

Toddlers and Preschool Children

Prediction Models

One study of high quality tested alternative prediction models and found that at one year of age a combination of sociodemographic factors, dietary habits and counts of mutans streptococci gave a sensitivity of 87% and a specificity of 83%. A new analysis, conducted when these children were 2.5 years of age, disclosed that the presence of caries lesions was then the single best predictor. In another study of high quality, the greatest precision was achieved by a combination of caries lesions (including initial lesions) at study start, dietary habits and the presence of mutans streptococci. The single best predictor was the presence of mutans streptococci (sensitivity 69%, specificity 78%). These latter two studies investigated populations of different sociodemography, used different follow-up intervals and in part different predictors in assessment of caries risk: comparison is therefore difficult. Both studies found a significant correlation between caries lesions and frequent consumption of products containing sugar (more than once a week), but the predictive power was limited.

Mutans Streptococci in Saliva

In toddlers (1–2 years) the presence of mutans streptococci as the sole predictor for caries during the following 2–3 years had low accuracy (either low sensitivity combined with high specificity, or vice versa).

Salivary Lactobacillus Count

In a large number of studies on both toddlers and preschool children, the presence of lactobacilli in saliva has been tested as the sole predictor or in models. The accuracy in predicting the development of caries lesions is low.

Visible Plaque

The presence of plaque on the labial surfaces of the front teeth of toddlers (1–2 years) has been tested as a predictor of the development of caries lesions during the following 2–3 years, but the accuracy is poor (sensitivity 26%, specificity 88%).

Children aged 1–3 years who brush their teeth with fluoride toothpaste at least once a day have a greater chance of remaining free of caries at age 3 than those with poor oral hygiene. However, as only one study on this topic was included, it is not possible to draw any conclusions about the frequency of toothbrushing as a predictor.

Caries Lesions in Deciduous Teeth as a Predictor of Caries in the Permanent Teeth

Three studies of at least moderate quality investigated the potential to predict caries lesions in the permanent teeth based from the presence of caries in the baby teeth. The studies are heterogeneous and the results vary with respect to predictive potential. The average values were 62% for sensitivity and 79% for specificity.

Schoolchildren and Teenagers

Prediction Models

Five studies of at least moderate quality tested various prediction models. In one study, past caries experience in combination with lactobacillus counts gave the highest precision, but the authors concluded that the additional advantage of including the lactobacillus counts was so minor that in practice it was not cost-effective. In older children and teenagers, high counts of mutans streptococci ($>10^5$ per ml saliva) were of little predictive value in models. Past caries experience and a general assessment of available clinical observations gave the best results. None of the models attained the predetermined accuracy (sensitivity $\geq 75\%$, specificity $\geq 85\%$). No study demonstrated that salivary secretion rate and buffer capacity made a marked contribution to the predictive potential.

Sugar Intake as a Predictor

In several studies it was noted that the association between sugar intake and caries lesions is today much less marked than it used to be, mainly because of more widespread exposure to fluoride. This is in good accordance with the results of the present report. In school children and teenagers (with generally low caries incidence and daily use of fluoride toothpaste), daily consumption of sugary snacks between meals is not particularly useful in prediction models.

Despite the limited comparability of the studies, it is obvious that current caries status – which is the result of past caries activity – is the most effective predictive factor. The presence of plaque, bacteria associated with caries, salivary factors and exposure to fluoride (from toothpaste) do not markedly improve the predictive power. This applies in particular to schoolchildren and teenagers and may be due to the fact that the current level of caries reflects relatively well both past and current interplay between the various disease-inducing factors.

Posteruptive Age as Predictor

In the permanent teeth, the risk of developing caries is greatest during the years immediately after eruption: for occlusal surfaces, the first molars are at greatest risk during the first year and the second molars during the first 2–3 years after eruption. The approximal surfaces are at greatest risk during the first 3–4 years after eruption.

Are there Effective, Non-Invasive Methods for Treating Early Caries Lesions?

Background

The aim of non-invasive treatment is to heal (remineralize) the initial caries lesion or to arrest or slow lesion progression. The most common form of treatment of initial caries on approximal surfaces is the application of various fluoride compounds. Application of other products has also been tested eg chlorhexidine and ozone, which have antimicrobial properties. Fissure sealants have also been tested on early caries lesions ie the chewing surface is sealed with a thin film of plastic, without first removing the damaged enamel.

Fluoride

Two studies of moderate quality evaluated the effect of applying fluoride varnish to early caries lesions, compared to fluoride rinsing. The results of the studies were contradictory. One reported that the proportion of approximal lesions which increased in size was significantly lower in the intervention group, whereas in the other study there was no statistically significant difference between the two groups.

Fissure Sealants, Chlorhexidine, Ozone

Of the other possible treatment methods, too few studies met the inclusion criteria to allow any conclusions to be drawn.

Cost-effectiveness of Diagnosis and Treatment of Early Caries Lesions

Because of the lack of studies there is no scientific basis for conclusions on cost-effectiveness. The literature search disclosed no study which met the inclusion criteria and which also analysed and compared the costs of diagnosis, prediction and treatment of early caries lesions. A model analysis was therefore undertaken. This disclosed i.a. that the use of a diagnostic method with low accuracy in detecting caries lesions increased costs, because it resulted in an increase in treatment of false positive cases. This applies particularly to groups with low caries incidence. The combination of visual-tactile examination, complemented by radiographs only in cases positively diagnosed by visual-tactile examination, leads to fewer false positive diagnoses, but at the same time identifies fewer true positive cases. Thus this procedure results in higher costs for diagnosis per case detected than when all patients undergo radiographic examination. If the cost of the filling is also included, then the selective radiographic examination gives the lowest cost per positive case.

Ethics

The procedures involved in caries diagnosis today raise questions about ethics. It may be asked whether it is ethical for children to undergo repeated radiographic examination, even though the radiation dose is negligible in comparison to other electromagnetic radiation.

Examination and treatment of frail elderly people, eg in institutions, also raises issues of ethics with respect to autonomy and paternalism.

Because the potential to identify risk individuals is limited, the effectiveness of preventive measures targeting these individuals may be queried. At the same time it may be asked whether it is ethical to refrain from such measures because the possibility that the measures have a caries preventive effect on the individual cannot be excluded.

Future Research

With respect to future research in the field of caries diagnosis, there is a need to standardize study design for in vitro tests of the different methods. This applies to the method's reliability, definitions of what constitutes a caries lesion, mandatory disclosure of the prevalence of caries in the selected teeth and also how various groups of teeth and various grades of lesion severity are to be represented.

In order to improve the predictive power, more effective risk factors for caries need to be identified and investigated in well-planned and well-conducted prospective studies of children, young adults and older adults. Another factor which warrants further study is the ability of dentists to assess caries risk on the basis of an overall clinical assessment. Today there are no studies which verify that identification of patients at risk leads to better treatment, ie that the effects of risk assessment and the subsequent intervention benefit the patient in the form of improved oral health.

Both experimental studies and clinical observation indicate that fluoride has an inhibiting effect on early caries lesions. However, there is to date an inadequate scientific basis for conclusions on the efficacy of the various methods of treating early caries lesions. In order to answer this important clinical question there is a need for further, well-designed clinical studies.

There is a great need for studies presenting cost aspects of various methods of caries diagnosis and early treatment and also for studies evaluating the benefits of risk assessment in preventing the development of the disease.

Possible Changes in Established Practice

The potential to identify caries lesions correctly on the basis of radiographic examination alone is limited. On its own, radiographic examination for caries results in both false positive and false negative findings. In Sweden, as in several other European countries,

bitewing radiographs are used more or less routinely at recall examination, often once a year or every second year. However, in international comparisons, the frequency of radiographic examination bears no relationship to dental health in the different countries. The practice may be changed so that the number of radiographic examinations of children and teenagers is reduced.

Children and teenagers who are not of an age at which their permanent teeth may be more susceptible to caries and who have no past caries experience, run a very low risk of developing caries in the next few years. With the currently available methods for risk assessment, trying to group other children and teenagers according to caries risk is probably of little consequence. A new perspective on risk groups could influence the interval between the regular recall examinations of children and teenagers, eg the interval could be varied in accordance with the age of the child. Instead of risk assessment strategies at the individual patient level, geographic regions with known high caries risk may serve as the unit and become the target for preventive measures.

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Below is a brief summary of the mission assigned to SBU by the Swedish Government:

- SBU shall assess healthcare methods by systematically and critically reviewing the underlying scientific evidence.
- SBU shall assess new methods as well as those that are already part of established clinical practice.
- SBU's assessments shall include medical, ethical, social and economic aspects, as well as a description of the potential impact of disseminating the assessed health technologies in clinical practice.
- SBU shall compile, present and disseminate its assessment results such that all parties concerned have the opportunity to take part of them.
- SBU shall conduct informational and educational efforts to promote the application of its assessments to the rational use of available resources in clinical practice, including dental care.
- SBU shall contribute to the development of international co-operation in the field of health technology assessment and serve as a national knowledge centre for the assessment of health technologies.

Caries – Diagnosis, Risk Assessment and Non-Invasive Treatment

The SBU report is based on a systematic and critical review of the scientific literature. It is one of a series of scientific reports published by SBU (The Swedish Council on Technology Assessment in Health Care).

The Summary and Conclusions of the report, presented in this booklet, have been approved by the SBU Board of Directors and the Scientific Advisory Committee.