Caries Research

Guidelines

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European Organisation for Caries Research and the European Federation of Conservative Dentistry Consensus Report on Clinical Recommendations for Caries Diagnosis: Paper III – Caries Diagnosis at the Individual Level

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Abstract
Objectives: The aim of the present consensus paper was to provide recommendations for clinical practice on the individual etiological and modifying factors to be assessed in the individual diagnosis of caries, and the methods for their assessment, supporting personalized treatment decisions. ***Material and Methods:*** The executive councils of the European Organisation for Caries Research (ORCA) and the European Federation of Conservative Dentistry (EFCD) nominated ten experts each to join the expert panel. The steering committee formed three work groups which were asked to provide recommendations on (1) caries detection and diagnostic methods, (2) caries activity assessment, and (3) forming individualized caries diagnoses. The experts responsible for "individualised caries diagnosis" searched and evaluated the relevant literature, drafted this manuscript and made provisional consensus recommendations. These recommendations were discussed and refined during the structured process in the whole work group. Finally, the agreement for each recommendation was determined using an anonymous eDelphi survey. The threshold for approval of recommendations was determined at 70% agreement. ***Results:*** Ten recommendations were approved and agreed by the whole expert panel, covering medical history, caries experience, plaque, diet, fluoride, and saliva. While the level of evidence was low, the level of agreement was typically very high, except for one recommendation on salivary flow measurement, where 70% agreed. ***Conclusion:*** It is recommended that all aspects of caries lesion progression and activity, recent caries experience, medical conditions and medications, plaque, diet, fluoride and saliva should be synthesized to arrive at an individual diagnosis. ***Clinical Relevance:*** The expert panel merged evidence from existing guidelines and scientific literature with practical considerations and provided recommendations for their use in daily dental practice.

Introduction

Caries remains among the most prevalent diseases in the world [1, 2]. It is currently recognized as a "biofilm-mediated, diet modulated, multifactorial, non-communicable, dynamic disease resulting in net mineral loss of dental hard tissues" [3]. Changes in different factors can lead to an imbalance towards increased demineralization versus remineralization, leading to disease progression. More contemporary aetiological models have identified risk factors at different levels (tooth, mouth, individual, society), indicating the complexity of the caries disease process [4].

Whereas detection and assessment of the lesions resulting from the net mineral loss of enamel and dentine are necessary for the initial diagnosis of the disease, for a comprehensive individual diagnosis more is required. Diagnosis is defined by Merriam Webster [5] as the "art or act of identifying a disease from its signs and symptoms," and additionally as "investigation or analysis of the cause or nature of a condition, situation, or problem." For personalized caries management, the knowledge of lesion activity or progression, which is already difficult to establish through signs and symptoms alone, is not enough to inform targeted treatment. The analysis of the combination of factors involved in the disease aetiology and prognosis is also needed for a comprehensive diagnosis at the patient level. Traditionally, assessing these factors has been referred to as caries risk assessment, with the aim of predicting how likely a patient is to develop new caries lesions in the near future. Prediction in the absence of disease has been shown to be very difficult, as the single best "predictor" is active or recent caries experience [6, 7]. In the context of caries diagnosis and treatment decision, it is better to use the term etiological or modifying factors.

Figure 1 illustrates the steps in the diagnostic process for caries at the individual patient level. A previous series of consensus papers from the European Organisation for Caries Research (ORCA) and the European Federation of Conservative Dentistry (EFCD) focused on the treatment decision elements of this process by considering "when and how to intervene" [8–12]. In the current series, we concentrate on the preceding three steps. Other papers in this series concentrate on tooth surface-level detection [13] and assessment [14] of caries lesions. In the present paper, we examine comprehensive disease diagnosis for individual patients.

Susceptibility to caries and the rate of its progression varies greatly between individuals depending upon complex combinations of aetiological and protective and non-protective modifying factors. Assessment of etiological factors, in this context, may be helpful in both selecting the content and intensity of caries non-operative management, as well as the interval between recall appointments, to be suggested to the patient. Figure 2 shows an example of a decision tree for undertaking comprehensive caries diagnosis; in the published literature many such models have been suggested. The starting point for

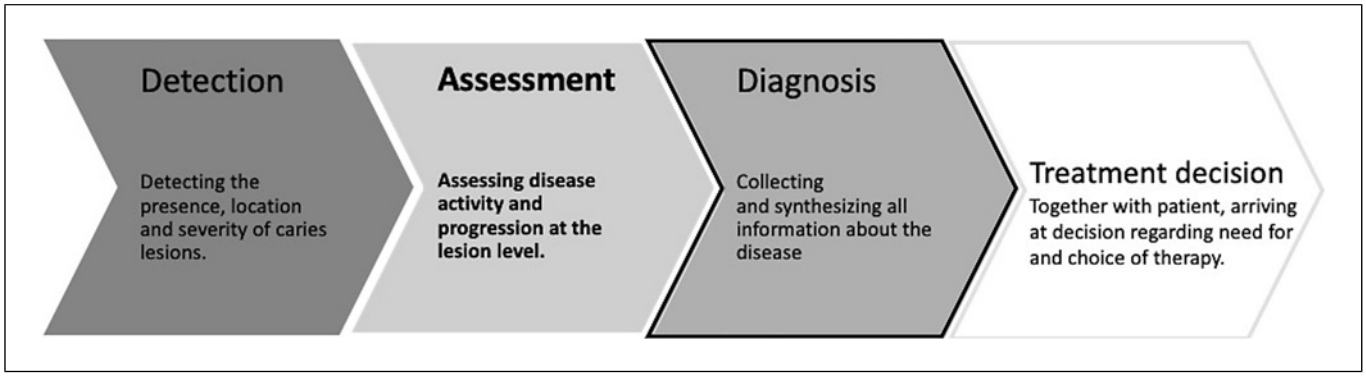

Fig. 1. Steps in the caries diagnostic process and selection of therapy. The current series of ORCA/EFCD consensus papers addresses step 1: Kühnisch et al., 2024 [13], step 2: Neuhaus et al., 2024 [14], and step 3: this paper.

most is the determination of whether there are active/progressing caries lesions present. However, there are other non-modifiable factors which contribute to the risk of new lesions even in individuals with an absence of (observed) active lesions. Examples may be the introduction of fixed braces, which carries a high risk of lesion development around the brackets, or non-surgical periodontal therapy, leading to a sudden exposure of significant root surface area, or the initiation of a medical condition or medication which may lead to hyposalivation.

The rate of caries lesion progression and/or location and/or number of lesions are major factors in determining disease severity in an individual. However, caries lesions may be the result of combinations of many different factors, and in order to provide a personal care plan with caries management options targeted to the individual, relevant factors must be assessed, and each individual's situation must be considered. As an example, consider the two patients in Figure 3; both are male adolescents with active caries. However, the presentation of the disease and the likely role of the quality of plaque removal in each case is very different, and therefore the proposed non-operative management will be different.

It has been suggested that a careful analysis of all factors, both pathological and protective, will allow the dental team and patient to better understand the specific reasons for the caries disease, resulting not only in a more effective tailoring and personalization of treatment but also in a recall interval to fit the patient's needs [16]. Existing guidelines have also supported individualized recall intervals based on a patient's risk of developing oral disease, which range in adults from a minimum of 3 months to a maximum interval of 24 months between recall appointments for patients who have repeatedly demonstrated an ability to maintain oral health [17]. However, there is ongoing debate about the frequency of recall dental check-up appointments, and their impact on oral health outcomes [18].

When considering how to protect and improve a patient's oral health and treat their existing disease, there are also patient-level or background factors which may influence a clinician's treatment planning decisions. Some of these are influential in considering the chances of success of treatment, e.g., the motivation level of the patient for self-care in the ongoing prevention of caries [19]. Other factors are more related to strength of association with the likelihood of dental disease, e.g., caries status of mother/siblings [20, 21]. Whilst all factors may have importance, some of them are more readily modified than others. For example, at a population level, socioeconomic status is predictive of caries status [22]. However, little can be done within the constraints of a dental treatment plan to change the socioeconomic status of individual patients. This paper therefore will not cover every element of a patient assessment which may help form patient-level diagnoses and influence treatment planning but will focus on only the key areas which are either most informative of individual caries disease characteristics (caries history and medical conditions) or are most modifiable such as diet, plaque, use of fluorides. Though this paper will not cover them in detail, it is vital when treatment planning to take into consideration patient-level factors which should play a role in communicating about, and deciding upon, the best care to provide. Health literacy is an important example of this since it is not simply the ability to read healthcare information and advice but also the ability to understand it

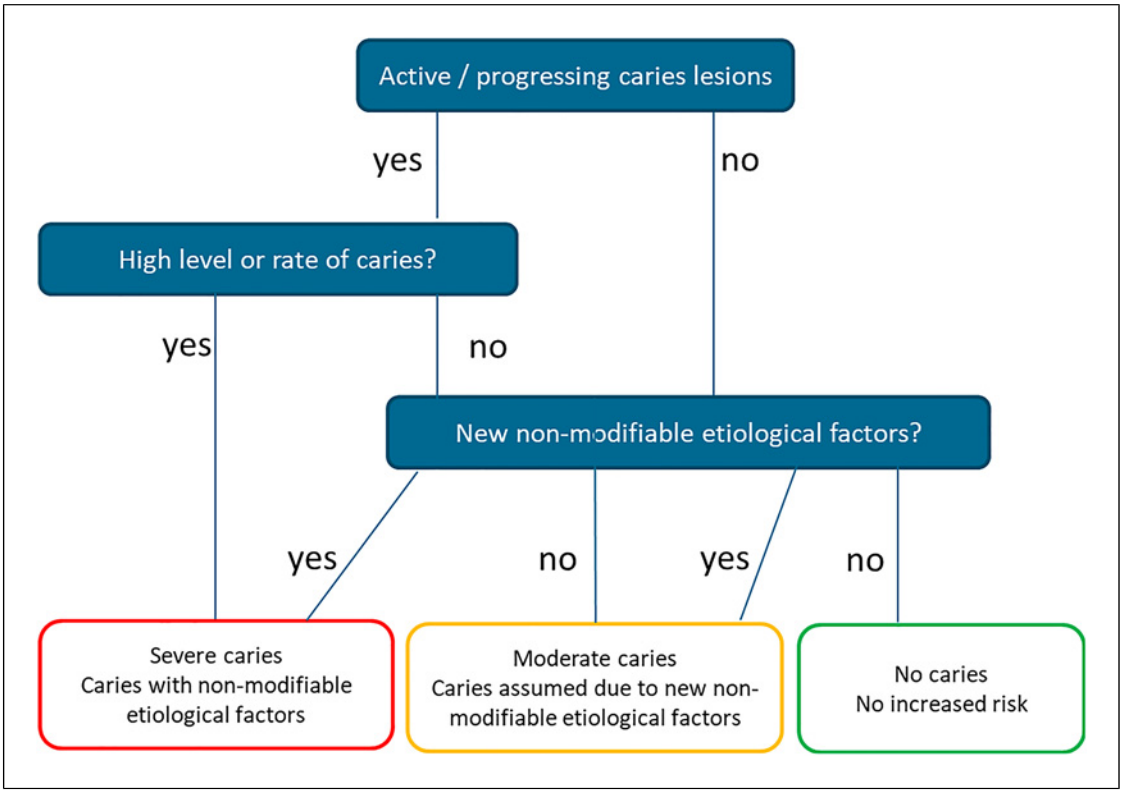

Fig. 2. Decision tree to assist in determining presence and level of disease in an individual. Non-modifiable risk factors, such as fixed braces, hyposalivation, or multiple exposed root surfaces are relatively strongly associated with caries, so they are specifically assessed, even in when active lesions or lesion progression have not yet been observed. Figure adapted from Oral Health Assessment and Review Dental Clinical Guidance from the Scottish Dental Clinical Effectiveness Programme, and Fontana and Zero [15].

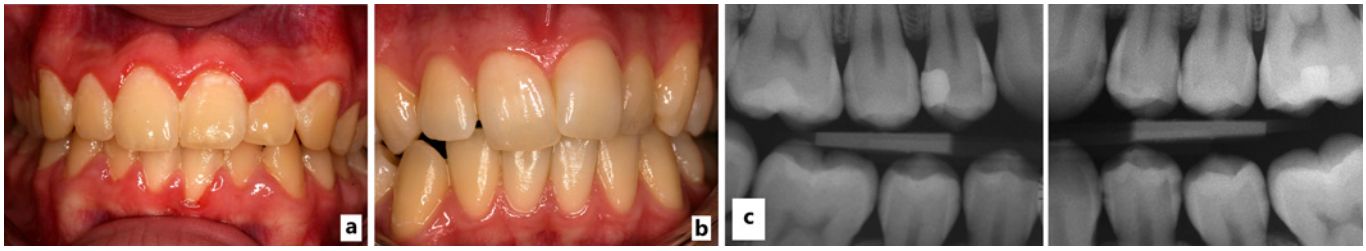

Fig. 3. Examples of caries active patients with different etiological backgrounds. **a** Patient A is an adolescent with low levels of motivation and compliance, high level of plaque, and a sugar-rich diet. Many caries lesions are present, including free surfaces. **b** Patient B is an adolescent with an acceptable oral hygiene level and a sugar-rich diet. **c** Bitewing radiographs from patient B show caries lesions in approximal surfaces only. The diagnosis in both cases will not be the same, as lack of oral self-care does not likely play a role in patient B. Therefore, non-operative caries management approach of patient A is much more likely to include or even focus on oral self-care advice, whereas for patient B the emphasis will lie on changing dietary habits.

and to act on it and so should form part of the patient assessment. The aim of this consensus paper was to provide clinical recommendations on the individual etiological and modifying factors to be assessed in the individual diagnosis of caries, and the methods for their assessment.

Table 1. Etiological/modifying factors mentioned in clinical guidelines as relevant for risk assessment, treatment decisions, and/or recall interval setting

Factor	Children	All ages	(Frail) older people
Medical history			
Conditions / medications increasing caries risk	S2; S3; F; A	N1; N2; S1; P	K1; K2
Conditions that reduce ability for oral selfcare	S2	S1; P; C	
Caries experience			
Previous disease	S3; F; A		
New / recent lesions		N2; S1; P; C	
Caries or restorations on anterior teeth		N2; S1; P	
Premature extractions due to caries	N2; S1; P; A		
Past root caries or large number of exposed roots		N2; S1; C	K1
Heavily restored dentition	A	N2; S1; P	
Plaque			
Poor level of oral hygiene	S2; F; A	N1; N2; S1; P; C	K1
Plaque retaining factors (e.g., orthodontic appliance)	F; A	N1; N2; P; C	
High level of Mutans Streptococci	S3; F		
Erupting molars	C		
Dietary Habits			
High and/or frequent sugar intake	S2; S3; F; A	N2; S1; P; C	
Exposure to fluoride			
Frequency of fluoride use (toothpaste / other)	S2; F; A	N2; S1; P; C	
Saliva			
Low saliva flow rate	S2; S3; F; A	N2; S1; C; P	K1; K2
Low saliva buffering capacity	F	P	

Codes (N1; N2; S1; S2; S3; K1; K2; P; C; A) indicate specific guidelines listed below. Factors included in most or all (7–10) guidelines (dark green shaded) were considered in this consensus statement. Factors included in 4–6 guidelines (especially when age-specific) were included, particularly when constituting non-modifiable risk factors or evidence of recent disease, which may be relevant also when no caries activity (no active lesions) has been observed. Factors only included in 1–3 guidelines were not considered (orange shaded). **National clinical guidelines:** N1 – Oral health promotion: general dental practice NICE guideline (2015); N2 – Dental checks: intervals between oral health reviews NICE Clinical guideline (2004); S1 – Oral Health Assessment and Review Dental Clinical Guidance Scottish Dental Clinical Effectiveness (2012); S2 – Prevention and management of dental caries in children. Scottish Dental Clinical Effectiveness Programme (2018); S3 – SIGN 138 • Dental interventions to prevent caries in children. Scottish Intercollegiate Guideline Network (2014); K1 – Wortelcariës bij (kwetsbare en zorgafhankelijke) ouderen. Klinische praktijkrichtlijn. Kennisinstituut Mondzorg (2019); K2 – Xerostomie en hyposialie gerelateerd aan medicatie en polyfarmacie Klinische praktijkrichtlijn. Kennisinstituut Mondzorg (2021); P – Periodiek Mondonderzoek (PMO). Klinische Praktijkrichtlijnen. UMC St Radboud Nijmegen (2007); F – Appréciation du risque carieux et indications du scellement prophylactique des sillons des premières et deuxièmes molaires permanentes chez les sujets de moins de 18 ans. HAS/Service des recommandations professionnelles et service évaluation médico-économique et santé publique (2005). **Professional guidelines:** C – CariesCare practice guide: consensus on evidence into practice. Brit Dent J 2019 [Martignon et al., 2019]; A – Caries-risk assessment and management for infants, children, and adolescents. American Academy of Pediatric Dentistry (2018).

Material and Methods

Expert Panel

The executive councils of ORCA and EFCD agreed in 2021 to develop consensus statements on (1) caries detection and diagnostic methods, (2) caries activity assessment, and (3) individualised caries diagnosis. The previously jointly published statements on caries management [10–12] served as a model for this process. Both academic societies identified and nominated ten experts each to join the development process. M. Huysmans, C. Splieth, K. Neuhaus, and J. Kühnisch formed the steering committee for the project. In detail, M. Huysmans moderated the process on individual caries diagnosis in the working group made up by G. Campus, S. Doméjean, G. Douglas, M. Fontana, and N. Opdam.

To determine which factors to include in the clinical recommendations for caries diagnosis at the patient-level, national clinical guidelines on oral health assessment and caries management were collated. The search strategy (both based on PubMed and clinical guideline websites, search conducted in March 2022) may be found in the Supplementary file (for all online suppl. material, see https://doi.

org/10.1159/000539427). Seven guideline websites were searched, six in English and one in Dutch, yielding seven national guidelines. Two older guidelines were added from personal knowledge of the authors. The PubMed search strategy yielded another two professional guidelines. The 11 guidelines included were analysed for recommendations on which etiological/risk factors should be considered for the determination of appropriate treatment and recall interval decisions. Table 1 summarizes these factors. Factors included in most or all (7–10) guidelines (dark green shaded) were considered in this consensus statement. Factors included in few guidelines (orange) were not included in this consensus document. Targeted individual searches were used to find evidence on when and how to assess the factors.

Structured Development of the Recommendations

The group consensus process to arrive at recommendations in this paper included multiple online meetings as well as a structured communication flow aiming to converge existing opinions and, finally, efforts to reach a unanimous group consensus. The experts identified practical needs from different perspectives, e.g., patient needs, potential and limitations of national health care systems, recent developments in caries epidemiology, availability and acceptance of diagnostic methods among dental practitioners and drafted a working paper including pre-phrased recommendations for discussion by the whole expert panel, completed in September 2022.

Level of Evidence

The level of evidence from the available literature was evaluated by the working group in accordance to published recommendations. Evidence supported by unequivocal scientific studies, e.g., multiple randomized controlled clinical trials or systematic reviews/meta-analyses were evaluated as "High." Evidence based on well-designed clinical studies, e.g., controlled clinical trials, was evaluated as "Moderate." Finally, evidence based on expert opinion only and that are based on weak evidence, e.g., no clinical studies or only low-quality studies or studies with contradicting results were ranked as "Low."

Level of Agreement

The structured consensus process was initiated during an online group workshop on October 5th, 2022. During this meeting, the existing scientific literature and empirical experiences were presented to the whole expert group, critically discussed and the provided recommendations were reviewed and rephrased until consensus was reached. Some nominees were unable to attend the meeting, but they had full access to all documents and were invited to suggest changes in the main text and recommendations later. The present manuscript was finalized by the work group on the basis of the discussions at the meeting. After this, all recommendations were redistributed to the expert panel giving all experts the opportunity for critical re-reading. Subsequently, all recommendations and documents were harmonized. The final manuscript versions were reviewed again by the whole expert panel before submission for publication.

Finally, a confidential e-Delphi survey (Castor EDC, Amsterdam, The Netherlands) was undertaken following the same methods used in earlier ORCA/EFCD projects [10–12]. During the voting process, all 20 experts gradually agreed independently from each other on every single recommendation. It was possible to vote from grade 1 (completely disagree) to grade 10 (completely agree). An additional field for free-text comments was made available to allow the reasoning for a certain decision or proposals for modifications. The level of agreement was calculated for each item as median value out of all votes. At least 70% of the vote >7 was considered as acceptance of the statement by the group and the results were reported as percentage agreement (10–8), neutral (7–4), or disagreement (3–1).

Results

Medical History

Worsening of general health might predispose to poor oral hygiene leading to an increased caries risk [23]. Diabetes, hypertension, rheumatoid arthritis, Alzheimer's disease, Parkinson's disease, and depression are among the prevalent diseases worsening with age; all these systemic diseases and related medications increase the vulnerability of older adults to oral diseases such as dental caries [24]. Medical conditions are often treated with prescription drugs and many drugs are associated with xerostomia and hyposalivation (see below for saliva).

Recommendation

1. Dental professionals should be aware of and update records of each patient's medical conditions and medications, and monitor patients with conditions that negatively impact upon plaque control, diet and/or salivation more closely for caries development.

Level of evidence: low.

Level of agreement: 100% (agree, N = 20)/0% (neutral)/0% (disagree).

Caries Experience

As the caries process may be intermittently inactive or active over the years, the caries history of the patient is an important indicator of caries risk and recent restorations/extractions related to caries are a possible indicator for caries activity/progression. However, as teeth may be missing or extracted for multiple reasons, and restorations placed for reasons other than caries, it important that patient's notes are detailed enough to determine their history of disease. Therefore, it is necessary to record the diagnosis on which restorative treatment indication is based. As well as the number of

Table 2. Examples of recommendations for plaque assessment

Scottish Dental Clinical Effectiveness Program, Dental Clinical Guidance, 2018 (Children)	• Assess whether the gingiva appears healthy or whether there is inflammation indicative of poor plaque removal • Consider recording plaque scores at each examination, particularly if the child is assessed as at increased risk • Record the presence of plaque on the surface of open caries lesions at recall visits
International Caries Classification and Management System (ICCMS^{TM}) [37]	Thick plaque: evidence of sticky biofilm in plaque stagnation areas (or poor oral hygiene with thick plaque accumulation
Evidence-based caries management for all ages-practical guidelines [38]	Heavy plaque on the teeth

restored surfaces and teeth, the location of restorations/lesions can provide information on the caries activity/risk, although evidence for this is limited and based on clinical experience.

Recommendations

2. Dental professionals should record the reasons for restorative interventions and extractions, so that interventions for caries can be identified.
Level of evidence: low.
Level of agreement: 95% (agree, $N = 19$)/5% (neutral, $N = 1$)/0% (disagree).
3. Patients with recent caries experience should be regarded as caries active, even if at the time no new or active/progressing lesions are detected.
Level of evidence: low.
Level of agreement: 80% (agree, $N = 16$)/20% (neutral, $N = 4$)/0% (disagree).

Plaque

The localized destruction of susceptible dental hard tissues during the caries process is caused by acidic by-products from constituents of dental biofilms (i.e., dental plaque on tooth surfaces) as a result of microbial fermentation of dietary carbohydrates [25]. Therefore, dental plaque is an important factor to consider during the comprehensive diagnosis of the caries disease process and prior to the development of a personalized caries management plan. It is a "modifiable" caries risk factor, meaning that it can be modified by intervention, thereby helping control the caries process. It is also involved in the aetiology of periodontal disease. Since plaque must be removed (i.e., surfaces of teeth must be clean) for accurate caries lesion detection, staging and activity assessment, plaque assessment needs to happen during the detection and assessment step, and not after.

It is important to assess the quality of oral hygiene and/or the resulting presence/absence of dental plaque [26]. In some cases, gingival inflammation has been used as an indirect measure of plaque accumulation near the gingival margin of smooth surfaces of teeth. In general, measurements of visible dental plaque are a more reliable indicator of the quality/effectiveness of oral hygiene habits and plaque removal than information provided during structured interviews [27], or information about frequency of tooth cleaning [28]. This has been studied particularly in young children [29, 30].

With regard to using plaque and/or oral hygiene assessment for caries risk assessment or prediction, dental plaque is commonly present in most caries risk forms and tools [31] and is evaluated in caries risk studies by assessing the presence of visible plaque [32, 33]; or a plaque index score [34]. However, current evidence is insufficient to determine the accuracy of using oral bacteria and/or oral hygiene related factors individually in caries prediction; an individual's caries activity might be better reflected by methods that show the present metabolic activity in the biofilm [6].

Typically, dental plaque is detected by clinicians visually either with the aid of an explorer or with the aid of a disclosing solution, and is quantified using indices based on the area of tooth covered or the plaque thickness [35]. In addition, techniques using light or laser induced fluorescence spectroscopy and digital imaging analysis have also been used [36], but equipment cost, and technique standardization are challenges to the popularity of such methods in everyday practice. More recently, artificial intelligence models have been used to provide automatic measurements of photographs of plaque coverage on the

facial tooth surfaces, using strategies based, for example, on deep learning. Even though more objective approaches, using such indices and technologies as described earlier, are preferred in research studies, many caries clinical guidelines use a much more subjective and simple approach, they refer to the presence of "thick" or "heavy" plaque on teeth as a caries factor to consider.

Table 2 lists some examples. The level of evidence supporting the causal relationship between accumulation of a thick layer of biofilm or in stagnation areas with increased caries risk is based on several case control and cross-sectional studies [39–44].

Recommendations

4. The quantity of dental plaque should be assessed prior to its removal to complete the caries detection and assessment step.

Level of evidence: low.

Level of agreement: 90% (agree, N = 18)/10% (neutral, N = 2)/0% (disagree).

5. In patients with active/progressing caries lesions and/or new conditions that hamper plaque removal (e.g., recent orthodontic braces), dental plaque should be assessed and recorded, so that the success of strategies to modify it can be monitored over time.

Level of evidence: low.

Level of agreement: 85% (agree, N = 17)/15% (neutral, N = 3)/0% (disagree).

Diet

Diet, and more specifically the consumption of fermentable carbohydrates, plays an indisputable role in caries initiation and progression. The carbohydrate-caries connection has been documented in five continents, in humans and other animals, and as far back in time as archaeology allows us to go [45]. In 2015, the World Health Organization recommended that if people do consume free sugars, they keep their intake below 10% of their total energy needs, and reduce it to less than 5% for additional health benefit [46]. This recommendation applies at all ages, and results in maximum recommended daily amounts of free sugar consumed of 19 g for a 4 to 6-year-old, to 30 g for all those over 10 years of age. More recently, in 2021, the International Association of Paediatric Dentistry (IAPD) published five consensus recommendations targeting children more specifically for caries prevention as well as prevention of future cardiovascular disease, diabetes, and obesity. Based on the best evidence available, the Brazilian Academy of Dentistry recommends: not to offer sugars to children younger than 2 years of age; to limit total sugar consumption to <25 g per day after 2 years of age; to inform families to limit sugar exposure; and to educate patients to verify the sugar content on the nutrition facts label [47].

When caries is present, to facilitate personalized diet counselling, both the frequency and amount of (added) sugar consumption must be considered. Both parameters have been shown to be associated with caries. Since being aware of every food or drink's sugar content is very difficult for patients and there is little evidence to determine the threshold sugar concentration at which a product becomes cariogenic in an individual's oral environment, the frequency of intake may be an easier factor to consider [48]. Dietary habits can be assessed by detailed interviewing, food frequency questionnaires or food diaries. The food frequency questionnaire is a dietary assessment instrument that attempts to capture an individual's usual food consumption by querying the frequency and sometimes quantity at which the patient consumed food items based on a predefined food list. In a food diary the patient (or his/her caregiver for children and dependent patients) reports, systematically and chronologically, all food/drinks and quantities consumed over a period of time (usually 3–5 days). The report must include working days (school days for children) and days off, as habits may be influenced by the environment or activities undertaken. A nutrition questionnaire has been specifically developed to assess the relationship between diet (type of food, frequency, and amount) and dental caries [49]. Parents may also be advised to use the NHS sugar calculator.

Recommendation

6. In patients with active/progressing caries lesions, sugar intake should be assessed and recorded, including frequency, amount, and timing, using detailed interviewing, a diet diary or food frequency questionnaire.

Level of evidence: low.

Level of agreement: 95% (agree, N = 19)/5% (neutral, N = 1)/0% (disagree).

Fluoride

Fluoride is universally recognized to prevent or arrest the pathologic challenges posed by caries risk factors [50]. Fluoride (usually via toothpaste) has the most consistent benefit in preventing caries development and early caries stages can be brought to a halt and even reversed by fluoride use. Still, caries develops in high-risk individuals of all ages, irrespective of the dose of fluoride used [51]. The lack of, or a low level of, fluoride exposure (via toothpastes, water fluoride, or other topical application) is considered a risk factor to development and progression of the disease [15]. On the other hand, caries activity in the presence of fluoride indicates a higher baseline level of caries risk.

The availability and maintenance of fluoride in the oral cavity can be checked via history taking [52]. Such history taking will include information on habitual fluoride sources and concentration (i.e., water, toothpaste, rinses) and professional fluoride use.

Recommendation

7. In patients with active/progressing caries lesions, regular use of fluoride toothpaste and other fluoride modalities (including frequency, concentration, amount) should be assessed.

Level of evidence: high.
Level of agreement: 90% (agree, N = 18)/10% (neutral, N = 2)/0% (disagree).

Saliva

Saliva is crucial for maintaining oral health, with functional aspects such as flow rate, pH and buffering capacity, but also compositional aspects such as proteins and peptides and calcium and phosphate playing a role in caries prevention. Although (weak) associations of caries development with various saliva variables have been found, no consistent effect has been reported for any saliva factor. The acceptance of the important role for salivary flow rate relies strongly on biological plausibility and experimental studies showing prolonged pH-drops in plaque with low or absent salivary flow [53]. No linear relationship, however, between salivary flow rates and caries has been found, and more often a "threshold effect" has been suggested [54]. Some relationships between the intake of salivary flow reducing medication and caries have been shown [55]. Most convincing is the literature on head and neck radiation and caries, where the main factor in typical "radiation caries" development was loss of salivary protection although direct radiation damage to dental tissues does play a role [56]. Radiation caries shows strong similarities with that seen in Sjögren's Disease, supporting the link with hyposalivation.

As a relationship between saliva flow and caries has not been shown in epidemiological studies, probably due to the multi-factorial nature of the disease, assessment of hyposalivation is only indicated to be of value in specific cases, such as patients with medical conditions or salivary flow reducing/multiple medication use, in older people, and in cases where other etiological factors are not clearly identified. Some patient-reported outcomes for xerostomia are related to hyposalivation and may form a starting point in diagnosis of dry mouth [57–59]. Clinical screening for dry mouth using the Clinical Oral Dryness Score has also been reported to be useful in determining hyposalivation [60]. Saliva flow tests using unstimulated and chewing or acid stimulated whole mouth saliva collection are the standard for assessing hyposalivation.

Recommendations

8. Patients with medical conditions or hyposalivation-inducing medications, and older patients should be regularly screened using a xerostomia questionnaire and/or the Clinical Oral Dryness Score.

Level of evidence: low.
Level of agreement: 85% (agree, N = 17)/10% (neutral, N = 2)/5% (disagree, N = 1).

9. Saliva flow rates should be measured in patients with active/progressing caries lesions in whom other etiological factors do not explain disease severity or who show signs or symptoms of dry mouth.

Level of evidence: low.
Level of agreement: 70% (agree, N = 14)/20% (neutral, N = 4)/10% (disagree, N = 2).

Conclusion

While the level of evidence was low, the level of agreement was typically very high, with no responses in the domain of disagreement for the recommendations on medical history, caries experience, plaque, diet, and fluoride. Only for the saliva factor, 5–10% disagreed with the recommendations. For the recommendation on salivary flow measurement, only 70% agreed, just reaching the limit for

acceptance of the recommendation. While most guidelines mentioned in Table 1 mentioned low saliva flow as a risk factor, no guidance was provided on when or how to assess this. As this is a relatively unexplored domain in risk assessment and there is no established routine for dentist to assess dry mouth or measure saliva flow, we expect that the level of agreement was influenced by concerns about feasibility. Nevertheless, there was overall agreement on including all listed factors: medical conditions and medication, recent caries experience, plaque, diet, fluoride, and saliva in the individual caries diagnosis.

Recommendation

10. All aspects of caries lesion progression and activity, recent caries experience, medical conditions and medications, plaque, diet, fluoride, and saliva should be synthesized to arrive at an individual diagnosis.

Level of evidence: low.
Level of agreement: 95% (agree, $N = 19$)/5% (neutral, $N = 1$)/0% (disagree).

Conflict of Interest Statement

The authors declare that they have no conflicts of interest.

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Author Contributions

Guglielmo Campus, Sophie Doméjean, Gail Douglas, Margherita. Fontana and Marie-Charlotte Huysmans drafted the paper based on the reviews and statements discussed and voted on by all authors. Marie-Charlotte Huysmans, Margherita Fontana, Adrian Lussi, Anahita Jablonski-Momeni, Avijit Banerjee, David Ricketts, Falk Schwendicke, Fausto M. Mendes, Gail Douglas, Gottfried Schmalz, Guglielmo Campus, Johan Aps, Keith Horner, Klaus Neuhaus, Monique van der Veen, Niek Opdam, Sophie Doméjean, Stefania Martignon, Jan Kühnisch, and Christian Splieth critically reviewed the paper.

References

1 Kassebaum NJ, Bernabe E, Dahiya M, Bhandari B, Murray CJ, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. J Dent Res. 2015;94(5):650–8. https://doi.org/10.1177/0022034515573272
2 Schwendicke F, Giannobile WV. Research for prevention of oral/dental diseases: how far have we come? J Dent Res. 2020;99(1):5–7. https://doi.org/10.1177/0022034519889054
3 Machiulskiene V, Campus G, Carvalho JC, Dige I, Ekstrand KR, Jablonski-Momeni A, et al. Terminology of dental caries and dental caries management: consensus report of a workshop organized by ORCA and cariology research group of IADR. Caries Res. 2020;54(1):7–14. https://doi.org/10.1159/000503309
4 Fejerskov O. Changing paradigms in concepts on dental caries: consequences for oral health care. Caries Res. 2004;38(3):182–91. https://doi.org/10.1159/000077753
5 Webster M. Available from: https://www.merriam-webster.com/dictionary/diagnosis
6 Mejare I, Axelsson S, Dahlen G, Espelid I, Norlund A, Tranaeus S, et al. Caries risk assessment. A systematic review. Acta Odontol Scand. 2014;72(2):81–91. https://doi.org/10.3109/00016357.2013.822548
7 Cagetti MG, Bonta G, Cocco F, Lingstrom P, Strohmenger L, Campus G. Are standardized caries risk assessment models effective in assessing actual caries status and future caries increment? A systematic review. BMC oral health. 2018;18(1):123. https://doi.org/10.1186/s12903-018-0585-4
8 Schwendicke F, Splieth C, Breschi L, Banerjee A, Fontana M, Paris S, et al. When to intervene in the caries process? An expert Delphi consensus statement. Clin Oral Investig. 2019;23(10):3691–703. https://doi.org/10.1007/s00784-019-03058-w
9 Banerjee A, Splieth C, Breschi L, Fontana M, Paris S, Burrow M, et al. When to intervene in the caries process? A Delphi consensus statement. Br Dent J. 2020;229(7):474–82. https://doi.org/10.1038/s41415-020-2220-4
10 Paris S, Banerjee A, Bottenberg P, Breschi L, Campus G, Domejean S, et al. How to intervene in the caries process in older adults: a Joint ORCA and EFCD expert Delphi consensus statement. Caries Res. 2020;54(5–6):1–7. https://doi.org/10.1159/000510843
11 Schwendicke F, Splieth CH, Bottenberg P, Breschi L, Campus G, Domejean S, et al. How to intervene in the caries process in adults: proximal and secondary caries? An EFCD-ORCA-DGZ expert Delphi consensus statement. Clin Oral Investig. 2020;24(9):3315–21. https://doi.org/10.1007/s00784-020-03431-0
12 Splieth CH, Banerjee A, Bottenberg P, Breschi L, Campus G, Ekstrand KR, et al. How to intervene in the caries process in children: a joint ORCA and EFCD expert Delphi consensus statement. Caries Res. 2020;54(4):297–305. https://doi.org/10.1159/000507692
13 Kühnisch J, Aps JKM, Splieth C, Lussi A, Jablonski-Momeni A, Mendes FM, et al. ORCA-EFCD consensus report on clinical recommendations for caries diagnosis. In: Paper I: caries lesion detection and depth assessment Clin Oral Investig. 2024.
14 Neuhaus KW, Kühnisch J, Banerjee A, Martignon S, Ricketts D, Schwendicke F, et al. ORCA-EFCD consensus report on clinical recommendations for caries diagnosis. In: Paper II: caries lesion activity and progression assessment (Caries Res 2024).
15 Fontana M, Zero DT. Assessing patients' caries risk. J Am Dent Assoc. 2006;137(9):1231–9. https://doi.org/10.14219/jada.archive.2006.0380
16 Fontana M, Gonzalez-Cabezas C. Evidence-based dentistry caries risk assessment and disease management. Dent Clin North Am. 2019;63(1):119–28. https://doi.org/10.1016/j.cden.2018.08.007
17 NICE. Dental recall: recall interval between routine dental examinations. National Institute for Clinical Excellence; 2004.
18 Fee PA, Riley P, Worthington HV, Clarkson JE, Boyers D, Beirne PV. Recall intervals for oral health in primary care patients. Cochrane Database Syst Rev. 2020;10:CD004346. https://doi.org/10.1002/14651858.CD004346.pub5

19 Leggett H, Csikar J, Vinall-Collier K, Douglas GVA. Whose responsibility is it anyway? Exploring barriers to prevention of oral diseases across europe. JDR Clin Trans Res. 2021;6(1):96–108. https://doi.org/10.1177/2380084420926972
20 Foxman B, Davis E, Neiswanger K, McNeil D, Shaffer J, Marazita ML. Maternal factors and risk of early childhood caries: a prospective cohort study. Community Dent Oral Epidemiol. 2023;51(5):953–65. https://doi.org/10.1111/cdoe.12794
21 Grieshaber A, Haschemi AA, Waltimo T, Bornstein MM, Kulik EM. Caries status of first-born child is a predictor for caries experience in younger siblings. Clin Oral Investig. 2022;26(1):325–31. https://doi.org/10.1007/s00784-021-04003-6
22 Schwendicke F, Dörfer CE, Schlattmann P, Foster Page L, Thomson WM, Paris S. Socioeconomic inequality and caries: a systematic review and meta-analysis. J Dent Res. 2015;94(1):10–8. https://doi.org/10.1177/0022034514557546
23 Keels MA. Personalized dental caries management in children. Dent Clin North Am. 2019;63(4):621–9. https://doi.org/10.1016/j.cden.2019.06.002
24 Ciancio SG. Medications as a risk factor for caries and periodontal disease. N Y State Dent J. 1997;63(8):32–6.
25 Fontana M, Young DA, Wolff MS, Pitts NB, Longbottom C. Defining dental caries for 2010 and beyond. Dent Clin North Am. 2010;54(3):423–40. https://doi.org/10.1016/j.cden.2010.03.007
26 Carvalho JC, Mestrinho HD, Oliveira LS, Varjao MM, Aimee N, Qvist V. Validation of the visible occlusal plaque index (VOPI) in estimating caries lesion activity. J Dent. 2017;64:37–44. https://doi.org/10.1016/j.jdent.2017.06.003
27 Azevedo MS, Romano AR, Correa MB, Santos IDSD, Cenci MS. Evaluation of a feasible educational intervention in preventing early childhood caries. Braz Oral Res. 2015;29:S1806-83242015000100286–8324. https://doi.org/10.1590/1807-3107BOR-2015.vol29.0089
28 Suparattanapong P, Chankanka O, Matangkasombut O, Govitvattana N. Dental caries and associated risk factors in 13- to 18-month-old infants receiving breast or formula milk feeding: a cross-sectional study. Int J Paediatr Dent. 2022;32(4):527–37. https://doi.org/10.1111/ipd.12930
29 Un Lam C, Khin LW, Kalhan AC, Yee R, Lee YS, Chong MF, et al. Identification of caries risk determinants in toddlers: results of the GUSTO birth cohort study. Caries Res. 2017;51(4):271–82. https://doi.org/10.1159/000471811
30 Chanpum P, Duangthip D, Trairatvorakul C, Songsiripradubboon S. Early childhood caries and its associated factors among 9- to 18-month old exclusively breastfed children in Thailand: a cross-sectional study. Int J Environ Res Public Health. 2020;17(9):3194. https://doi.org/10.3390/ijerph17093194
31 Dental Quality Alliance. Guidance on caries risk assessment in children. Chicago, IL: American Dental Association; 2018. https://www.nidcr.nih.gov/sites/default/files/2021-12/Oral-Health-in-America-Advances-and-Challenges.pdf
32 Pienihakkinen K, Jokela J, Alanen P. Assessment of caries risk in preschool children. Caries Res. 2004;38(2):156–62. https://doi.org/10.1159/000075940
33 Zhou Y, Yang JY, Lo EC, Lin HC. The contribution of life course determinants to early childhood caries: a 2-year cohort study. Caries Res. 2012;46(2):87–94. https://doi.org/10.1159/000335574
34 Gao XL, Hsu CY, Xu Y, Hwarng HB, Loh T, Koh D. Building caries risk assessment models for children. J Dent Res. 2010;89(6):637–43. https://doi.org/10.1177/0022034510364489
35 Loe H. The gingival index, the plaque index and the retention index systems. J Periodontol. 1967;38(6):610–6. https://doi.org/10.1902/jop.1967.38.6.610
36 Volgenant CMC, Fernandez Y Mostajo M, Rosema NAM, van der Weijden FA, Ten Cate JM, van der Veen MH. Comparison of red autofluorescing plaque and disclosed plaque-a cross-sectional study. Clin Oral Investig. 2016;20(9):2551–8. https://doi.org/10.1007/s00784-016-1761-z
37 Pitts NB, Ekstrand KR, ICDAS Foundation. International caries detection and assessment system (ICDAS) and its international caries classification and management system (ICCMS): methods for staging of the caries process and enabling dentists to manage caries. Community Dent Oral Epidemiol. 2013;41(1):e41–52. https://doi.org/10.1111/cdoe.12025
38. Featherstone JDB, Crystal YO, Alston P, Chaffee BW, Doméjean S, Rechmann P, Zhan L, Ramos-Gomez F. Evidence-Based Caries Management for All Ages-Practical Guidelines. Front Oral Health. 2021;27(2):657518.
39 Ekstrand KR, Bruun G, Bruun M. Plaque and gingival status as indicators for caries progression on approximal surfaces. Caries Res. 1998;32(1):41–5. https://doi.org/10.1159/000016428
40 Ferreira MA, Mendes NS. Factors associated with active white enamel lesions. Int J Paediatr Dent. 2005;15(5):327–34. https://doi.org/10.1111/j.1365-263X.2005.00641.x
41 Quaglio JM, Sousa MB, Ardenghi TM, Mendes FM, Imparato JC, Pinheiro SL. Association between clinical parameters and the presence of active caries lesions in first permanent molars. Braz Oral Res. 2006;20(4):358–63. https://doi.org/10.1590/s1806-83242006000400014
42 Ekstrand K, Martignon S, Holm-Pedersen P. Development and evaluation of two root caries controlling programmes for home-based frail people older than 75 years. Gerodontology. 2008;25(2):67–75. https://doi.org/10.1111/j.1741-2358.2007.00200.x
43 Leroy R, Bogaerts K, Martens L, Declerck D. Risk factors for caries incidence in a cohort of Flemish preschool children. Clin Oral Investig. 2012;16(3):805–12. https://doi.org/10.1007/s00784-011-0579-y
44 Skrivele S, Care R, Berzina S, Kneist S, de Moura-Sieber V, de Moura R, et al. Caries and its risk factors in young children in five different countries. Stomatologija. 2013;15(2):39–46.
45 Hujoel P. Dietary carbohydrates and dental-systemic diseases. J Dent Res. 2009;88(6):490–502. https://doi.org/10.1177/0022034509337700
46 WHO. Guideline: sugars intake for adults and children Geneva. 2015.
47 Feldens CA, Pinheiro LL, Cury JA, Mendonca F, Groisman M, Costa RAH, et al. Added sugar and oral health: a position paper of the Brazilian Academy of Dentistry. Front Oral Health. 2022;3:869112. https://doi.org/10.3389/froh.2022.869112
48 van Loveren C. Sugar restriction for caries prevention: amount and frequency. Which is more important? Caries Res. 2019;53(2):168–75. https://doi.org/10.1159/000489571
49 A Patenaude S, Papagerakis P, R L Lieffers J. Development of a nutrition questionnaire for dental caries risk factors. Int J Environ Res Public Health. 2020;17(5):1793. https://doi.org/10.3390/ijerph17051793
50 Featherstone JD. The science and practice of caries prevention. J Am Dent Assoc. 2000;131(7):887–99. https://doi.org/10.14219/jada.archive.2000.0307
51 Marinho VC, Higgins JP, Sheiham A, Logan S. Fluoride toothpastes for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. 2003;2003(1):CD002278. https://doi.org/10.1002/14651858.CD002278
52 Featherstone JD. Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol. 1999;27(1):31–40. https://doi.org/10.1111/j.1600-0528.1999.tb01989.x
53 Lagerlof F, Oliveby A, Ekstrand J. Physiological factors influencing salivary clearance of sugar and fluoride. J Dent Res. 1987;66(2):430–5. https://doi.org/10.1177/00220345870660020801
54 Bulthuis MS, van Gennip LLA, Thomas RZ, Bronkhorst EM, Laheij AMGA, Raber-Durlacher JE, et al. Caries progression after haematopoietic stem cell transplantation and the role of hyposalivation. Caries Res. 2022;56(3):187–96. https://doi.org/10.1159/000525599
55 Aliko A, Wolff A, Dawes C, Aframian D, Proctor G, Ekstrom J, et al. World Workshop on Oral Medicine VI: clinical implications of medication-induced salivary gland dysfunction. Oral Surg Oral Med Oral Pathol Oral Radiol. 2015;120(2):185–206. https://doi.org/10.1016/j.oooo.2014.10.027
56 Lieshout HF, Bots CP. The effect of radiotherapy on dental hard tissue: a systematic review. Clin Oral Investig. 2014;18(1):17–24. https://doi.org/10.1007/s00784-013-1034-z
57 Fox PC, Busch KA, Baum BJ. Subjective reports of xerostomia and objective measures of salivary gland performance. J Am Dent Assoc. 1987;115(4):581–4. https://doi.org/10.1016/s0002-8177(87)54012-0
58 van der Putten GJ, Brand HS, Schols JM, de Baat C. The diagnostic suitability of a xerostomia questionnaire and the association between xerostomia, hyposalivation and medication use in a group of nursing home residents. Clin Oral Investig. 2011;15(2):185–92. https://doi.org/10.1007/s00784-010-0382-1

59 Hijjaw O, Alawneh M, Ojjoh K, Abuasbeh H, Alkilany A, Qasem N, et al. Correlation between xerostomia index, clinical oral dryness scale, and ESSPRI with different hyposalivation tests. Open Access Rheumatol. 2019;11:11–8. https://doi.org/10.2147/OARRR.S188937
60 Jager DHJ, Bots CP, Forouzanfar T, Brand HS. Clinical oral dryness score: evaluation of a new screening method for oral dryness. Odontology. 2018;106(4):439–44. https://doi.org/10.1007/s10266-018-0339-4