Monitoring of caries disease by risk assessments and activity

Jenny ABANTO1
Gabriela Oliveira BERTI1
Lucyene MIGUITA2
Marcelo BONECKER1

ABSTRACT
Dental caries is a non-communicable disease and is considered a public health problem. For diagnosis and correct treatment, the study of risk assessment and caries activity is necessary. The caries risk assessment is a way to formalize the balance and imbalance of predictably disease to diagnose dental caries. Therefore, the caries risk assessment is performed through different evaluation systems. Another parameter of great importance to be studied is the activity of caries, because through it is done the correct treatment decision for the patient. The objective of this article is to inform the reader about: the concepts and caries risk factors; the different caries risk assessment systems described in the literature; and which systems are validated. In addition, this literature review provides for identification and evaluation of risk factors and activity of caries lesions in order to enable greater objectivity in the diagnosis and facilitate the decisions of a successful treatment.

Indexing terms: Dental caries. Diagnosis oral. Risk.

INTRODUCTION
Dental caries is defined a non-communicable disease of slow progression that presents a dynamic character. It can be reversed at any time if the cause-effect relationship is modified in some manner1. The prevalence of dental caries decreased among children in Latin America and the Caribbean2 countries. In Brazil, the dmf-t/DMF index decreased 13% and 26% in children aged 5 and 12 years, respectively, during the years 2003 to 20103. Even so, tooth decay is still considered a public health problem affecting both developed and developing countries around the world4, resulting in a negative impact on quality of life among children5.

Among the factors involved in the process of caries the biofilm sugars have to be cited. The biofilm is the necessary factor for the development of the dental disease, however, its presence it is not enough if we considered that sugars is the determinant negative factor for development of dental caries6. At this respect, the caries risk can be decreased with the control of diet and guidance of hygiene, by reducing the consumption of sugar and regularly disrupting the biofilm6. The caries risk assessment (CRA) requires systems that include different factors or parameters to establish the likelihood of development of new dental caries lesions7. The effectiveness of the systems vary widely, depending on the number and type of factors/ risk indicators studied, clinical indicators of the disease

1 Universidade de São Paulo, Faculdade de Odontologia, Departamento de Ortodontia e Odontopediatria. Av. Lineu Prestes, 2227, 05508-000, São Paulo, SP, Brasil. Correspondência para / Correspondence to: J ABANTO. E-mail: <jennyaa@usp.br>.
2 Universidade de São Paulo, Faculdade de Odontologia, Departamento de Patologia Oral e Maxilofacial. São Paulo, SP, Brasil.
The CRA is a way of formalizing the equilibrium and disequilibrium of the disease. It helps to predict future injuries, to determine the factors that are out of balance and it is necessary to reach a correct clinical decisions of evidence-based treatment. The end result of any CRA is to match current clinical data and history of the patient. For this, the systems included some data such as the patient past experience of caries, socio-demographic, socioeconomic, oral hygiene and eating habits, and may include additional tests, such as saliva, pH and the bacterial load. All this will help establish the patient’s caries risk and the level of activity of the disease (active or inactive caries lesions).

The factors considered to estimate the caries risk can be divided into two groups:

- Factors immediately involved and needed in the dental caries process: are factors of “attack” or mechanisms of “protection” in the evolution of the injury site. In the attacking factors, the sugars, the biofilm, the presence of bacteria in the biofilm and eating habits should be included. But when it comes to protective factors, salivary protection systems and exposure to fluoride should be considered.

- Factors related to the onset of caries without participation in the development of disease: for this group is considered various social factors as well as the past caries experience. Such factors may be designated as caries risk indicators, but are not required to occur the progression of the lesions.

A systematic review by Mejâre et al. evaluated the ability of multivariate models and individual factors to properly identify the development of new caries lesions in preschool and schoolchildren/adolescents. Among the individual factors, past experience of caries was the most powerful and accurate predictive factor at all ages for reflecting the caries activity in the past (Figure 1B). However, caries activity would be better reflected by methods that show the current metabolic activity in the biofilm. The counts of different bacterial species have been used for this purpose, but in general, its accuracy is poor. Eating habits, as individual factor, showed a predictive limited factor for all ages, although probably more significant in children with preschool age, since its fluoride exposure is limited to the use of a small amount of fluoridated toothpaste. Despite this results, more recent evidence showed that sugars are the only cause of dental caries, all the other factors simply modify the speed of the cariogenic properties of sucrose.

Without sugars, the chain of causation is broken, so the disease does not occur.
Regarding the determinant and protective factors, another systematic review\textsuperscript{16} concluded that sugar intake is probably the most powerful indicator for risk of caries in people who do not have regular exposure to fluoride. This has been proven experimentally by showing that when fluoride toothpaste is not being used, an enamel demineralization occurs with only three exposures to sugar per day\textsuperscript{17-18}. However, if the individual is regularly using fluoride toothpaste, this can reduce enamel demineralization of the sugar consumption when it is not greater than six times per day\textsuperscript{19}. On the other hand, sucrose consumed only twice a day changes the composition of the biofilm, increasing the risk for developing caries even if the person uses fluoride toothpaste\textsuperscript{19}. Thus, the role of diet in the pathogenesis of the disease requires the assessment of dietary habits of the individual, the quality (type of carbohydrate - sucrose) and consistency of the diet (sugary foods, solid and sticky) to make the dietary advice\textsuperscript{21-22}. Besides, the frequency of food intake is also an important information\textsuperscript{21}. With the intake of carbohydrates, the pH of the biofilm decreases due to lactic acid production by Streptococcus mutans and Lactobacillus. This activity is interrupted by buffering system after 30-60 minutes\textsuperscript{21-22}. When the carbohydrate intake frequency is high, pH levels of biofilm reduce promoting more dental demineralization\textsuperscript{21}. Regarding the dietary advice, a randomized clinical study showed that guidance through home visits was effective in reducing early childhood caries\textsuperscript{23}. Then, interference within factors that lead to the development of caries is fundamental, i.e., regularly disrupt the biofilm and reduce sugar consumption\textsuperscript{6}.

Evidences showed that the period of greatest risk for the incidence of caries in permanent teeth were the first years after the tooth eruption\textsuperscript{9}. As an alternative or complement to individual risk assessment, post-eruptive dental age could be used by considering all children at risk during the first years after dental eruption of permanent teeth.

The systematic review of Leong et al.\textsuperscript{24} focused on studies about the relationship between the acquisition/colonization of cariogenic oral bacteria and early childhood caries, as well as about risk factors and/or protective factors for babies at 0 to 12 months old\textsuperscript{24}. They confirmed that factors present during the first year of life affect early childhood caries experience. Despite the oral bacteria heterogeneity, the results indicated that there is an association between the acquisition of cariogenic oral bacteria in the baby and the levels of maternal bacteria. The cariogenic bacteria are a significant risk factor for caries in the first childhood\textsuperscript{24}. However, the authors point that other factors such as eating habits, frequency and/or the type of food and fluid consumed by the baby are involved in colonization and the progression of the disease\textsuperscript{24}. Moreover, the same authors reported that regular brushing with a dentifrice acts as a factor protection. Therefore, there is no scientific evidence to justify tracking oral bacteria such as mutans streptococci in babies\textsuperscript{25}.

In this way, the results on the transmissibility of dental caries show that the vertical transmission (mother to child) cannot be controlled, because the transmission is not limited only by oral bacteria and, there is also horizontal transmission (other family members or baby surroundings). As fact, all babies acquire their environmental microbiota where they live, but once its microbiota is established, the bacteria of others do not implant in the resident oral cavity\textsuperscript{8}. So, it is much more significant to consider the hygiene habits and family diet incorporated in the child's routine and not the oral bacteria acquired, as they sooner or later will form part of the natural microbiota\textsuperscript{8}.

In addition to the determining factors - individual, biofilm and diet - it is known that social, economic and behavioural factors can directly influence the prevalence of caries disease\textsuperscript{26}. Studies have shown that the difference in health levels can be largely explained by differences in socioeconomic indicators and inequality levels in health\textsuperscript{20,27}.

Another recently published study evaluated pre-existing systematic reviews covering the caries risk assessment in children\textsuperscript{28}. Based on the findings, it concluded that caries risk assessment should be carried out in the child's first dental visit and reassessments should be done throughout childhood. Moreover, multivariate models of CRA exhibit better accuracy than the use of individual predictors, particularly in preschool children. However, there is no superior method, which forecast future caries, and there is no evidence to support the use of a specific model, program or existing technology for this purpose. Furthermore, from the child's caries risk should be carried out adequate care, preventive treatments and regular individual follow up appointment\textsuperscript{28}.

It is important to remember that the risk of caries changes over time and needs to be reassessed in each follow up appointment\textsuperscript{12,29}.

**Caries risk assessment systems**

In the international literature, the more often named and reported systems/guidelines are the CRA.
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High methodological design limitations on the CRA used in CAMBRA were found through a retrospective study, which noted higher incidence of cavitated caries lesions among patients classified at high risk of caries compared to low risk. Importantly, this study demonstrated no predictive ability of white spot lesions in contrast to studies using the Cariogram in which the risk of caries was a predictor of non-cavitated lesions. There is still an urgent need to develop valid and reliable methods for CRA that are based on the best scientific evidence from randomized clinical trials to predict and manage caries disease rather than experts' opinion.

The following describes the Cariogram and SMS-USP systems in detail so that they can be applied as a basis for the oral health professional to discuss with the patient about different existing caries risk factors and to develop strategies for treatment and prevention of caries.

Cariogram

The Cariogram® program is an interactive system for categorizing patients that shows through a chart the level of caries risk. It can be downloaded for free on internet in different languages using the website: http://www.mah.se/fakulteter-och-omraden/Odontologiska-fakulteten/Avdelning-och-kansli/Cariologi/Cariogram/. The Cariogram® parameters analyses the microbial factors, the intake frequency of diet, the carbohydrate content, past experience of caries, plaque amount, fluoride application, the buffer capacity of saliva and salivary flow rate. The combination of these factors determines the opportunity (probability) to avoid the appearance of dental caries or new lesions. Each of these elements is represented in a different colour, which facilitates the interpretation and identification of components that must be modified.

This software demonstrate graphically the risk of caries expressed as “The opportunity to prevent new caries lesions” in the near future. The CRA result is represented as a pie chart divided into five sectors, indicating the different groups of factors related to dental caries (see Figure 2).
• The green sector (actual chance to avoid new cavities): shows an estimation of “real likelihood of avoiding new caries lesions” and “what is left” when other factors have taken their share. The “probability of avoiding new caries and the risk of caries” are topics for the same process but inversely expressed. When the probability to avoid new caries is high, the caries risk is small and vice versa, as shown below: High risk = low probability = small green sector; Low risk = high probability = big green sector.

• The dark blue sector (diet): is based on a combination of the amount of biofilm and Streptococcus mutans.

• The light blue sector (susceptibility): is based on a combination of fluoride use based on the information given by patients and / or guardians, the secretion of saliva and saliva buffering capacity.

• The yellow sector (circumstances): is based on a combination of past experience of caries and related diseases.

To interpret the chart, when higher the green sector, better the standpoint of oral health. When a narrow green sector is identified it means that there is high risk of caries. In other sectors, when the area marked on the graph is small, greater is indicative of good oral health.

SMS-USP
SMS-USP determines the recall intervals of patients according to their risk of caries, based on their oral clinical conditions, as detailed in Table 1. These oral conditions include the presence of biofilm, occurrence of gingivitis, caries experience and assessment of caries activity. Children are classified into five groups at risk of dental caries (A, B, C, D or E) and risk groups have different return intervals.

The recall interval of risk groups A (low risk), B and C (moderate risk) is determined every 12 months, while the recall interval for high risk patients, groups D and E, is every 8 months and 4 months, respectively.

It is important to note that both caries risk groups D and E include active caries, however, the D-risk group consist of initial carious lesions, whereas in the caries risk group E consists of cavitated caries lesions.

The patients returned to their recall visits according to this classification, and during the follow-up exam the children are re-examined and their caries risk are re-classified, if necessary. It is important to mention that this CRA tool is applied for the public health system, and for this reason, recall intervals are spaced farther apart than would be commonly used in private clinical practice.

The oral clinical conditions on table 1 are evaluated according to different clinical criteria such as bleeding index, plaque index and DMFT/dmft. Initial carious lesions are evaluated according to ICDAS criteria. The activity of caries lesions is assessed according with the Lesion Activity Assessment (LAA) criteria. The presence of plaque is determined by the plaque index and classified...
as fair or poor (scores of 1.0-3.0) and the clinical condition presence of gingivitis is determined by the gingival bleeding index and classified as mild to severe (values 0.1-3.0).

Table 1. Evaluation of the risk of caries and determination of return intervals. SMS-USP tool.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Group</th>
<th>Clinical conditions</th>
<th>Recall interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low risk</td>
<td>A</td>
<td>Absence of cavitated caries lesions or restored teeth, without dental plaque, without gingivitis and/or without active initial caries lesions</td>
<td>Every 12 months</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presence of restored teeth, absence of dental plaque, gingivitis and/or absence of active initial caries lesions</td>
<td>Every 12 months</td>
</tr>
<tr>
<td>Moderate risk</td>
<td>B</td>
<td>Presence of only inactive caries lesions associated with absence of dental plaque or gingivitis</td>
<td>Every 12 months</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Presence of dental plaque, gingivitis and/or presence of active initial caries lesions</td>
<td>Every 8 months</td>
</tr>
<tr>
<td>High risk</td>
<td>D</td>
<td>Absence of cavitated caries lesions or restored teeth</td>
<td>Every 4 months</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Presence of one or more active cavitated caries lesion.</td>
<td>Every 4 months</td>
</tr>
</tbody>
</table>

Caries activity concept

The diagnosis of caries has changed over the years. Long ago, the most important part in the diagnostic process was only to detect the lesions, or simple recognition of the depth, regardless of the clinical features of the lesions. When caries lesion was found mainly in dentin, the treatment decision was the restoration20.

Studies show that it is also necessary to verify the clinical appearance of these lesions and through this make the best form of treatment and can often be the non-invasive treatment and monitoring of these carious lesions47-48. Thus, it is extremely important to check the activity of caries, the caries activity indicator shows us that the disease is present, i.e., presence of active lesions at the time of the clinical examination23. However, in a practical way, the caries activity is the manifestation of caries at that particular time, indicating that carious lesions are probably in progression.

Thus, the diagnosis of dental caries activity is essential for the treatment decision for each patient when properly evaluated favouring a better prognosis in the treatment of disease49. Regarding the treatment of inactive lesions (paralyzed), the only indication is the monitoring for the control and follow-up consultations. In the case of active lesions treatment is based on controlling the etiologic factors and surgical treatment and/or non-operative, depending on the depth of the lesion (enamel or dentin).

How to evaluate the activity of caries lesion?

Considering the large number of risk factors described, the evaluation of the caries activity can become complex. It is correct to say that the actual activity of a carious lesion can be confirmed by actual progression (or not) over a given period of time. But some authors have proposed diagnostic criteria for evaluating caries activity by visual and tactile inspection by a “ball-ended point” or WHO probe passed smoothly over the tooth surface46,50-51.

To evaluate the lesion activity, some clinical parameters for expression of caries activity in the tooth surfaces have been associated52-53: accumulation and/or biofilm retention potential; opacity associated with caries (brighter or dimmer); cavities, and depth of the lesion; texture (smooth or rough) and pigmentation of the lesion (white, yellow or blackened).

It is worth mentioning as extremely valid that all the features explained above reflect the carious lesion activity and its assessment as a whole is very important to make a correct diagnosis. Moreover, some studies show that prophylaxis prior to clinical evaluation of the activity is indicated by classifying each site according to their potential for biofilm accumulation, while other studies claim the examination of visible biofilm during the clinical examination46,54-55.

To make the correct detection of the activity or not of carious lesion the professional can resort to the use of appropriate indexes, making this assessment less subjective46,50.

Systems of Dental Caries Activity Assessment

There are some validated systems of caries activity assessment (SCAA) that have been proposed by some researchers and used clinically:

(1) System Nyvad (NY) or Nyvad index (NY)50,56;
(2) The ICDAS-LAA (International Caries Detection and Assessment System - Lesion Activity Assessment)45,57.

The SCAA proposed by Nyvad takes into account the classification of lesions with intact surface, discontinuous surface and surfaces with cavities. And still
ranks the injury as active or inative\textsuperscript{50,56}. Thus, the Nyvad evaluation system demonstrated a good reliability\textsuperscript{50}, as well as a good predictive validity for the evaluation of caries activity\textsuperscript{56}.

To standardize the caries detection procedures and describe more accurately the characteristics of the injury, a visual index for diagnosis of caries was proposed and is termed as ICDAS\textsuperscript{46}. Recently, to be used in conjunction with ICDAS, a scoring system has been reported to the Lesion Activity Assessment (LAA), the ICDAS-LAA. Each LAA parameter observed in injuries is according to the predictive power of each parameter in the progression of lesion\textsuperscript{46}. The ICDAS-LAA system proposes the sum of these points as a way of classifying these injuries on the caries activity\textsuperscript{56}. This system takes into account the pigmentation of the lesions, the severity, the accumulation potential and also the plate texture\textsuperscript{58}.

Thus, in general, we considered that the lesion is active in enamel, when the enamel is opaque with whitish or yellowish discoloration, loss of gloss, rough surface when passing the probe and the lesion is located under biofilm accumulation region (pits and cracks, near the gingival margin, proximal surfaces below the contact point)\textsuperscript{46}. The active lesions in dentin follows the same characteristics associated with softened dentin when the probe is passed over\textsuperscript{46}.

CONSIDERATIONS

Regarding the monitoring of caries, two systematic reviews have shown that there is insufficient evidence coming from clinical trials to draw conclusions on the beneficial and harmful potential to alter the return intervals between dental visits\textsuperscript{59,60}. Assuming that each child is an individual with different clinical conditions and treatment needs, this requires professional recall strategies and preventive care with differentiated treatment based on risk and caries activity.

It would then be possible to extend the recall intervals for children classified as low risk, and shorter recall intervals would be used for patients at higher risk or need. At the level of public health, increasing the recall interval between consultations would offer a substantial saving of resources that could be used in other areas\textsuperscript{61}. Although, there is no conclusive scientific evidence about the specific recall intervals for caries risk groups in children, the National Institute for Clinical Excellence (NICE)\textsuperscript{62} in 2004, issued a document (based on opinions of experts and a pre-existing systematic review)\textsuperscript{59}, with recommendations on the most short and long return intervals between dental visits. This document depicts the shortest interval, between dental visits, for all patients should be three months, but no smaller than three months, unless if it is for specific reasons. This document also indicated that the longest interval between appointments for patients under 18 years-old should be 12 months\textsuperscript{62}.

However, identify and assess the risk factors and characteristics of activity appropriately of caries lesions in appointments allows the clinician to decide the most appropriate treatment for the patient favouring their prognosis. In many cases, depending on the diagnosis of lesions or the progression of lesions, the clinician can choose more conservative treatments.

Regarding the treatment of inactive lesions (paralyzed) the only indication is the monitoring for the control and follow-up consultations, which the etiologic factors involved in the development of dental caries are evaluated. For active lesions treatment plan must be based on the control of etiologic factors and operative and non-operative treatment, depending on the depth of the lesion (enamel or dentin). It is important to highlight that the control of etiologic factors in follow-up consultations are based on proper oral hygiene habits with regular use of fluoridated toothpaste, since the accumulation of biofilm on the tooth surface favours the appearance of new lesions and the progression of those already existing.

Collaborators

All authors contributed to the bibliographical survey and to the conception, composition and to the final review of the article.

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