CAMBRA®

Caries Management by Risk Assessment

A Comprehensive Caries Management Guide for Dental Professionals

cda®

published by the California Dental Association
1201 K St., 14th Floor
Sacramento, CA 95814
800.232.7645
cda.org

Stay Connected cda.org/journal

TABLE OF CONTENTS

3 CAMBRA: A Comprehensive Caries Management Guide for Dental Professionals

Kerry K. Carney, DDS, CDE

4 CAMBRA Turns 21

An introduction to the guide.

Peter Rechmann, DMD, PhD

6 Caries Management by Risk Assessment: Results From a Practice-Based Research Network Study

This study with clinical practices outside of a university setting demonstrates that the principles and philosophy of CAMBRA could be successfully implemented into dental practice with dramatic reductions in caries risk and in the development of new caries clinical indicators.

Peter Rechmann, DMD, PhD; Benjamin W. Chaffee, DDS, MPH, PhD; Beate M.T. Rechmann; and John D.B. Featherstone, MSc, PhD

16 Caries Management by Risk Assessment (CAMBRA): An Update for Use in Clinical Practice for Patients Aged 6 Through Adult

This paper provides a practical evidence-based update for the clinician to use in practice for patients aged 6 through adult.

John D.B. Featherstone, MSc, PhD; Pamela Alston, DDS, MPP; Benjamin W. Chaffee, DDS, MPH, PhD; and Peter Rechmann, DMD, PhD

26 An Updated CAMBRA Caries Risk Assessment Tool for Ages 0 to 5 Years

This paper provides a practical caries risk assessment tool for use by the clinician in caries management by risk assessment in 0- to 5-year-olds that updates the original tool published in 2007 and reviewed in 2010.

John D.B. Featherstone, MSc, PhD; Yasmi O. Crystal, DMD, MSc; Benjamin W. Chaffee, DDS, MPH, PhD; Ling Zhan, DDS, PhD; and Francisco Ramos-Gomez, DDS, MS, MPH

37 Appendix

Self-management goals pictorial check sheet and caries risk assessment forms.

CAMBRA: A Comprehensive Caries Management Guide for Dental Professionals

Kerry K. Carney, DDS, CDE

A paradigm shift in dental practice occurred more than a decade ago, when the CDA Foundation in partnership with the University of California, San Francisco, School of Dentistry published evidence in the October and November 2007 issues of the *Journal of the California Dental Association* that caries could be prevented and managed through risk assessment and appropriate intervention.

The next few years were spent educating dentists on the findings. The CDA Foundation hosted forums and workshops at *CDA Presents The Art and Science of Dentistry*, CDA's biennial convention, and made plans to engage decision-makers in health policy and financing to embrace and support this disease-management model. The *Journal of the California Dental Association* continued to keep the profession informed of the newest developments in CAMBRA, publishing them in the October and November 2011 issues.

Further, to expand the evidence base for CAMBRA use in dental practice, the CDA Foundation entered into a multiyear collaboration with the UCSF School of Dentistry to replicate the results of university-based clinical studies in dental offices. To accomplish that task, they assembled a practice-based research network of dentists and community health centers to collect in a controlled clinical trial data on changes in patients' risk level and disease status by practicing CAMBRA protocols.

Contained in this publication are the results of that research and the latest, state-of-the-art CAMBRA approach to managing dental caries.

The articles in this guide were originally published in the January 2019 issue of the *Journal of the California Dental Association*. This stand-alone format is provided to allow easy access to the latest CAMBRA protocols and to facilitate integration of caries management by risk assessment into everyday practice. ■

CAMBRA* Comes of Age

Peter Rechmann, DMD, PhD

GUEST EDITOR

Peter Rechmann, DMD, PhD, is a professor at the University of California, San Francisco, School of Dentistry and is the director of the clinical sciences research group. He has been involved in clinical research for more than 35 years and has published more than 140 papers and book chapters.
Conflict of Interest Disclosure: None reported.

* CAMBRA is a registered trademark of the University of California, San Francisco

CAMBRA has reached legal age. Twenty-one years ago in 1997, John D.B. Featherstone, MSc, PhD, at the University of California, San Francisco (UCSF), applied for a National Institute of Health Grant to conduct the first clinical trial with a preventive approach to caries management — known later as the caries management by risk assessment (CAMBRA) study.

In April 2002, the California Dental Association Foundation hosted a conference where experts reviewed and updated the science and practice of caries prevention. This led to a two-part publication series that featured 16 expert papers in the *Journal of the California Dental Association* in 2003 entitled "Cariology in the New World Order: Moving From Restoration Toward Prevention." The goal was to provide practitioners with tools to elevate this preventive standard in their own practices.

The ideological movement of preventing caries rather than the provisional "drill and fill" supplanted the traditional treatment path. CAMBRA began the medical-model approach to disease management. The Western, Central and Eastern CAMBRA coalitions were created, each with their own unique focus. Emphases were directed toward practicing dentists and their staff, development of a standardized cariology curriculum for all U.S. dental schools and inclusion of CAMBRA principles in the licensure process.

In 2007, the October and November issues of the *Journal* presented CAMBRA clinical protocols, products and the roles of RDHs, RDAs and office staff, which influenced change and a consensus statement with implementation guidelines to support oral health. The consensus document was adopted by hundreds of dental experts, academic researchers, practitioners and dental organizations summarizing the main principles and clinical application of CAMBRA.

The CDA Foundation hosted a symposium in January 2011 to advance the practice of dental disease management. The symposium engaged researchers, clinicians, insurers and policymakers in a discussion on caries management, the impact of caries on access to care and financial implications and policies at the time that inhibited widespread adoption of the protocols. In its October 2011 issue, the *Journal*, for the first time, included a validation paper confirming the validity of the CAMBRA caries risk assessment (CRA) as a result of a six-year retrospective study by Doméjean and co-workers.

Recently, a national CAMBRA coalition was created. Annual meetings have been held since 2015 bringing together all areas of dental professionals and public and private-payers groups. In 2018, the National CAMBRA Coalition hosted its annual event for the first time in conjunction with the American Academy of Cariology (AAC). The topic of AAC's second annual conference was "Dental Caries Progress — Sugar or Bacterial Dysbiosis" featuring a series of national and international speakers who presented impressive highlights of modern cariology.

This guide features a series of three

papers reporting the latest CAMBRA-related research results and updates on clinical-practice CAMBRA implementation.

The series begins with the results from a practice-based research network (PBRN) created in the San Francisco Bay Area by Peter Rechmann, DMD, PhD, and co-workers to study the efficiency of CAMBRA in "the real world outside the university ivory tower." This randomized, controlled, double-blind two-year clinical CAMBRA-PBRN trial with individual-level caries risk assignment of 460 patients to standard of care versus active CAMBRA treatment demonstrated that caries risk level as well as caries disease indicators were significantly reduced in the CAMBRA intervention group.

The introduction of the CAMBRA-PBRN trial paper summarizes the CAMBRA history, the results of the first UCSF-CAMBRA clinical trial and available evidence related to the validity of the CAMBRA CRA system. The second paper, authored by John D.B. Featherstone, MSc, PhD, and co-workers, provides a practical evidence-based update of the CAMBRA system for use in clinical practice for patients aged 6 years through adult. This paper updates the CAMBRA CRA tool, allowing the preparation of a risk-based treatment plan that combines chemical therapy with necessary restorative treatment for a minimally invasive, successful outcome. The paper's "caries self-management menu of options" assists patients in setting their self-management goals for caries management.

The third paper provides an updated practical CRA tool for use by the clinician in CAMBRA for young children aged 0 to 5. The paper provides updates on the original CRA tool for children aged 0 to 5 that was published in 2007 and reviewed in 2010 and includes risk-factor updates such as the caries status of the caregiver or sibling and the family health literacy status. Comprehensive guidelines for CRA and detailed management plans for each risk level with additional guiding principles were provided to create a personalized management plan.

It has been a great honor for me to introduce this special CAMBRA guide, not only because of the 21 years of CAMBRA existence, but more important because of the overwhelming evidence we have that the developed CRA tool results in an accurate assessment of caries risk and consequently supports the creation of effective and individualized caries management plans. This guide contains the specific information that will guide dental practitioners into the future. ■

Caries Management by Risk Assessment: Results From a Practice-Based Research Network Study

Peter Rechmann, DMD, PhD; Benjamin W. Chaffee, DDS, MPH, PhD; Beate M.T. Rechmann; and John D.B. Featherstone, MSc, PhD

ABSTRACT Thirty dentists with clinical practices outside of a university setting were trained and calibrated successfully in DMFS and ICDAS-scoring. This randomized, controlled, parallel-arm, double-blind two-year clinical trial with individual-level caries risk assignment of 460 patients to standard of care as control versus active CAMBRA* treatment as intervention demonstrated that caries risk level, as well as caries disease indicators, were significantly reduced in the CAMBRA intervention group compared to the controls at all recall time points.

AUTHORS

Peter Rechmann, DMD, PhD, is a professor at the University of California, San Francisco, School of Dentistry and is the director of the clinical sciences research group. He has been involved in clinical research for more than 35 years and has published more than 140 papers and book chapters. *Conflict of Interest Disclosure: None reported.*

Benjamin W. Chaffe, DDS, MPH, PhD, is an assistant professor of oral epidemiology and dental public health at the University of California San Francisco, School of Dentistry. His research interests include caries management, tobacco control and oral health disparities. *Conflict of Interest Disclosure: None reported.*

Beate M.T. Rechmann is a senior research associate and research coordinator at the University of California, San Francisco, School of Dentistry in the department of preventive and restorative dental sciences. *Conflict of Interest Disclosure: None reported.*

John D.B. Featherstone, MSc, PhD, is dean emeritus and professor emeritus at the University of California, San Francisco, School of Dentistry. His 44 years of research have included caries prevention and management. *Conflict of Interest Disclosure: None reported.*

* CAMBRA is a registered trademark of the University of California, San Francisco

Dental caries is the most prevalent disease condition of humankind, imposing a significant burden at all life stages from childhood to adulthood.[1] The disease is chronic, transmissible and infectious[2] and, consequently, the disease develops under conditions that favor dysbiosis. In oral health, a dynamic balance is reached between the host, the environment and the microbiome (symbiosis). Frequent intake of sugar and/or reductions in saliva flow result in extended periods of low pH in the biofilm, which disrupts this symbiotic relationship. Such conditions inhibit the growth of beneficial species and drive the selection of bacteria with an acid-producing/acid-tolerating phenotype, thereby increasing the risk of caries (dysbiosis).[3] Nevertheless, dental practitioners and patients alike have often assumed that placing a restoration "fixes" dental caries, which is not true. Placing a filling or crown does not eliminate the load of cariogenic bacteria in the mouth or address other risk factors that cause the disease. Consequently, caries is not stopped by placing a restoration.[4] The vicious cycle of caries, restoration and secondary caries followed by a new and larger restoration is not interrupted.[5] Instead, the stability of the tooth declines over time through loss of structure at every successive treatment and retreatment.

When the principles of caries management by risk assessment (CAMBRA) were introduced in 2003, a major transformation in how to conceptualize and treat the caries disease was underway.[6–9] With

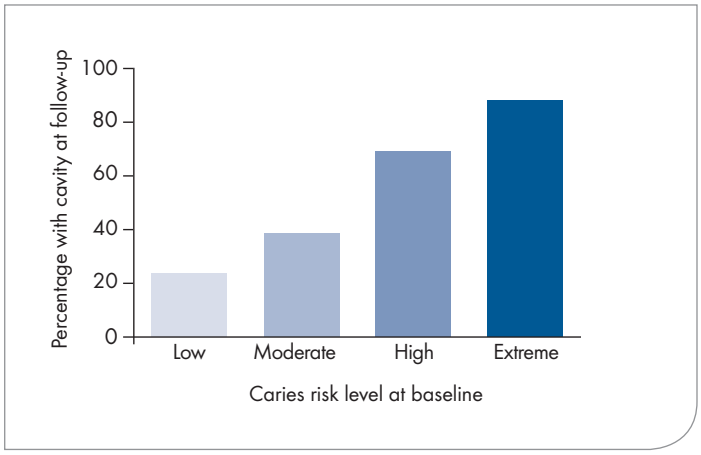


FIGURE 1. Percentage of patients with new cavities at follow-up separated into low, moderate, high and extreme caries risk levels at baseline (patients had not received the appropriate preventive measures). Generated from Doméjean S, White JM, Featherstone JD. Validation of the CDA CAMBRA caries risk assessment – a six-year retrospective study. *J Calif Dent Assoc* 2011;39(10):709–715.

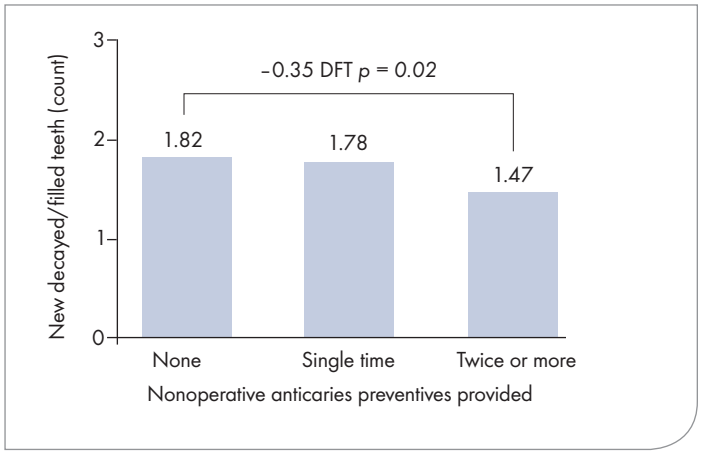


FIGURE 2. Number of new decayed/filled teeth of patients who received none, a single-time and twice or more often anticaries preventives; a 20 percent reduction in new decayed/filled teeth over 18 months in the group receiving twice or more anticaries preventives was shown. (Adapted from *BMC Oral Health* 2015;15(1):111.)

CAMBRA, scientific, evidence-based solutions for prevention and treatment of caries as a manageable medical condition, not a mechanical problem, were translated into clinically relevant guidelines for dentists.[10]

The ideology of managing caries lesions very early, before they have reached the cavitated stage, without drilling but by preventive measures has been embraced within many modern dental practices.[11,12] Noninvasive and minimally invasive treatment concepts[13–15] are now widely accepted by dental practitioners. Following these concepts and taking into consideration each patient's caries risk, invasive restorative treatments can be delayed and performed at more advanced caries lesion stages, if not avoided entirely.[11,12,16]

In many dental practices throughout the world, the CAMBRA philosophy has been completely incorporated into the practice routine and embodied by the entire patient care team, including dental assistants and hygienists, front desk staff and dentists.

In short, CAMBRA requires the dentist to identify the caries risk level of the individual patient by evaluating their disease indicators, risk factors and preventive factors using a caries risk assessment (CRA) form (see other articles in this guide). Taking those factors into account, a caries risk level of low, moderate, high or extreme is assigned. According to the assigned risk level, changes in the patient's lifestyle are discussed and, if necessary, additional preventive chemical measures are recommended.[10,17–22] CAMBRA also includes carrying out noninvasive therapies and minimally invasive restorative procedures for tooth structure conservation and, finally, recall and review.[23]

First CAMBRA Clinical Trial

The first CAMBRA study was performed at the University of California, San Francisco (UCSF) between 1999 and 2004.[4] The study was a randomized, prospective, controlled clinical trial over two years. Impressively, the results indicated that an over-the-counter (OTC) fluoride toothpaste and rinse combined with an antibacterial agent (chlorhexidine) were able to significantly reduce the cariogenic bacterial load over the study period. Bacteria testing also strikingly revealed that, in the control group, placing restorations alone did not reduce the mutans streptococci (MS) bacterial challenge. MS represent a group of major cariogenic bacteria. The MS bacterial challenge in the CAMBRA intervention group was significantly lower at each recall visit.

In addition, it was shown that just placing restorations did not lower the caries risk level of individuals in the control group.[4] In contrast, the intervention group receiving the antibacterial and preventive fluoride measures showed a significantly decreased number of subjects at high caries risk. The antibacterial and fluoride therapy had successfully altered the balance between pathological and protective caries risk factors, lowering the caries risk level among intervention group patients.

One other major finding of the first CAMBRA clinical trial was a reduced number of new caries lesions over the two years for the high-caries-risk subjects in the intervention group. The participants in the intervention group developed fewer new cavities, with a statistically significant 24 percent lower increase in decayed, missing, filled tooth surfaces (DMFS) than the control subjects. In summary, the CAMBRA trial demonstrated that for high-caries-risk patients, employing fluoride and bactericidal agents lowers caries risk and fewer cavitated lesions will occur.[4]

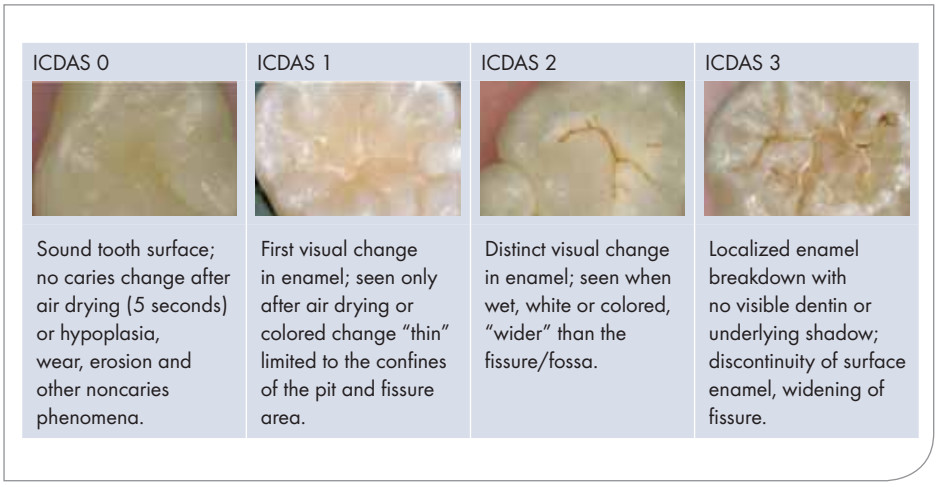


FIGURE 3. ICDAS scoring criteria for healthy (score 0), noncavitated lesions (score 1 and 2) and first representation of a cavitated lesion (score 3). (Adapted from *BMC Oral Health* 2018;18(2).)

Predictive Validity of the CAMBRA Risk Assessment System

The CAMBRA CRA system was evaluated in several outcomes studies.[20,24] First, at the UCSF School of Dentistry clinics Doméjean and co-workers tracked charts of 2,571 patients who had been assessed for their caries risk. At baseline, they were identified as having low, moderate, high or extreme caries risk.[24] At a follow-up examination roughly 1.5 years later (16 ± 13 months), new cavitated lesions, radiographic lesion into dentin or approximal enamel lesions on X-rays were registered and their occurrence was closely related to the earlier assigned risk level; among low-risk patients, 24 percent developed those disease indicators, while disease occurrence was higher in each category of greater caries risk: moderate 39 percent, high 69 percent and extreme 88 percent (**FIGURE 1**). These patients had not received the appropriate preventive measures[24] and consequently developed new caries lesions.

In another outcomes study, Chaffee and co-workers reported and confirmed that baseline caries risk is strongly associated with future caries.[25] From 18,004 patient charts with 4,468 recall visits at the UCSF student dental clinics, they found that the originally assigned risk level predicted the mean number of newly decayed or filled teeth (DFT) that patients developed: Low-risk patients showed a DFT increase of 0.94 at recall and at each higher-risk level patients developed higher DFT values. Between each risk category, changes in DFT increment were statistically significant, with extreme risk patients having an increment of three[26] DFT between baseline and recall.[25]

In another electronic records study of 2,724 patients with follow-up at the UCSF School of Dentistry, Chaffee and co-workers reported the effectiveness of anticaries agents, including 5,000 ppm fluoride toothpastes, chlorhexidine rinse and xylitol. They showed that patients who had received any of these agents twice or more over 18 months had developed a 20 percent lower increase of decayed or filled teeth over those who never or only once had received those anticaries products (**FIGURE 2**).[26]

CAMBRA Practice-Based Research Network Study

The original UCSF-CAMBRA trial took place in a university dental school setting.[4] In order to demonstrate that CAMBRA not only works in a university "ivory tower" but can also successfully be implemented in the "real world," a practice-based research network (PBRN) was created in the San Francisco Bay Area. The idea behind performing studies in PBRNs is to engage dentists in studies that are directly related to daily clinical practice.[27] PBRNs should advance both research and dental practice through quality improvement.[27,28] PBRN studies are meant to move scientific advances rapidly into daily practice and simultaneously provide structure for sharing of information between practitioners.[29]

The California Dental Association (CDA) was instrumental in establishing the San Francisco Bay Area network, which was created to conduct a CAMBRA study in dental offices and health care centers. The basic goal of the CAMBRA-PBRN trial was to recruit 30 dentists to perform a two-year randomized, controlled, double-blind study involving approximately 30 patients per dental practice. The hypothesis to be tested was that caries management based on caries risk level assignment significantly reduces patient caries risk level and reduces the need for caries restorative treatment over two years compared to a generally accepted standard of care.

Materials and Methods

Dentist Recruitment, Training and Calibration

San Francisco Bay Area dentists were invited by CDA newsletter advertisements and phone calls to attend informational meetings about the CAMBRA-PBRN study. CDA organized one-day information sessions. During these sessions, study design, expected involvement of the dentists in conducting the study and requirements to join the PBRN were explained. Based on a priori power calculation, it was determined that a sample size of 30 dentists to be recruited into the study would be sufficient. Before the main CAMBRA-PBRN study started, a total of 30 dentists

TABLE 1

Dispensed Treatment Products Based Upon the Assessed Caries Risk Level for the Intervention Group and the Control Group

Group assignment/ products at risk level	Low risk	Moderate risk			High risk			
Intervention group	Crest cavity protection (P&G) (1,100 ppm F) 2x daily	Crest cavity protection (P&G) (1,100 ppm F) 2x daily	Ortho wash rinse (3M ESPE) (0.05% F), daily	Xylitol candies (Epic) 4x daily (8 grams total)	Clinpro 5000 (3M ESPE) (5,000 ppm F toothpaste)	Peridex (3M ESPE) Chlorhexidine gluconate (0.12%) rinse 1/day for 1 week, every month*	Xylitol candies (Epic) 4x daily (8 grams total)	Vanish (3M ESPE) F varnish
Control group	Crest cavity protection (P&G) (1,100 ppm F) 2x daily	Crest cavity protection (P&G) (1,100 ppm F) 2x daily	Crest Scope rinse (P&G) (mint taste), daily	Sorbitol candies (Epic) 4x daily (8 grams total)	Crest cavity protection (P&G) (1,100 ppm F) 2x daily	Crest Scope rinse (P&G) (mint taste), 1/ day for 1 week, every month*	Sorbitol candies (Epic) 4x daily (8 grams total)	Placebo varnish (3M ESPE)

* Until the next periodic oral exam, then reassess.

(13 female, 17 male) had joined. Three dentists were employed at three different federally qualified health centers (FQHC) and 27 were dental-office owners.

A calibration study was performed in order to assure that all participating dentists would record oral conditions in the same detailed way[30] in the main CAMBRA study and to assure that results could be compared among participating practices. In order to minimize interexaminer variability in data gathering, including the assessment of caries risk, carious lesion classification and recording of existing restorations, the study dentists were required to attend one training meeting and one calibration workshop. Training meetings and calibration workshops were offered on multiple dates and attended by three to eight dentists per session. The study examiners participated in the training and calibration sessions with other staff members of their dental practices to enhance understanding and support of the study with the entire patient-care team. The UCSF Institutional Review Board (IRB) had approved the prestudy dentist calibration (IRB #10-04804).

The attendees were trained and calibrated in two caries classification systems that were later used in the main CAMBRA-PBRN study. First, they were trained in examining and correctly charting decayed, missing, filled tooth surfaces — the DMFS index,[31,32] following strict scoring rules. Because noncavitated caries lesions in enamel can be managed by remineralization without restorative intervention,[33,34] the dentists were also calibrated in classifying caries lesions at a noncavitated stage.[35] The International Caries Detection and Assessment System (ICDAS)[35,36] offers criteria for scoring of noncavitated lesions.[37] The dentists were specifically trained to differentiate between sound (ICDAS 0), noncavitated caries lesions (ICDAS 1 or 2) (**FIGURE 3**) and cavitated caries lesions (ICDAS 3 and above). This allowed the participating dentists to record consistent and detailed clinical findings in the main study.

Examinations occurred after the teeth were carefully cleaned (dental prophylaxis). Dentists performed a visual exam without tactile probing of enamel, using loupes with 2x magnification.

The 30 participating dentists were calibrated to a single gold-standard examiner during the six calibration sessions.[38] To determine the interexaminer reliability with the gold standard, an average of 13 or more patients per examiner were checked for DMFS and ICDAS. Each examiner scored between 1,036 and 2,220 tooth surfaces. To calculate the interexaminer reliability, kappa statistics were used. All dentists achieved interexaminer kappa values of > 0.75 in comparison to the gold-standard examiner, with a mean interexaminer kappa of 0.84 considered as a "very good" agreement with the gold standard. A "moderate" kappa of 0.55 for agreement in noncavitated lesions showed that this differentiation was more difficult and might require additional time and clinical education for future PBRN studies.[39] For both indices, interexaminer reliability values achieved between the gold-standard examiner and future study examiners were at least as high as typically found in the literature and considered acceptable for high-quality dental assessments.[40]

Main Study: Eligibility Criteria, Enrollment and Treatment Assignment

The UCSF IRB approved the main study (IRB #10-02153) and the study was registered on clinicaltrials.gov (ID: NCT01176396). In the PBRN practices, potential patients were informed about the study goals, possible risks and

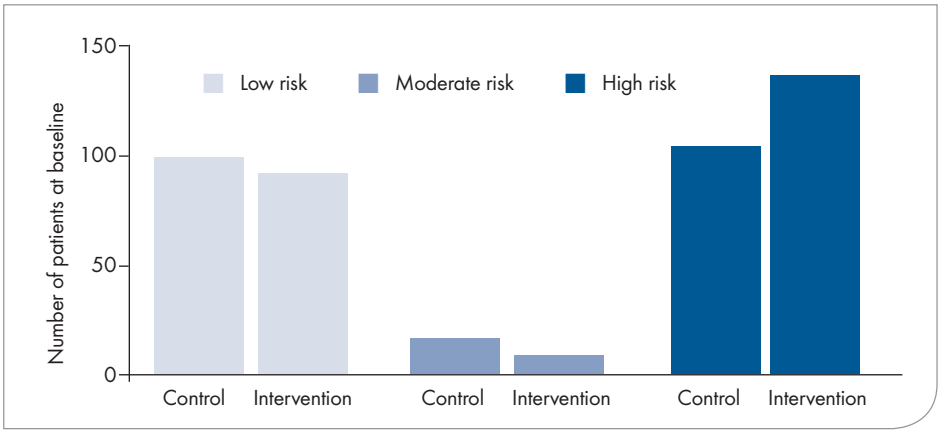


FIGURE 4. Number of eligible patients at baseline separated into caries risk levels and assignment to control group and intervention group treatment.

participation requirements. UCSF's IRB classified the study as minimal risk. When inclusion and exclusion requirements were fulfilled, the patients were finally consented (signing a written consent).

Of the 30 calibrated dentists who went through training and calibration, only 21 (11 female and 10 male) recruited patients for the study. Of those, three dentists were employees of a FQHC and 18 were practice owners.

After all existing restorative needs of a patient were met, the patient's DMFS and ICDAS scores were recorded in Denticon, a web-based dental charting program (Planet DDS Inc., Irvine, Calif.). CRAs with disease indicators, risk factors, protective factors and patient's caries risk level were also calculated with and recorded in Denticon at baseline and at each recall visit planned for six, 12, 18 and 24 months after the initial risk assessment. In a 2014 study, dental university instructors had been asked to complete CRA forms for simulated patient cases and demonstrated only moderate reliability to assign caries risk levels in accordance with a gold-standard assessor.[41] In that study, high-caries-risk cases were frequently categorized (erroneously) at low or moderate caries risk. Goolsby and Young confirmed similar findings.[42,43] To reduce such risk level misclassification in the PBRN trial, a digital system was developed at UCSF[41] that required information input about clinical findings and answers to questions found on CDA's CRA form.[44,45] The system automatically assigned risk level following an algorithm modeled after the way a gold-standard assessor and two experienced clinical instructors had assigned caries risk in the UCSF quality assurance study.[41]

For each caries risk level (i.e., low, moderate and high), randomization lists had been provided to help PBRN dentists to randomize their patient to the "active intervention" group or the "standard of care" control group. Providers were blinded to actual group assignment, which appeared on the randomization lists as two different colors: black or white. Extreme-risk patients were excluded from the study due to ethical reasons (to avoid withholding anticaries therapies). Intervention group products and recommendations were based on CAMBRA guidelines.[19,45] **TABLE 1** itemizes the provided products for each caries risk level, separated into "intervention" and "control" treatment. Patient participants as well as all members of the dental practice, including the dentist, were blinded to actual group assignment. All products were covered with black or white wraps with printed user instructions on each product; thus, brand name and product content could not be identified. Products were given to the participant in black and white product bags, comprising all products suggested for the specific risk level. Patients received sufficient product supplies to last six months and were instructed to request more if needed. Each product bag included laminated instruction sheets on how to use the products at home.

Finally, participants were scheduled for a recall every six months for the two-year study duration. The high-caries-risk patients received a phone call from the PBRN practice a week before a new calendar month started. During this phone call, patients were reminded to use their dispensed rinse for the first week of the month (one-minute rinse, 60 minutes after brushing teeth each evening). In addition, each PBRN practice was reminded by the UCSF study coordinator to place those reminder phone calls.

Of the 21 PBRN practices actively recruiting patients into the study, all data from one office were excluded from the final analysis (19 participants). The office did not follow recruitment, recall and data-collection instructions. The remaining 20 dentists enrolled 460 eligible patients. The eligibility criteria to be included in data analysis were: A baseline CRA was performed and assignment to the "black" or "white" group was recorded in the computer chart. Each practice enrolled a mean of 23.0 ± 16.8 patients with a range from two to 55 patients.

CAMBRA-PBRN Study Results

At enrollment, of the 460 eligible patients, 192 patients were at low caries risk, 26 at moderate and 242 were assessed as having high caries risk. Of the high-caries-risk patients, 137 were randomly assigned to the intervention group and 105 to the control group. For the low-caries-risk patients, 93 were assigned randomly to the intervention and 99 to the control (**FIGURE 4**). At baseline, the intervention

and control groups were not statistically significantly different in mean age (37 years intervention; 35 years control) and gender (69 percent female intervention; 68 percent female control). By chance, of the 242 baseline high-caries-risk patients, more (n = 137) were assigned to the intervention group (57 percent) than to the control group (P = 0.05).

High Caries Risk

TABLE 2 illustrates the number and percentage of participants who at baseline were classified as having high caries risk. The table also shows for each follow-up visit, in total and by treatment group assignment, how many patients were still classified as high risk. The follow-up rate for the intervention group was 58.4 percent at six months, 50.4 percent at 12 months, 39.4 percent at 18 months and 32.1 percent at 24 months. For the control group, the follow-up rates were similar (54.3 percent, 44.8 percent, 39.0 percent and 37.1 percent, respectively). In total, 151 initially high-caries-risk participants came to at least one follow-up visit with 85 (62.0 percent follow-up) in the intervention group and 66 (62.9 percent follow-up) in the control group.

For participants assessed as having high caries risk at baseline, **FIGURE 5** shows the percentage staying at high risk, separately at each recall. Over the two years, the percentage of patients who stayed at high caries risk was lower in the intervention group than the control group, with just 25 percent of participants staying at high caries risk in the intervention group at the 24-month recall. Interestingly, the percentage of high-caries-risk participants was also reduced over time for the control group down to 54 percent staying at high risk. Nevertheless, for all recall time points differences between the two groups were statistically significant (overall significance P < 0.001).

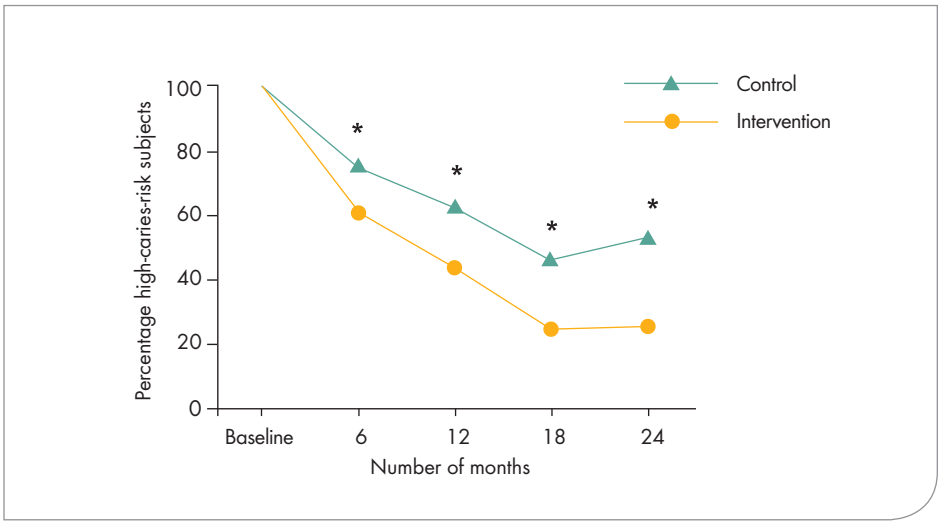


FIGURE 5. Change in caries risk levels for patients assessed as high caries risk at baseline; showing the percentage of patients staying at high risk over time for the intervention group and the control group (* marks statistically significant difference at specific recall time point; overall significance P < 0.001).

Low Caries Risk

TABLE 2 shows at each follow-up visit, in total and by treatment group, the number and percentage of patients who at the beginning of the study were classified as having low caries risk and then later were assessed as increasing their risk level to moderate or high risk. For the intervention group, the follow-up rate was 68.8 percent at six months, 60.2 percent at 12 months, 57.0 percent at 18 months and 38.7 percent at 24 months. The follow-up rates for the controls were 72.7 percent, 70.7 percent, 59.6 percent and 49.5 percent, respectively. In total, 154 initially low-risk participants provided data from at least one follow-up visit, with 73 (78.5 percent follow-up) patients in the intervention group and 81 (81.8 percent follow-up) in the control group.

FIGURE 6 shows the percentage of patients who changed their caries risk level from low at baseline to a higher caries risk at recalls. Only a small percentage converted to high caries risk over time. At the 18-month recall, 3.9 percent of the intervention group and 18.0 percent of the control group were assessed as having moderate or high caries risk, the difference being statistically significant (P = 0.05) (**FIGURE 6**). The difference between the intervention group and control group was not significantly different at any other individual time point. Over the entire study period, the percentage of participants changing their caries risk from low to moderate or high was significantly lower in the intervention group (P = 0.03).

Clinical Outcomes — Disease Indicators

In this CAMBRA-PBRN trial, the number of new fillings due to caries was very low in both groups. For this reason, we looked further into the registered disease indicators, namely visually or radiographically observed cavities into dentin, proximal enamel lesions, restorations due to caries in the last year and active white spot lesions at each recall time point with a white spot lesion defined as active if the surface appeared chalky and nonactive if the surface was shiny. These disease indicators include cavities and account for other signs of the existence of the caries disease. Consequently, they give a broader view of the caries situation of a patient. **FIGURE 7** represents the percentage of initially high-risk patients demonstrating newly registered disease indicators. The percentage of newly developed disease indicators decreased over time in both study groups. At all recall

TABLE 2

Caries Risk Category at Baseline and Follow-Up Visits, According to Baseline Caries Risk and Treatment Group Assignment

		Total		Intervention Group		Control Group	
High caries risk at baseline	Visit	n	Stay at high risk: n	n	Stay at high risk: n	n	Stay at high risk: n
	Baseline	242		137		105	
	6 months	137	92	80	49 (61.3%)	57	43 (75.4%)
	12 months	116	60	69	30 (43.5%)	47	30 (63.8%)
	18 months	95	32	54	13 (24.1%)	41	19 (46.3%)
	24 months	83	32	44	11 (25.0%)	39	21 (53.8%)
Low caries risk at baseline	Visit	n	Change to moderate or high risk: n	n	Change to moderate or high risk: n	n	Change to moderate or high risk: n
	Baseline	192		93		99	
	6 months	136	12	64	5 (7.8%)	72	7 (9.7%)
	12 months	126	14	56	3 (5.4%)	70	11 (15.7%)
	18 months	112	11	53	2 (3.8%)	59	9 (15.3%)
	24 months	85	15	36	4 (11.1%)	49	11 (22.5%)

For patients classified at baseline as high caries risk (upper rows) or low caries risk (lower rows), the number of patients who remained high risk (upper rows) or changed to moderate or high risk (lower rows) are shown according to their assigned treatment group.

time points, the percentage of patients with newly registered disease indicators was lower for patients in the intervention than for those in the control group. These differences were statistically significant at the 12- and 18-month recall visits. The intervention group showed new disease indicators in only 46 percent and 31 percent at the 12- and at the 18-month recall, respectively, while in the control group 64 percent and 53 percent, respectively, had developed new disease indicators. The overall statistical significance for differences between the intervention group and control group was P = 0.04 (**FIGURE 7**).

Discussion

To study whether CAMBRA can be successfully implemented outside a structured university setting,[4] a practice-based research network was created in the San Francisco Bay Area. Thirty dentists were enrolled to perform a two-year, randomized, controlled, double-blind clinical CAMBRA trial in their practices. The dentists were trained and calibrated to assess caries risk, score the conventional DMFS index and use the ICDAS clinical scoring system.

The first UCSF-CAMBRA trial included only patients who were high caries risk at the study start.[4] In that study, the chemical therapy (OTC fluoride toothpaste daily, OTC F mouth rinse daily and 0.12% chlorhexidine gluconate mouth rinse once a day for one week every month) in the intervention group resulted in significantly lower numbers of patients at high caries risk over time. In the intervention group, 50–70 percent of participants stayed at high caries risk and 70–90 percent of participants stayed at high caries risk in the control group. In contrast, in the present CAMBRA-PBRN study, only 25 percent of the participants in the intervention group and 54 percent of the control group remained at high caries risk after two years (**FIGURE 5**). Nevertheless, at all recall intervals, differences between the control group and intervention group in percentage of patients remaining at high risk were statistically significant.

Impressively, the percentage of high-risk participants remaining at this risk level during subsequent visits was much lower in the present CAMBRA-PBRN study than in the first UCSF-CAMBRA trial. There might be several reasons. For instance, in the UCSF-CAMBRA study 5,000 ppm prescription toothpaste was not available at that time, thus only 0.12% chlorhexidine plus OTC fluoride rinse (0.05% NaF) and OTC fluoride toothpaste (1,100 ppm F paste) were provided as intervention products. High-caries-risk participants assigned to the intervention group in the CAMBRA-PBRN study received a combination of prescription 5,000 ppm F paste, chlorhexidine rinse, xylitol mints and fluoride varnish. In the UCSF-CAMBRA study, the control group "continued their usual products" — they did not receive any products. In the present PBRN study, the control-group participants all received standard-of-care products. It is likely

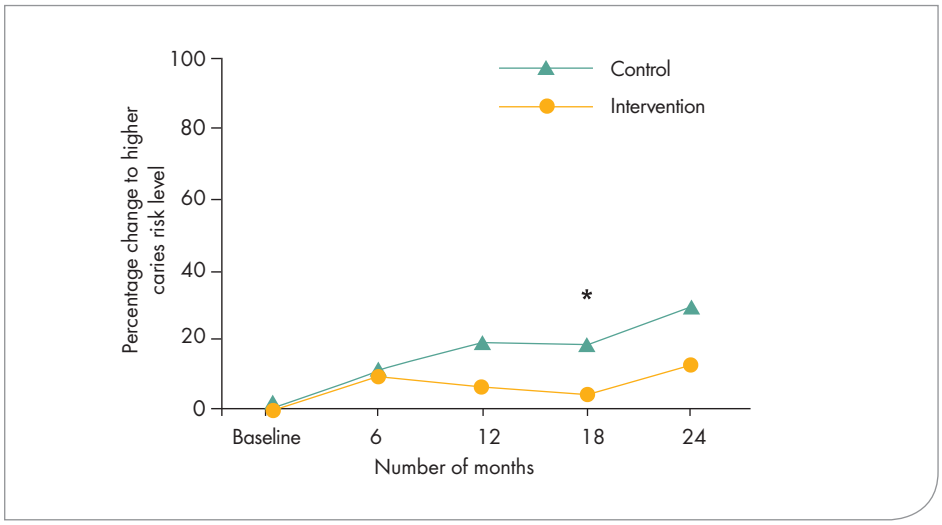


FIGURE 6. Percentage of participants classified as low caries risk at baseline, showing increased caries risk level to moderate or high caries risk over time for the intervention group and control group (* marks statistically significant difference at specific recall time point).

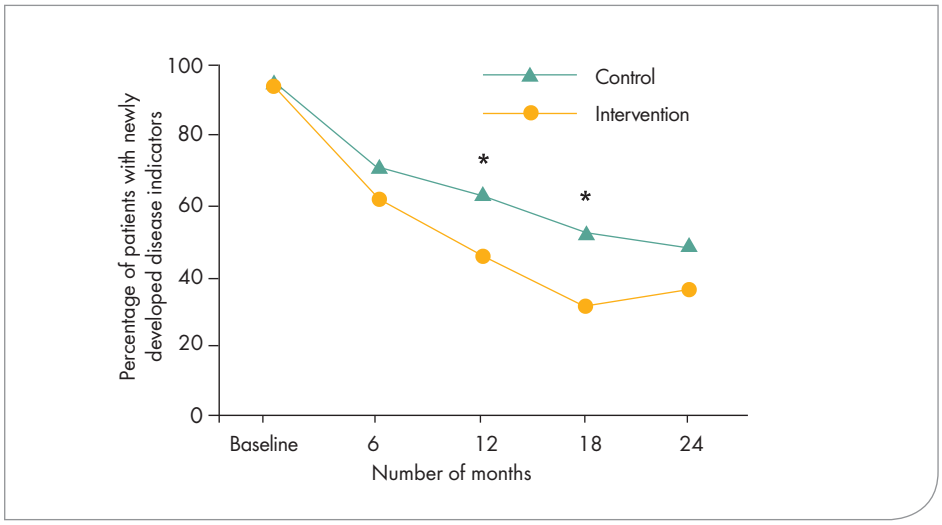


FIGURE 7. Percentage of patients with initial high risk at baseline developing any of the four clinical outcomes/disease indicators (cavities on radiographic into dentin, proximal enamel lesions on radiographs, active white spot lesions on smooth surfaces, restorations within prior year). *Percentages statistically significantly different (cluster-adjusted $P < 0.05$) newly developed disease indicators (* marks statistically significant difference at specific recall time point).

that these products contributed to the observed risk-level reduction in this control group. The control products heightened saliva flow (sorbitol candies) and in addition might have had bactericidal effects (cetylpyridinium chloride rinse). Thus, the participants' risk level in the control group was also dramatically reduced, unlike in the UCSF-CAMBRA study. Another important factor in the present study was that participants in both groups were called monthly to remind them to use their products. Most participants were also patients of record in private practices and, presumably, had ongoing personal relationships with the providers. Therefore, it is likely that compliance was much better in this study than in the university-based original UCSF-CAMBRA study, in which the primary providers were students in the predoctoral clinic and the patients' compliance may have been poor.

As a plausible consequence of using saliva-enhancing mints and other potentially beneficial products in the control group in the present study, newly developed disease indicators (ongoing caries measures, as described above) decreased for both the intervention and control treatment groups. Nonetheless, the percentage of newly developed disease indicators for participants in the intervention group was lower than for those in the control group. Fewer newly developed disease indicators unmistakably establish a reduced manifestation of the caries disease, which is expressed by radiographically observed cavities into dentin, proximal enamel lesions, restorations due to caries in the last year and active white spot lesions (**FIGURE 7**). Only 30–35 percent of intervention group patients and 50–55 percent in the control group had new caries indicators at 18 to 24 months, whereas in the original CAMBRA study this number was about 55–60 percent in the intervention group and about 70–75 percent in the control group. Recorded disease indicators strongly determine the caries risk level of the patient. Consequently, the monitored reduction in numbers of participants with high caries risk parallels the declined percentage of newly developed disease indicators.

In contrast to the original UCSF-CAMBRA study, the CAMBRA-PBRN not only enrolled high-caries-risk patients but also studied patients at moderate or low caries risk. The hypothesis was that provision of

chemical therapy, including OTC fluoride rinse and xylitol products to moderate-risk patients would prevent increases to high-risk status over time. However, at baseline, few patients (5.7 percent of the total sample) were classified at moderate risk, and thus, there were insufficient numbers to allow assessment as a separate category. Among initially low-risk patients, as expected, only a small percentage showed an increased caries risk over time. This finding provides evidence that the initial low-risk assignment was correct. The small number with an increase in caries risk level at 24 months might have resulted from changes in participant behaviors or other risk or protective factors. At the 18-month visit, a statistically significant difference between groups was observed despite the fact that both intervention and control low-risk patients received the same prevention study products (1,100 ppm F toothpaste).

All of the above discussion points are based upon the observed data for study participants who returned for further visits and examinations. As in all studies, as the study progressed some participants did not return for further examination or only returned for some but not all visits. It is interesting to speculate that all of the no-show patients did not return because they were no longer at high risk and no longer felt they needed to seek dental care.

Conclusion

Thirty dentists as potential participants in a CAMBRA-PBRN trial were trained and calibrated successfully in DMFS and ICDAS scoring. The interexaminer reliability to a gold standard was high. The high interexaminer reliability showed that dentists who work in their own primarily nonresearch practices can be successfully trained and calibrated in data collection, based on specific guidelines created to anticipate potential research-study scenarios. However, separate reliability for assessment of noncavitated lesions, as in other studies, was lower.

In this CAMBRA-PBRN study with clinical practices outside of a university setting, it was demonstrated that the principles and philosophy of CAMBRA could be successfully implemented into dental practice with dramatic reductions in caries risk and in the development of new caries clinical indicators. Twenty dentists of the network successfully completed the two-year CAMBRA trial. The randomized, controlled, parallel-arm, double-blind clinical trial with individual-level CRA of 460 patients to standard of care as control versus active CAMBRA treatment as intervention demonstrated that caries risk levels, as well as caries disease indicators, were significantly reduced in the CAMBRA intervention group compared to the controls at all recall time points.[46] ■

ACKNOWLEDGMENT

This study is a principal investigator-initiated study and was funded in part by PacifiCare/UnitedHealthcare, DentaQuest and the California Dental Association through the University of California, San Francisco, Contracts & Grants Division. The authors acknowledge Proctor & Gamble, 3M ESPE and Epic for providing products for the participants at no cost or reduced cost. NIH-NCATS (grant KL2TR001870) supported B.W.C. The authors thank Planet DDS for adjusting the patient-charting program to their needs. The authors are extremely thankful to the following dentists and their staff who supported and performed the CAMBRA-PBRN trial in their practices: Drs. Pam Alston, Lawrence Bartlett, Susan Caliri, Marianela Carter, Tamara Clauson, Elizabeth Demichelis, Zarin Ferdowsi, Jan Gabus, Theresa Hall, Ted Hochstein, Nate Kaufman, Gordon Lai, Vince Lim, Ellen Pacleb, Curtis Raff, Andrew Rowe, Gayatri Sakhrani, Allen Sio, Norma Solarz and Cathrine Steinborn. CAMBRA is a registered trademark of the University of California, San Francisco.

REFERENCES

1. Kassebaum NJ, Bernabé E, Dahiya M, Bhandari B, Murray CJL, Marcenes W. Global Burden of Untreated Caries: A Systematic Review and Metaregression. *J Dent Res* 2015;94(5):650–658.
2. Berkowitz RJ. Mutans streptococci: Acquisition and transmission. *Pediatr Dent* Mar–Apr 2006;28(2):106–109; discussion 192–108.
3. Marsh PD. In Sickness and in Health — What Does the Oral Microbiome Mean to Us? An Ecological Perspective. *Adv Dent Res* Feb 2018;29(1):60–65.
4. Featherstone JD, White JM, Hoover CI, et al. A randomized clinical trial of anticaries therapies targeted according to risk assessment (caries management by risk assessment). *Caries Res* 2012;46(2):118–129.
5. Brantley CF, Bader JD, Shugars DA, Nesbit SP. Does the cycle of rerestoration lead to larger restorations? *J Am Dent Assoc* Oct 1995;126(10):1407–1413.
6. Featherstone JDB, Roth JR. Cariology in the new world order: Moving from restoration toward prevention. *J Calif Dent Assoc* 2003;31(2):123–124.
7. Featherstone JD. The caries balance: Contributing factors and early detection. *J Calif Dent Assoc* Feb 2003;31(2):129–133.
8. Anderson MH, Bales DJ, Omnell KA. Modern management of dental caries: The cutting edge is not the dental bur. *J Am Dent Assoc* Jun 1993;124(6):36–44.
9. Loe H. Changing paradigms in restorative dentistry. *J Am Coll Dent* Fall 1995;62(3):31–36.
10. Featherstone JD. The caries balance: The basis for caries management by risk assessment. *Oral Health Prev Dent* 2004;2 Suppl 1:259–264.
11. Vidnes-Kopperud S, Tveit AB, Espelid I. Changes in the treatment concept for approximal caries from 1983 to 2009 in Norway. *Caries Res* 2011;45(2):113–120.
12. Rechmann P, Domejean S, Rechmann BM, Kinsel R, Featherstone JD. Approximal and occlusal caries lesions: Restorative treatment decisions by California dentists. *J Am Dent Assoc* Feb 9 2016;147(5):328–338.
13. Mertz-Fairhurst EJ, Curtis JW Jr., Ergle JW, Rueggeberg FA, Adair SM. Ultraconservative and cariostatic sealed restorations: Results at year 10. *J Am Dent Assoc* Jan 1998;129(1):55–66.
14. Walsh LJ, Brostek AM. Minimum intervention dentistry principles and objectives. *Aust Dent J* Jun 2013;58 Suppl 1:3–16.
15. Tassery H, Levallois B, Terrer E, et al. Use of new minimum intervention dentistry technologies in caries management. *Aust Dent J* Jun 2013;58 Suppl 1:40–59.
16. Domejean S, Leger S, Maltrait M, Espelid I, Tveit AB, Tubert-Jeannin S. Changes in Occlusal Caries Lesion Management in France from 2002 to 2012: A Persistent Gap Between Evidence and Clinical Practice. *Caries Res* Jun 24 2015;49(4):408–416.
17. Young DA, Featherstone JD, Roth JR. Curing the silent epidemic: Caries management in the 21st century and beyond. *J Calif Dent Assoc* Oct 2007;35(10):681–685.
18. Young DA, Featherstone JD, Roth JR, et al. Caries management by risk assessment: Implementation guidelines. *J Calif Dent Assoc* Nov 2007;35(11):799–805.
19. Jenson L, Budenz AW, Featherstone JD, Ramos-Gomez FJ, Spolsky VW, Young DA. Clinical protocols for caries

management by risk assessment. *J Calif Dent Assoc* Oct 2007;35(10):714–723.
20. Domejean-Orliaguet S, Gansky SA, Featherstone JD. Caries risk assessment in an educational environment. *J Dent Educ* Dec 2006;70(12):1346–1354.
21. Featherstone JDB, Gansky SA, Hoover CI, et al. Chlorhexidine and fluoride therapy reduces caries risk. *J Dent Res* 2005;84 (Spec Iss A, abstract 0023).
22. Hoover CI, Weintraub JA, Gansky SA, White JM, Wilson RS, Featherstone JDB. Effect of a caries management regimen on cariogenic bacterial population. *J Dent Res* 2004;83 (Spec Iss A, abstract 0779).
23. Ismail AI, Pitts NB, Tellez M, et al. The International Caries Classification and Management System (ICCMS) an Example of a Caries Management Pathway. *BMC Oral Health* 2015;15 Suppl 1:S9.
24. Domejean S, White JM, Featherstone JD. Validation of the CDA CAMBRA caries risk assessment – a six-year retrospective study. *J Calif Dent Assoc* Oct 2011;39(10):709–715.
25. Chaffee BW, Cheng J, Featherstone JD. Baseline caries risk assessment as a predictor of caries incidence. *J Dent* May 2015;43(5):518–524.
26. Chaffee BW, Cheng J, Featherstone JD. Nonoperative anticaries agents and dental caries increment among adults at high caries risk: A retrospective cohort study. *BMC Oral Health* 2015;15(1):111.
27. Makhija SK, Gilbert GH, Rindal DB, et al. Dentists in practice-based research networks have much in common with dentists at large: Evidence from the Dental Practice-Based Research Network. *Gen Dent* May–Jun 2009;57(3):270–275.
28. Mold JW, Peterson KA. Primary care practice-based research networks: Working at the interface between research and quality improvement. *Ann Fam Med* May–Jun 2005;3 Suppl 1:S12–20.
29. Lenfant C. Shattuck lecture – clinical research to clinical practice – lost in translation? *N Engl J Med* Aug 28 2003;349(9):868–874.
30. Nelson S, Eggertsson H, Powell B, et al. Dental examiners consistency in applying the ICDAS criteria for a caries prevention community trial. *Community Dent Health* Sep 2011;28(3):238–242.
31. Klein H, Palmer CE, Knutson JW. Studies on Dental Caries. I. Dental Status and Dental Needs of Elementary School Children. *Pub Health Rep* 1938;53(19):751–765.
32. World-Health-Organization. Oral Health Surveys: Basic Methods – 5th ed. World Health Organization; 2013.
33. Baelum V, Machiulskiene V, Nyvad B, Richards A, Vaeth M. Application of survival analysis to carious lesion transitions in intervention trials. *Community Dent Oral Epidemiol* Aug 2003;31(4):252–260.
34. Sbaraini A, Evans RW. Caries risk reduction in patients attending a caries management clinic. *Aust Dent J* Dec 2008;53(4):340–348.
35. Ismail AI, Sohn W, Tellez M, et al. The International Caries Detection and Assessment System (ICDAS): An integrated system for measuring dental caries. *Community Dent Oral Epidemiol* Jun 2007;35(3):170–178.
36. ICDAS. Rationale and Evidence for the International Caries Detection and Assessment System (ICDAS II) International Caries Detection and Assessment System (ICDAS) Coordinating Committee. 2005 2005/2012.
37. Pitts N. "ICDAS" – an international system for caries detection and assessment being developed to facilitate caries epidemiology, research and appropriate clinical management. *Community Dent Health* 2004;21(3):193.
38. Rechmann P, Jue B, Santo W, Rechmann BMT, Featherstone JDB. Calibration of dentists for Caries Management by Risk Assessment Research in a Practice Based Research Network – CAMBRA PBRN. *BMC Oral Health* Jan 4 2018;18(1):2.
39. Thompson VP, Schenkel AB, Penugonda B, et al. A pilot study of dentists' assessment of caries detection and staging systems applied to early caries: PEARL Network findings. *Gen Dent* May–Jun 2016;64(3):20–27.
40. Braga MM, Oliveira LB, Bonini GA, Bonecker M, Mendes FM. Feasibility of the International Caries Detection and Assessment System (ICDAS-II) in epidemiological surveys and comparability with standard World Health Organization criteria. *Caries Res* 2009;43(4):245–249.
41. Rechmann P, Featherstone JD. Quality assurance study of caries risk assessment performance by clinical faculty members in a school of dentistry. *J Dent Educ* Sep 2014;78(9):1331–1338.
42. Goolsby SP, Young DA, Chiang HK, Carrico CK, Jackson LV, Rechmann P. The Effects of Faculty Calibration on Caries Risk Assessment and Quality Assurance. *J Dent Educ* Nov 2016;80(11):1294–1300.
43. Young DA, Fa BA, Rogers N, Rechmann P. The Effect of Calibration on Caries Risk Assessment Performance by Students and Clinical Faculty. *J Dent Educ* 2017; in press.
44. Featherstone JD, Adair SM, Anderson MH, et al. Caries management by risk assessment: Consensus statement, April 2002. *J Calif Dent Assoc* Mar 2003;31(3):257–269.
45. Featherstone JD, Domejean-Orliaguet S, Jenson L, Wolff M, Young DA. Caries risk assessment in practice for age 6 through adult. *J Calif Dent Assoc* Oct 2007;35(10):703–707, 710–703.
46. Rechmann P, Chaffee BW, Rechmann BMT, Featherstone JDB. Changes in Caries Risk in a Practice-Based Randomized Controlled Trial. *Adv Dent Res* Feb 2018;29(1):15–a23.

THE CORRESPONDING AUTHOR, Peter Rechmann, DMD, PhD, can be reached at Peter.Rechmann@ucsf.edu.

Caries Management by Risk Assessment (CAMBRA)*: An Update for Use in Clinical Practice for Patients Aged 6 Through Adult

John D.B. Featherstone, MSc, PhD; Pamela Alston, DDS, MPP; Benjamin W. Chaffee, DDS, MPH, PhD; and Peter Rechmann, DMD, PhD

ABSTRACT A system for caries management by risk assessment (CAMBRA) was published in 2007. This paper provides a practical evidence-based update for the clinician to use in practice for patients aged 6 through adult. Use of this updated CAMBRA tool allows preparation of a risk-based treatment plan that combines chemical therapy (fluoride, with or without antibacterial) with necessary restorative treatment for a minimally invasive successful outcome. Fluoride therapy must be supplemented by antibacterial therapy in high- and extreme-caries-risk patients.

AUTHORS

John D.B. Featherstone, MSc, PhD, is dean emeritus and professor emeritus at the University of California, San Francisco, School of Dentistry. His 44 years of research include caries prevention and management. He has received numerous national and international awards and has published more than 300 papers and book chapters.
Conflict of Interest Disclosure: None reported.

Pamela Alston, DDS, MPP, is dental director at Eastmont Wellness Center, one of Alameda Health System's federally qualified health center delivery sites. She is faculty advisor to the UCSF Student National Dental Association.
Conflict of Interest Disclosure: None reported.

Benjamin W. Chaffee, DDS, MPH, PhD, is assistant professor of oral epidemiology and dental public health at the University of California, San Francisco, School of Dentistry. Research interests include tobacco-related behaviors, caries management and oral health disparities.
Conflict of Interest Disclosure: None reported.

Peter Rechmann, DMD, PhD, is a professor at the University of California, San Francisco, School of Dentistry and the director of the clinical sciences research group. He has been involved in clinical research for more than 35 years and has published more than 140 papers and book chapters.
Conflict of Interest Disclosure: None reported.

*CAMBRA is a registered trademark of the University of California, San Francisco

Dental caries continues to be a major problem for patients of all ages. Billions of dollars are spent annually in the U.S. on restorative treatment of dental caries. Placing restorations can restore tooth form and function but does not affect the risk factors that caused the disease, such as a cariogenic diet, insufficient saliva or high levels of cariogenic bacteria in the rest of the mouth.[1] Nor does it change the protective factors. Therefore, successful management of dental caries requires management of the disease with chemical therapy and behavior change, in addition to minimally invasive restorative work. Assessment of the level of risk for future occurrence of dental caries

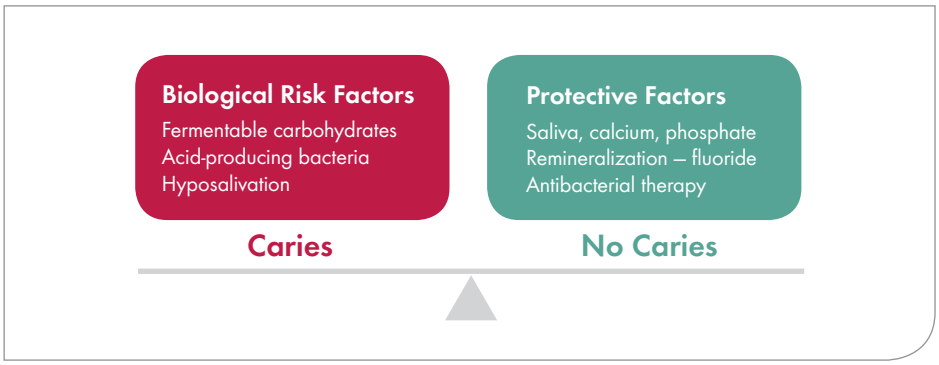


FIGURE 1. The caries balance showing the balance between biological caries risk factors (pathological factors) and protective factors. The balance can either be toward progression or reversal of the disease. Updated from Featherstone, 1999.[13] Each component is described in the text. Antibacterial agents may include chlorhexidine, silver diamine fluoride, hypochlorite (bleach) or new agents currently in development.

lesions is very important as the first step in managing dental caries. The risk level determines the personalized caries management approach for each patient. The procedure for determining caries risk status is described in practical terms below, together with appropriate caries management approaches including chemical therapy. While the caries risk assessment (CRA) form used in this paper has been further simplified based on available evidence, further discussion on this topic can be found elsewhere.[2]

For decades there have been numerous attempts to provide methodology to predict future dental caries or to assess caries risk and to manage the disease.[3–6] There are many publications related to these topics. It is not the aim of this paper to review these published works. The purpose of this paper is to provide an update and practical guidelines for dental practitioners for a CRA and caries management system that has been developed in California for patients aged 6 through adult, originally published in 2007[7,8] but utilized for more than 15 years in the teaching clinics of the University of California, San Francisco (UCSF), School of Dentistry.[9] The procedures and philosophy are known as "caries management by risk assessment" and abbreviated to CAMBRA. This paper also briefly summarizes the science behind the methodology of CAMBRA and the outcomes of 15 years of clinical application in thousands of patients.

The Science Behind Caries Risk Assessment and Caries Management

There are hundreds of papers that have contributed to our understanding of the overall mechanism of dental caries and the roles of fluoride and other agents in the management of the disease. Based upon decades of research on dental caries by many investigators, we proposed the "caries balance" as a clinically oriented way of understanding the difference between progression or reversal of caries in the mouth.[10–13] In summary, dental caries is demineralization of tooth mineral caused by acid generated when cariogenic bacteria in the plaque (biofilm) on the teeth metabolize fermentable carbohydrates. The demineralization can be inhibited by salivary components, antibacterial agents and fluoride or reversed by remineralization that requires calcium, phosphate and fluoride. The progression or reversal of dental caries is driven by the "caries balance" (**FIGURE 1**), namely the balance between the biological caries risk factors (pathological factors) [primarily: 1) cariogenic (acid-producing) bacteria, 2) fermentable carbohydrates and 3) salivary dysfunction] and protective factors [primarily: 1) sufficient saliva, 2) remineralization that requires calcium, phosphate and fluoride and 3) antibacterial agents]. Possible antibacterial agents include chlorhexidine, silver diamine fluoride (SDF), hypochlorite (bleach) and others currently in development. See following sections for further detail.

Caries Risk Assessment – Practical Stepwise Guidelines

The assessment of caries risk for each individual patient is essential as the basis for the management of dental caries. Caries risk is the likelihood of the patient having new caries lesions (white spots, cavities, etc.) in the near future. There are many CRA forms and procedures in the recent literature and some are commercially available. Two such systems have been extensively studied in long-term patient-outcomes research. One is the Cariogram system from Sweden[14] and the other is the CAMBRA system that was developed at the University of California, San Francisco, in conjunction with several other universities and the California Dental Association.[7–9,15] The CAMBRA system has been shown to be highly predictive of future caries in three different studies, featuring thousands of patients, for the group aged 6 years through adult and most recently for the group aged 0 to 5 years.[9,16–18] An electronic version of the CAMBRA CRA procedure is expected to be available in the near future.

The following step-by-step outline guide is for use of the CAMBRA system with the group aged 6 years through adult. Details are given later in this paper. The CAMBRA system identifies four risk levels, namely low, moderate, high and extreme. CRA takes place as part of the regular comprehensive oral exam in the following sequence, leading to formulating

an individualized caries management treatment plan that includes chemical therapy. Here are the steps in the process:

1. Take dental and medical history.
2. Conduct clinical examination.
3. Detect caries lesions early enough to reverse or prevent progression.
4. Assess and document the caries risk as low, moderate, high or extreme utilizing data from steps 1, 2 and 3 and a short list of questions listed in the CRA form (**TABLE 1**).
5. Produce and document a treatment plan that includes chemical therapy appropriate to the caries risk level.
6. Prescribe and/or provide chemical therapy for the patient that includes fluoride with or without antibacterial therapy based upon the caries risk level.
7. Use minimally invasive restorative procedures to conserve tooth structure and function.
8. Recall and review at intervals appropriate to the caries risk status.
9. Reassess and document caries risk level at recall and modify the treatment plan as necessary.

The first four steps of the process comprise the CRA, which identifies clinical status, pathological factors and protective factors to provide an individualized, overall portrait of caries risk (**TABLE 1**). In the following steps, that risk assessment, in turn, informs the development and implementation of a personalized caries management plan. Hence, CAMBRA is a two-phase process involving both CRA and management of caries as a biologically determined, clinical disease. Steps 1, 2 and 3 are familiar elements of any conventional oral examination and form the basis of the CRA. Steps 2 and 3 provide a list of what are called "disease indicators," which are simply clinical signs of the presence of caries, most likely ongoing over time.

Step 4 uses a few simple questions (as listed in the CRA form in **TABLE 1**) to attempt to determine the cause of the ongoing disease or to determine whether it is under control. Only those factors that have been shown to be statistically significantly related to ongoing caries risk or reversal are included here.[18] **TABLE 1** is a ready-to-use CRA form that provides a visual summary of all three categories. Instructions for its use and definitions of terms follow here and are briefly summarized in the second page of the form (**FIGURE 2**).

The CAMBRA system has been shown to be highly predictive of future caries in three different studies, featuring thousands of patients.

Disease Indicators

Disease indicators are these clinically observed results of previous and/or ongoing dental caries destruction of the tooth mineral:

a. Observed cavitation or radiographic evidence of progression into the dentin.
b. White spot lesions (that are new or active) on smooth surfaces.
c. Radiographic evidence of noncavitated demineralization into the enamel (usually by bitewing radiographs).
d. Existing restorations placed due to caries in the last three years for a new patient or in the last year for a patient of record. A new patient becomes a patient of record after the first visit and necessary restorations are completed, and from then on the one-year rule applies for any new restorations.

For a new-patient visit, one or more of these disease indicators signals at least "high caries risk." For a patient of record at a follow-up visit, any new appearance of a disease indicator signals at least "high caries risk." If hyposalivation is present, in addition, this signals "extreme risk."

Biological and Environmental Risk Factors (Pathological Factors)

The following are biological and environmental risk factors that have been shown to be statistically related to caries risk:[9,18]

a. Heavy plaque on the teeth. This simple measure, as observed by the clinician, has been shown in our clinical outcomes studies in thousands of patients to be a strong indicator of cariogenic bacterial activity and is strongly related to ongoing caries.[9,17–19] Note: At the time of writing, there is no validated chairside test commercially available for measuring cariogenic bacterial levels. Therefore, cariogenic bacteria counts have been eliminated from the CRA form in this revised version, although a placeholder has been retained in **TABLE 1** to allow for a quantitative bacteria test to be added back at a later date when an evidence-based test becomes available.
b. Frequent snacking on fermentable carbohydrates, at least three times daily outside of meal times.
c. Use of medications that induce hyposalivation. Xerostomia is a side effect of some of the most commonly prescribed medications and risk of dry mouth increases with the number of medications prescribed.[20]

TABLE 1

Updated CAMBRA* Caries Risk Assessment Form for Patients Aged 6 through Adult (January 2019) (Refer to Figure 2 for details and instructions for use; available in its original form as a patient download at cda.org/CAMBRA1 and on page 38.)

Caries risk component	Column 1	Column 2	Column 3
Disease indicators	Check if yes		
1. New cavities or lesion(s) into dentin (radiographically)			
2. New white spot lesions on smooth surfaces			
3. New noncavitated lesion(s) in enamel (radiographically)			
4. Existing restorations in last three years (new patient) or the last year (patient of record)			
Biological or environmental risk factors		Check if yes	
1. Cariogenic bacteria quantity – **not currently available**			
2. Heavy plaque on the teeth			
3. Frequent snacking (> 3 times daily)			
4. Hyposalivatory medications			
5. **Reduced salivary function (measured low-flow rate)****			
6. Deep pits and fissures			
7. Recreational drug use			
8. Exposed tooth roots			
9. Orthodontic appliances			
Protective factors			Check if yes
1. Fluoridated water			
2. F toothpaste once a day			
3. F toothpaste 2X daily or more			
4. 5,000 ppm F toothpaste			
5. F varnish last six months			
6. 0.05% sodium fluoride mouthrinse daily			
7. 0.12% chlorhexidine gluconate mouthrinse daily seven days monthly			
8. Normal salivary function			
Final Score: Yes in Column 1: Indicates high or extreme risk Yes in columns 2 and 3: Consider the caries balance **Hyposalivation plus high-risk factors = extreme risk	Column 1 total	Column 2 total	Column 3 total

Final overall caries risk assessment category **Extreme ❒ High ❒ Moderate ❒ Low ❒**

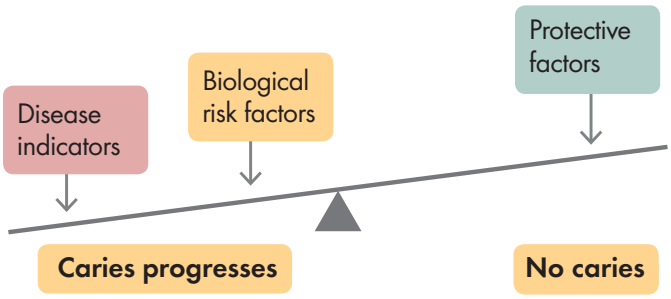
***CAMBRA is a registered trademark of the University of California, San Francisco**

d. Reduced salivary function (low flow rate) by observation (dry mouth appearance and symptoms) or by measurement (stimulated flow rate less than 0.5 ml/minute) — hyposalivation.
e. Deep pits and fissures.
f. Daily or regular use of recreational drugs.
g. Exposed tooth roots.
h. Orthodontic appliances.

In the risk-assessment procedure, any items on this list with a positive response are marked with a yes (**TABLE 1**) in the appropriate column. Each yes adds to the risk level. Items a and b can be modified by behavioral management. A yes to items c and d will normally indicate extreme risk if other risk factors and disease indicators suggest at least high risk. Deep pits and fissures suggest the use of preventive sealants (depending on the age and risk status of the patient). Item f, most likely, indicates hyposalivation, depending on the drugs used. "Meth mouth" is an extreme-caries-risk situation. Older people almost all have exposed tooth roots, indicating more attention is needed to fluoride and other preventive measures. Orthodontic appliances, such as brackets, automatically place the patient at least into moderate risk. Orthodontic appliances lead to preferential growth of cariogenic bacteria during the time of the orthodontic treatment.[21]

Determining the caries risk as low, moderate, high or extreme

Add up the number of "yes" checks for each of the disease indicators (Column 1) and risk factors (Column 2). Offset this total by the total number of "yes" checks for protective factors (Column 3). Use these numbers to determine whether the patient has a higher risk-factor score than a protective-factor score or vice versa. Use the caries balance to visualize the overall result and determine the risk level:



This enables a determination of low, moderate or high risk determined by the balance between disease indicators/risk factors and protective factors. The "yes" indications are also used to modify behavior or determine additional therapy.

In addition to counting the "yes" checks as described above, the following three modifiers apply:

1. High and extreme risk. One or more disease indicators signals at least high risk. If there is also hyposalivation, the patient is at extreme risk. Even if there are no positive disease indicators the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Think of the caries balance: Visualize the balance diagram as illustrated above.

2. Low risk. If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk. Usually this is obvious.

3. Moderate risk. If the patient is not obviously at high or extreme risk and there is doubt about low risk, then the patient should be allocated to moderate risk and followed carefully, with additional chemical therapy added. An example would be a patient who had a root canal as a result of caries four years ago and has no new clinical caries lesions, but has exposed tooth roots and only uses a fluoride toothpaste once a day.

FIGURE 2. Instructions for using the caries risk assessment form. (Available in its original form as a patient download at cda.org/CAMBRA1 and on page 39.)

Protective Factors

Protective factors are environmental factors or chemical therapy that helps to swing the caries balance to caries prevention or reversal. The most important factors that are proven effective are:

a. Lives, goes to school or works in a fluoridated drinking water area.
b. Uses a fluoride toothpaste once daily.
c. Uses a fluoride toothpaste at least twice daily. (It is well established that twice daily provides considerable added benefit. If the patient provides a yes to question c, a yes should be marked to question b.)
d. Uses a high-concentration prescription (5,000 ppm F) fluoride toothpaste twice daily.
e. Has had fluoride varnish applied in the last six months.
f. Uses 0.05% sodium fluoride mouthrinse daily.
g. Uses 0.12% chlorhexidine gluconate mouthrinse daily for one week each month as prescribed for caries control or other proven antibacterial treatment.[1]
h. Has normal adequate salivary flow and function by inspection or measurement.

Each of these items with a positive response receives a "yes" score.

Note: Xylitol use is no longer listed as a protective factor in this revised CRA version as the evidence is limited.[22] For patients with high-frequency carbohydrate consumption, xylitol gum or lozenges can be considered as substitutes for fermentable carbohydrates.

Determining the Caries Risk as Low, Moderate, High or Extreme

Add the number of "yes" checks for each of the risk-factor and protective-factor columns. Use these numbers to determine whether the patient has a higher risk-factor score than a protective-factor score or vice versa. This enables a determination of low, moderate or high risk determined by the balance between risk factors and protective factors. The yes indications are also used to modify behavior or determine additional therapy (see below). The use of a modified caries balance (**FIGURE 2**) to visualize the caries risk and the contributions of disease indicators, risk factors and protective factors will be helpful.

- High and extreme risk. One or more disease indicators signals at least high risk. If there is also hyposalivation, the patient is at extreme risk. Even if there are no positive disease indicators, the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Think of the caries balance: Visualize a scale (**FIGURES 1** and **2**).

TABLE 2

Caries Self-Management Menu of Options (See below for patient handout download option.)

Protective factors	Use an antibacterial mouthrinse/ fluoride mouthwash	When possible, drink fluoridated tap water or fluoridated bottled water	2 tsp. baking soda in 8 oz. water for buffering	Brush at least 2x daily with a fluoridated toothpaste
Fermentable carbohydrate changes	Reduce frequency of processed starchy snacks	Substitute xylitol-based products for fermentable carbohydrates	Reduce frequency of sugary snacks	
Sugar control options	Eliminate or reduce frequency of sugar-sweetened beverages; limit to meal time if at all	Dilute juice; exercise portion control; limit to meal time if at all	Read labels for sugar content	
Oral health lifestyle reinforcements	Daily plaque removal	Keep all oral health appointments		
Goals to go	How important it is (1–10)		How likely to accomplish it (1–10)	

Example of a pictorial check sheet used to assist patients in setting their self-management goals for caries management (courtesy of Pamela Alston, MPH, DDS). Available as a handout at cda.org/CAMBRA2 and on page 42.

- Low risk. If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk. Usually this is obvious.
- Moderate risk. If the patient is not obviously at high or extreme risk and there is doubt about low risk, then the patient should be allocated to moderate risk and followed carefully with additional chemical therapy added. An example would be a patient who had a root canal as a result of caries four years prior and has no new clinical caries lesions but has exposed tooth roots and only uses a fluoride toothpaste once a day.

Chemical Therapy Needed According to the Caries Risk Assessment

The following guidelines have been used and proven by a practice-based clinical trial and by outcomes assessment in thousands of patients.[9,23] Chemical therapy, such as fluoride toothpaste, must be included in the treatment plan for all patients (even low risk).[24] Fluoride-containing agents are likely to be sufficient to maintain a healthy caries balance in low-risk or moderate-risk patients. Restorative work as needed will be included in conjunction with the chemical therapy. The restorative work, which is typically needed in high-risk patients, must be done according to the principles of minimally invasive dentistry.[25] The biggest issue related to success of the CAMBRA treatment is compliance with the chemical therapy, especially when it is home-use. It is essential to work with the patient through motivational interviewing and counseling so that they use the home-use regimens as prescribed or the therapy will not be effective.

Low-Caries-Risk Chemical Therapy

The guideline is to "keep it simple." Whatever the patient is doing appears to be working. If the plaque levels are low, oral hygiene looks good and the patient uses a fluoride toothpaste daily, then the recommendation is simple: "Keep doing what you are doing and use an over-the-counter fluoride toothpaste (1,000–1,450 ppm F) at least twice daily." Recall for a follow-up visit at 12-month intervals.

Moderate-Caries-Risk Chemical Therapy

The moderate-caries-risk patient needs additional therapy to keep them where they are, or better, to move them to low caries risk. Two alternatives are given, depending on the level of compliance.

- Alternative 1: Over-the-counter fluoride toothpaste twice daily plus 0.05% sodium fluoride mouthrinse daily at night. The patient should also be counseled to reduce between-meal snacking and to conscientiously follow this regimen.
- Alternative 2: Prescription high-fluoride (5,000 ppm F) toothpaste at least twice daily plus counseling on reducing between-meal snacking of fermentable carbohydrates (substituting with xylitol-containing lozenges or candies). This regimen is very simple and is recommended for those who may not comply with the toothpaste plus fluoride mouthrinse as in Alternative 1. The disadvantage is the need to prescribe the fluoride toothpaste and the additional cost. The advantage of this second alternative is the simplicity of the protocol and better likelihood of compliance.

Recall at six-month intervals for follow-up visits.

High-Caries-Risk Chemical Therapy

The high-caries-risk patient *must* have antibacterial therapy to lower the bacterial challenge. Fluoride alone, at whatever concentration and frequency, will not be enough and the caries will continue to develop. The best proven antibacterial therapy currently available is chlorhexidine mouthrinse (or gel). It is not ideal, as it is only partially effective. It was proven effective in two clinical trials provided a specific regimen is used.[1,23] New and better therapy will be available in the future. SDF has recently gained popularity and guidelines for use in young children have been published.[26] There are several systematic reviews on SDF,[27–29] but it has severe staining as a side effect and can only be used in limited settings. Hypochlorite (bleach)-based antibacterial caries rinse is also marketed, but at the time of writing there is no published clinical trial demonstrating its efficacy and there may be safety concerns for use in children. New antibacterial agents are in development, specifically for caries control, but none are currently available.

As of the time of writing, the following is the proven chemical therapy for high-caries-risk patients.[1,9] There are three components:

a. Fluoride varnish applied in the clinic at the time of the clinical visit and reapplied every four to six months (for children and adults).
b. Brushing with a prescription, high-fluoride (5,000 ppm F) toothpaste, at least twice daily, plus counseling on reducing between-meal snacking of fermentable carbohydrates.
c. Rinse for one minute once daily for one week each month with a chlorhexidine gluconate mouthrinse (0.12%).[1] This should be done at least one hour apart from the fluoride toothbrushing, preferably last thing at night before bed. The regimen is to be continued for at least a year until the disease is controlled and the risk level is lowered.

Recall at four- to six-month intervals for follow-up visits.

Extreme-Caries-Risk Chemical Therapy

The extreme-caries-risk patient *must* have antibacterial therapy to lower the bacterial challenge. Fluoride alone, at whatever concentration and frequency, will not be enough and the caries will continue to develop. The therapy is the same as for high risk (including antibacterial therapy) *plus* additional buffering.

a. Fluoride varnish applied in the clinic at the time of the clinical visit and reapplied every four to six months (for children and adults).
b. Brushing with a prescription, high-fluoride (5,000 ppm F) toothpaste, at least twice daily, plus counseling on reducing between-meal snacking of fermentable carbohydrates.
c. Rinse for one minute once daily for one week each month with 10 ml of a chlorhexidine gluconate mouthrinse (0.12%). This should be done at least one hour apart from the fluoride toothbrushing, preferably last thing at night before bed. The regimen is to be continued for at least a year, until the disease is controlled and the risk level is lowered to moderate or low.
d. Rinse ad libitum throughout the day every day with a baking soda solution made fresh daily (2 teaspoons in 8 ounces (250 ml) of water).
e. In cases that are not responding, consider adding the home use of fluoride trays with 5,000 ppm F gel for five minutes daily.

Recall at three- to four-month intervals for follow-up visits.

High- and Extreme-Caries-Risk Patients – Guiding Principles

In the case of high- and extreme-caries-risk patients, their caries progression cannot be controlled by conventional fluoride therapy and conventional restorative work alone. All clinical studies on such subjects clearly show major caries progression in spite of combined fluoride and restorative therapy. Therefore, antibacterial therapy, dietary modification, fluoride therapy and minimally invasive restorative procedures must all be used in combination to manage dental caries in high- and extreme-risk patients. In extreme-risk patients, pH control must also be added as described above. In cases where patients do not appear to be responding, additional therapy may be needed, such as home-use fluoride gel, additional antibacterial therapy such as SDF and, very importantly, additional help to assist the patient with compliance.

Implementation in a Clinical Practice Setting – Patient and Practice Commitments

Implementing the CAMBRA system delivers to dental practices a new capability to manage caries and influence patient behavior. While the CAMBRA system involves changing patients' mindsets and attitudes, it may involve changing dental team members' mindsets and attitudes as well. With training and coaching, support and encouragement, dental staff members can learn how to interview patients effectively using motivational interviewing (MI) skills and gain self-satisfaction using them. They can learn how to assist patients in setting self-management goals and achieving them. They can build on their skills in delivering oral health education tailored to patients' oral health literacy levels.

Implementing CAMBRA into practice goes smoother when the entire team is engaged, kept informed and able and encouraged to give input and feedback. Making decisions as democratically as possible helps to keep the team invested. Decisions principally involve how to incorporate CAMBRA into the workflow. CAMBRA does add time to the patient visit and this requires scheduling adjustments. Whether the additional time is significant or nominal depends upon the dental team members' communication proficiency and time-management skills. With training and experience, both improve over time.

The questions on the CRA form are asked in an open-ended fashion using MI tactics. MI is a way of creating effective dialogue with patients so patients will share genuinely their health behaviors.[30,31] Open-ended questions require more time, thought and effort for patients to answer, but they elicit helpful insights. Sometimes ambivalence to making health behavior changes surfaces. MI guides patients through their ambivalence. The interviewer's affirmations are designed to empower patients by helping them to recognize their intrinsic strengths. The interviewer's reflective listening allows patients to clarify misinterpretations and add more depth to their responses. Summaries by the interviewer are a way of pulling together the information gathered during the CRA in order to guide patients toward action.

The benefits of taking time to perform the CRA using MI skills are that patients are more likely to take self-responsibility and make sustainable health behavior changes when they select goals that they believe are important and achievable. Sometimes patients prefer to break goals into incremental steps; in such cases, progress is monitored at each patient encounter. While not reimbursable by payers, reporting the Current Dental Terminology (CDT) Code for motivational interviewing, D9993, can be used to document how providers are utilizing MI with patients to improve their oral health outcomes.

A prepared outline for each type of CAMBRA visit (initial, recall, treatment) and standard talking points promote visit consistency for all patients. Scripting patient education helps to keep the visit on track, but scripting must also allow for differences in patients' oral health literacy levels. A CDT code, D9994, has been added in the dental case management series to document patient education to improve oral health literacy. With attention to time management, the added visit length does not detract from overall practice productivity. When all clinical staff members are trained on the CAMBRA system, any available staff member can be deployed to perform parts of the CAMBRA component of the patient visit.

Patients are more likely to take self-responsibility and make sustainable health behavior changes when they select goals that they believe are important and achievable.

In the course of CAMBRA visits, staff will invariably encounter patients who will struggle to make changes and adhere to their caries self-management goals. With coaching, dental staff members can learn how to help patients who have low self-efficacy, that is, little confidence in their ability to make changes. YouTube videos and continuing dental education courses/webinars can assist with didactic training in coaching techniques.

Another key decision relates to how the therapeutic products will be made available to the patients. Options include writing prescriptions. If the patients will receive prescriptions, the dental staff will need to make sure the selected pharmacy actually stocks the products. Another option is to dispense the products at the practice, either by selling them on a retail basis or on a fee basis using CDT code D9630. The option to make the products available gratis, although very generous, does not necessarily lead to a commitment by the patients to use them. Even if the practice does not want to charge full price, a nominal fee reinforces the notion to the patient that the products have value. If the CAMBRA therapeutics are dispensed at the practice, dental staff will need to find the time and space to maintain the inventory and follow rules for dispensing the prescription drugs.

Taking care to tailor the delivery of information to patients' oral health literacy levels improves patient understanding. A concise written summary of patients' self-management goals is helpful for postvisit recall. **TABLE 2** is an example of a check sheet that can be used to assist patients to determine their specific goals.

Although the entire dental team is involved, dental practices may benefit from having a CAMBRA champion helping to drive the implementation process. The CAMBRA champion may be a dentist, dental assistant, dental hygienist or dental care coordinator. The CAMBRA champion will identify resources, such as CAMBRA webinars, YouTube videos and continuing dental education courses, arrange lunch-and-learn meetings, speak to dental supply representatives about new products, function as a troubleshooter and keep the team motivated. It behooves

the CAMBRA champion to take the time to check in with staff during staff meetings and informally. The CAMBRA champion should stay sufficiently attentive to the clinic environment to identify opportunities and barriers proactively to support long-term sustainability of the CAMBRA system in the practice.

When patients understand caries as a chronic disease and adhere to their personalized caries self-management plans, the behavioral changes they make are likely to be more sustainable. They are more motivated to keep their appointments and complete their treatment plans. They don't want to face recare due to failure to manage the aspects of caries disease that are within their control. The reward for staff is satisfaction in successfully providing high-quality, evidence-based, patient-focused successful dental care.

Future Directions in Caries Management and Risk Assessment

Risk-based noninvasive caries management, as embraced in CAMBRA, effectively and significantly lowers the occurrence of new caries lesions in continuing dental patients. However, CAMBRA falls short of eliminating caries risk entirely. Additional research and emerging therapies aim for future advances. For the practicing dentist, implementing up-to-date evidence-based approaches is key to providing patients with the best possible care.

CRA is strongly predictive but is not deterministic: Even with widely vetted CRA instruments, some patients who appear to be low risk will develop active disease, while not all patients who seem to be high risk are destined to have cavities. Recent developments in personalized dentistry, notably the incorporation of genetic information, promise new, precise insight into caries risk but may be many years from practical application.[32] For the clinician today, no single existing method perfectly predicts future caries. The CAMBRA risk assessment and management guidelines offer a straightforward protocol, grounded in evidence, but are not intended to be prescriptive. Adding clinical reasoning and judgment allows the clinician to work collaboratively with the patient to develop a caries management plan that accounts for individual patient preferences, life situations and goals.

The effectiveness of anticaries chemical therapies will improve with better treatments to manage plaque biofilms and reduce cariogenic bacterial challenge. Classic 20th century experiments underscored the importance of lactobacilli and mutans streptococci in caries development; yet, species-specific therapies, such as an anticaries vaccine, have not proven successful.[33] Modern concepts view the oral microbiome as an interconnected and dynamic system featuring symbiotic relationships between microbiota, the host and the oral environment.[34] In this model of oral health and disease, newer therapies will seek to modify the microbiome itself (e.g., probiotics or prebiotics), modulate biofilm growth and metabolism or manipulate the oral environment (e.g., enhance saliva and/or host defenses), leading to a health-promoting balance.[34]

For the practicing dentist, implementing up-to-date evidence-based approaches is key to providing patients with the best possible care.

Many existing anticaries therapies rely on routine patient engagement in home care. Poor adherence often undermines what would be efficacious treatments, but achieving lasting behavior change at the individual patient level is notoriously difficult. Motivational interviewing in dental settings has demonstrated success as a communication strategy to promote patient behavior change.[31] Further effort is needed to enhance training and educational opportunities for integrating motivational interviewing techniques into dental practice.

In addition to helping each individual patient, dental professionals can support broader health-promoting policies in their communities. For example, dentists can be effective advocates for community water fluoridation and reducing sugar consumption. The World Health Organization guidelines for limiting sugar consumption were based partly on evidence that lower sugar intakes would dramatically reduce tooth decay worldwide.[35]

One of the barriers to adoption of the CAMBRA system, or other similar systems, is that reimbursement by insurance carriers is currently very limited for dental providers for doing CRA and the related chemical therapy and patient guidance. This situation is changing as evidence accumulates.

Conclusions

This paper provides a practical, straightforward, evidence-based update for the clinician to use in practice for patients aged 6 through adult. The evidence described here consists of a wide body of background literature, two clinical trials[1,9,23] and several clinical outcomes studies in thousands of patients.[9,16–19] Use of this updated CAMBRA tool allows

preparation of an individualized, risk-based treatment plan that combines chemical therapy (fluoride with or without an antibacterial agent) with necessary restorative treatment for a minimally invasive successful outcome. Fluoride therapy must be supplemented by antibacterial therapy in high- and extreme-caries-risk patients. ■

ACKNOWLEDGMENT

The authors gratefully acknowledge Jessica Baisley for her support in developing the Caries Self-Management Options Menu. Ms. Baisley is a fourth-year dental student at UCSF.

REFERENCES

1. Featherstone JD, White JM, Hoover CI, et al. A randomized clinical trial of anticaries therapies targeted according to risk assessment (caries management by risk assessment). *Caries Res* 2012;46(2):118–29.
2. Young DA, Goolsby SP, Rechmann P. Caries Management by Risk Assessment – Guidelines To Improve Caries Risk Level Assignments. *J Calif Dent Assoc* 2019 Jan;47(1):49–55.
3. Emilson CG, Krasse B. Support for and implications of the specific plaque hypothesis. *Scand J Dent Res* 1985;93(2):96–104.
4. Rask PI, Emilson CG, Krasse B, Sundberg H. Effect of preventive measures in 50–60-year-olds with a high risk of dental caries. *Scand J Dent Res* 1988;96(6):500–4.
5. Beck JD, Weintraub JA, Disney JA, et al. University of North Carolina Caries Risk Assessment Study: Comparisons of high-risk prediction, any-risk prediction and any-risk etiologic models. *Community Dent Oral Epidemiol* 1992;20(6):313–21.
6. Disney JA, Graves RC, Stamm JW, et al. The University of North Carolina Caries Risk Assessment study: Further developments in caries risk prediction. *Community Dent Oral Epidemiol* 1992;20(2):64–75.
7. Featherstone JD, Domejean-Orliaguet S, Jenson L, Wolff M, Young DA. Caries risk assessment in practice for age 6 through adult. *J Calif Dent Assoc* 2007;35(10):703–7, 10–3.
8. Jenson L, Budenz AW, Featherstone JD, et al. Clinical protocols for caries management by risk assessment. *J Calif Dent Assoc* 2007;35(10):714–23.
9. Featherstone JDB, Chaffee BW. The Evidence for Caries Management by Risk Assessment (CAMBRA(R)). *Adv Dent Res* 2018;29(1):9–14.
10. Featherstone JD. The caries balance: Contributing factors and early detection. *J Calif Dent Assoc* 2003;31(2):129–33.
11. Featherstone JD. The caries balance: The basis for caries management by risk assessment. *Oral Health Prev Dent* 2004;2 Suppl 1:259–64.
12. Featherstone JD. The science and practice of caries prevention. *J Am Dent Assoc* 2000;131(7):887–99.
13. Featherstone JD. Prevention and reversal of dental caries: Role of low-level fluoride. *Community Dent Oral Epidemiol* 1999;27(1):31–40.
14. Bratthall D, Hansel Petersson G. Cariogram – a multifactorial risk assessment model for a multifactorial disease. *Community Dent Oral Epidemiol* 2005;33(4):256–64.
15. Ramos-Gomez FJ, Crall J, Gansky SA, Slayton RL, Featherstone JD. Caries risk assessment appropriate for the age 1 visit (infants and toddlers). *J Calif Dent Assoc* 2007;35(10):687–702.
16. Chaffee BW, Cheng J, Featherstone JD. Baseline caries risk assessment as a predictor of caries incidence. *J Dent* 2015;43(5):518–24.
17. Chaffee BW, Featherstone JDB, Zhan L. Pediatric Caries Risk Assessment as a Predictor of Caries Outcomes. *Pediatr Dent* 2017;39(3):219–32.
18. Domejean S, White JM, Featherstone JD. Validation of the CDA CAMBRA caries risk assessment – a six-year retrospective study. *J Calif Dent Assoc* 2011;39(10):709–15.
19. Chaffee BW, Featherstone JD, Gansky SA, Cheng J, Zhan L. Caries Risk Assessment Item Importance: Risk Designation and Caries Status in Children Under Age 6. *JDR Clin Trans Res* 2016;1(2):131–42.
20. Guggenheimer J, Moore PA. Xerostomia: etiology, recognition and treatment. *J Am Dent Assoc* 2003;134(1):61–9; quiz 118–9.
21. Liu J, Bian Z, Fan M, et al. Typing of mutans streptococci by arbitrarily primed PCR in patients undergoing orthodontic treatment. *Caries Res* 2004;38(6):523–9.
22. Riley P, Moore D, Ahmed F, Sharif MO, Worthington HV. Xylitol-containing products for preventing dental caries in children and adults. *Cochrane Database Syst Rev* 2015(3):CD010743.
23. Rechmann P, Chaffee BW, Rechmann BMT, Featherstone JDB. Changes in Caries Risk in a Practice-Based Randomized Controlled Trial. *Adv Dent Res* 2018;29(1):15–23.
24. Wong MC, Clarkson J, Glenny AM, et al. Cochrane reviews on the benefits/risks of fluoride toothpastes. *J Dent Res* 2011;90(5):573–9.
25. Featherstone JD, Domejean S. Minimal intervention dentistry: Part 1. From 'compulsive' restorative dentistry to rational therapeutic strategies. *Br Dent J* 2012;213(9):441–5.
26. Crystal YO, Marghalani AA, Ureles SD, et al. Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those With Special Health Care Needs. *Pediatr Dent* 2017;39(5):135–45.
27. Crystal YO, Chaffee BW. Silver Diamine Fluoride Is Effective in Arresting Caries Lesions in Primary Teeth. *J Evid Based Dent Pract* 2018;18(2):178–80.
28. Crystal YO, Janal MN, Hamilton DS, Niederman R. Parental perceptions and acceptance of silver diamine fluoride staining. *J Am Dent Assoc* 2017;148(7):510–18 e4.
29. Crystal YO, Niederman R. Silver Diamine Fluoride Treatment Considerations in Children's Caries Management. *Pediatr Dent* 2016;38(7):466–71.
30. Harrison R, Benton T, Everson-Stewart S, Weinstein P. Effect of motivational interviewing on rates of early childhood caries: A randomized trial. *Pediatr Dent* 2007;29(1):16–22.
31. Kay EJ, Vascott D, Hocking A, Nield H. Motivational interviewing in general dental practice: A review of the evidence. *Br Dent J* 2016;221(12):785–91.
32. Opal S, Garg S, Jain J, Walia I. Genetic factors affecting dental caries risk. *Aust Dent J* 2015;60(1):2–11.
33. Fejerskov O. Changing paradigms in concepts on dental caries: Consequences for oral health care. *Caries Res* 2004;38(3):182–91.
34. Marsh PD. In Sickness and in Health –What Does the Oral Microbiome Mean to Us? An Ecological Perspective. *Adv Dent Res* 2018;29(1):60–65.
35. World Health Organization. Sugar Intake for Adults and Children: Guideline. www.who.int/nutrition/publications/guidelines/sugars_intake/en. Geneva; 2015.

THE CORRESPONDING AUTHOR, John D.B. Featherstone, MSc, PhD, can be reached at john.featherstone@ucsf.edu.

An Updated CAMBRA* Caries Risk Assessment Tool for Ages 0 to 5 Years

John D.B. Featherstone, MSc ,PhD; Yasmi O. Crystal, DMD, MSc; Benjamin W. Chaffee, DDS, MPH, PhD; Ling Zhan, DDS, PhD; Francisco J. Ramos-Gomez, DDS, MS, MPH

ABSTRACT This paper provides a practical caries risk assessment (CRA) tool for use by the clinician in caries management by risk assessment (CAMBRA) in 0- to 5-year-olds that updates the original tool published in 2007 and reviewed in 2010. This CRA incorporates evidence-based research from recent implementation studies and is the basis of a risk-based disease-management model that targets individual risk factors, as fluoride therapy alone may be insufficient for high-risk patients.

AUTHORS

John D.B. Featherstone, MSc, PhD, is dean emeritus and professor emeritus at the University of California, San Francisco. His 44 years of research has included caries prevention and management. He has received numerous national and international awards and has published more than 300 papers and book chapters.
Conflict of Interest Disclosure: None reported.

Yasmi O. Crystal, DMD, MSc, is a clinical professor of pediatric dentistry in the College of Dentistry at New York University. She is a diplomate and examiner for the American Board of Pediatric Dentistry. Dr. Crystal is the founder of Comprehensive Pediatric Dentistry in Bound Brook, N.J., has been in private practice for more than 25 years and has published numerous papers.
Conflict of Interest Disclosure: None reported.

Benjamin W. Chaffee, DDS, MPH, PhD, is assistant professor of oral epidemiology and dental public health at the University of California, San Francisco, School of Dentistry. Research interests include tobacco-related behaviors, caries management and oral health disparities.
Conflict of Interest Disclosure: None reported.

Ling Zhan, DDS, PhD, is an associate professor in the division of pediatric dentistry at the University of California, San Francisco, School of Dentistry. She is a practicing pediatric dentist with a prevention-oriented philosophy. Her research interests include clinical and translational research in caries prevention, especially on microbiological aspects of caries.
Conflict of Interest Disclosure: None reported.

Francisco J. Ramos-Gomez, DDS, MS, MPH, is a professor in the section of pediatric dentistry at the University of California, Los Angeles, School of Dentistry. He is the executive director for the UCLA Center for Children's Oral Health and the director of the Pediatric Dentistry Advanced Clinical Global Training program. He has pioneered protocols in early detection, early intervention and prevention of early childhood caries.
Conflict of Interest Disclosure: None reported.

*CAMBRA is a registered trademark of the University of California, San Francisco

Early childhood caries (ECC) in young children aged 0 to 5 years continues to be a major problem, negatively affecting the well-being, development and growth of children and their families.[1,2] Severe cases of ECC are very difficult to manage and are often accompanied by future decay.[3–5] Assessment of the risk level for future occurrence of dental caries lesions is an important first step in managing dental caries and monitoring oral health improvement over time. Successful management of ECC requires a risk-based approach to formulate an individualized treatment plan using a chronic disease management model, which aims at targeting the risk factors (biological, environmental and social) that contribute to the establishment and progression of this multifactorial disease. This individualized treatment plan should include behavior/

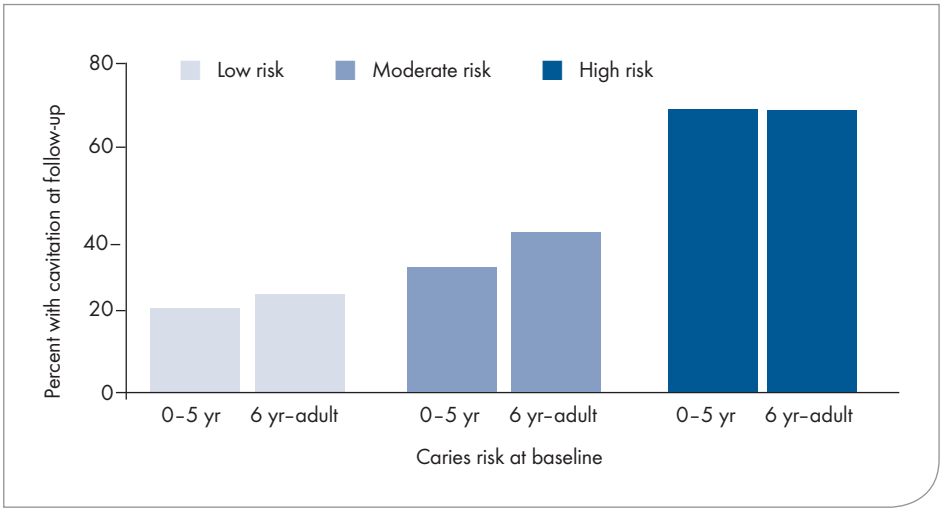


FIGURE 1. Percent cavitation 6 years to adult and 0 to 5 years. Percent of patients with cavities for each risk category (low, moderate and high) at follow-up, based upon provider-assigned caries risk at baseline. The 0-to-5-years groups are from Chaffee and co-workers.[31] The 6-years-to-adult groups are from Doméjean and co-workers.[30]

lifestyle modification (for diet improvement, less sugar intake and plaque control) and nonsurgical caries management,[6,7] in addition to appropriate restorative work. The caries risk level determines the personalized caries-management approach for each patient. Personalization further takes into consideration the behavioral barriers of the individual child (their level of cooperation for restorative treatment and home oral health care) and the social context of the child and family.

For decades, there have been numerous attempts to provide methodology to predict future dental caries, to assess caries risk and to manage the disease process.[8–11] There are many publications related to these topics, including those for children aged 0 to 5 years.[6,7,12,13] It is not the aim of the present paper to review these published works.

The purpose of this paper is to provide an updated, evidence-based, practical CRA tool for use by dental practitioners for young children aged 0 to 5 years. The procedures and philosophy known as caries management by risk assessment and abbreviated to CAMBRA were published in the *Journal of the California Dental Association* in 2007 for patients aged 6 years through adult[14,15] as well as for young children aged 0 to 5 years[16] and have been utilized for more than 15 years in the teaching clinics of the University of California, San Francisco, School of Dentistry (UCSF)[17] and at the University of California, Los Angeles, School of Dentistry pediatric dental clinic as well as several community health centers in California.[18,19]

Caries Balance as the Basis for Caries Risk Assessment

Many papers have contributed to our understanding of the overall mechanism of dental caries and the roles of fluoride and other agents in the management of the disease process.[20,21] Based upon decades of research on dental caries by many investigators, we proposed the "caries balance" as a clinically oriented way of evaluating the continuum between progression or reversal of caries in the mouth.[22–25] Driving this continuum is the balance between the biological caries risk factors (pathological factors), which are, primarily, cariogenic (acid-producing) bacteria, fermentable carbohydrates and salivary dysfunction, and protective factors, which are sufficient saliva, antibacterial agents and remineralization that requires calcium, phosphate and fluoride.

Caries Risk Assessment for Ages 0 to 5: Evidence to Date From UCSF Clinical Outcomes Studies

Assessment of caries risk for each patient is essential as the basis for the management of dental caries for patients of all ages.[26,27] Caries risk is the likelihood of the patient having new caries lesions (white spots, cavitated lesions) in the near future. The CAMBRA system has been shown to be highly predictive of future caries in three different studies, totaling more than 20,000 patients, for the age group 6 years through adult and for the age group 0 to 5 years.[17,28–30] The results of the outcomes studies in the UCSF pediatric dental clinics are summarized here as the basis for the updated CRA that follows.

An evaluation published in 2016 described the importance of individual risk-assessment items in relation to providers' CRA decisions and clinical outcomes.[31] This study assessed the relative importance of 17 CRA items, for children aged 6 months to 72 months, in dental provider's decision-making regarding CRA and in association with clinically evident dental caries at follow-up. At baseline, 3,810 children were assessed and follow-up data were available for 1,315 after four to 36 months. The CRA procedures used to assess low, moderate, high or extreme risk were as published previously by Ramos-Gomez and co-workers.[6,16,32] Extreme risk was defined as high risk plus hyposalivation. The 17 CRA indicators are listed in **TABLE 1** and can be categorized to align with the American Association of Pediatric Dentistry risk-assessment item types: biological and environmental risk factors, protective factors and clinical indicators. A provider-assigned risk category (low, moderate, high or extreme) was strongly associated with follow-up decay (**FIGURE 1**). There were very few

TABLE 1

Caries Risk Assement Components as Currently Used in the UCSF Pediatric Dental Clinics for Patients Aged 0 to 5 *

Baseline CRA item Column 1***	Column 2*** CRA items statistically significantly related to decay at follow-up P < 0.05	Column 3*** CRA items by random forest analysis independently related to decay at follow-up
Risk indicators		
Low socioeconomic status	YES	
Frequent snacking	YES	YES
Caregiver or sibling has tooth decay	YES	
Bottle used that is not water or milk**	**	
Bottle used continually		
Bottle used in bed		
Special care needs		
Inadequate saliva flow		
Salivary reducing medications	YES	
Protective items		
Community water fluoridation		
Drinks fluoridated water		
Brushes daily with fluoride toothpaste		
Fluoride varnish in past six months		
Caregiver uses xylitol		
Clinical disease indicators		
Evident tooth decay or white spots	YES	YES
Heavy dental plaque on the teeth	YES	YES
Recently placed restorations (past two years)	YES	YES

** Use of a bottle that contains fluids other than water or milk was significant in a later clinical outcomes study.[29]
***CRA items are based upon Ramos-Gomez et al.[6,7,16] Column 1 lists the 17 CRA items utilized in these clinics. Column 2 highlights the seven CRA items found statistically significantly related to decay at follow-up (n = 3,810 at baseline; n = 1,315 at follow-up) in Chaffee et al, 2016.[31] Column 3 highlights the four CRA items found independently associated with decay at follow-up by random forests analysis in the same study.[31]

extreme-risk patients (2 percent), so they were combined with high-risk patients. **FIGURE 1** also shows similar results for ages 6 through adult CAMBRA CRA for comparison.[17] Both studies showed very good assignment of caries risk by multiple providers using the CAMBRA procedures. Of the 17 CRA indicators used in children aged 0 to 5 years, seven were statistically significantly associated with decay at follow-up (**TABLE 1, COLUMN 2**). In further assessment of the data using random forest analysis, only four of those seven baseline CRA items were independently associated with follow-up decay (**TABLE 1, COLUMN 3**). Four items were evident – decay, heavy dental plaque, recent restorations and frequent snacking – with baseline evident decay being the strongest predictor.

A subsequent clinical outcomes study in the UCSF pediatric dentistry clinics examined cumulative dental treatment (restorations) over two years in children initially aged 6 months to 72 months in relation to baseline CRA indicators.[29] Of 2,188 available patients, 919 had no follow-up exam and 1,260 returned for follow-up. From those, 519 were excluded (treated under general anesthesia or sedation) and the cumulative restorative treatment of the remaining 750 treated in the conventional clinic setting was assessed in the analyses. All patients had a CRA at baseline and risk was assigned according to the published procedures, based upon the provider's judgment after evaluating the 17 CRA indicators as shown in **TABLE 1, COLUMN 1**. Of the 750 children included, at baseline, 21 percent were classified as low risk, 25 percent as moderate, 53 percent as high and 1 percent as extreme. Nearly all children received fluoride varnish (FV) at baseline. Thereafter, high-risk children were intended to receive FV every three to four months (for those who attended follow-up visits) and every six months for moderate-risk children. FV was not indicated for low-risk patients.

Risk category was associated with the cumulative mean number of treated teeth over two years, namely 0.53, 1.02 and 4.47 for low, moderate and high/extreme, respectively. Receiving any treatment was greatest for high/extreme-risk children but not statistically significantly different between low-risk and moderate-risk children. More than 50 percent of the cumulative restorative treatment performed in the high-risk group was done in the first 190 days after assessment, presumably reflecting existing treatment needs at the time of CRA, a time period in which the low- and moderate-risk groups required almost no restorative treatment. The respective increments for low-, moderate- and high/extreme-risk groups from 190 days to two years, which presumably is a better measure of new caries lesions after the initial CRA, were 0.51, 0.89 and 2.11, clearly showing a continuing need for restorations in the high/extreme-risk group in spite of fluoride preventive measures (figure 2 in Chaffee et al.[29]). As in the previous study, heavy plaque, obvious decay and recent restorations were strongly associated with subsequent decay. Caregiver/sibling decay,

low socioeconomic status and bottle use with nonmilk or nonwater were also significantly associated with subsequent decay. However, it should be noted that the use of milk in a bottle overnight and nursing on demand in the presence of cariogenic bacteria provides a prolonged acid challenge that increases the risk for caries and should be strongly discouraged.

The significant associations in the previous two studies form the basis for the updated CRA form presented here. As there was very limited data for the extreme-risk category, this updated version of the CRA will use three risk categories for 0- to 5-year-olds, namely low, moderate and high.

Caries Risk Assessment — Practical Stepwise Guidelines

The following step-by-step guide is for use of the CAMBRA system with young children aged 0 to 5 years. Details are given in the following sections. The updated 0- to 5-year-old CRA procedure (**TABLE 2**) identifies low, moderate and high risk for this age group. CRA takes place as part of the regular comprehensive or periodical oral exam in the following sequence or in a sequence that suits the workflow of each individual practice or practitioner. The CRA is the basis for formulating an individualized caries management treatment plan. Here are the steps in the process:

1. From the medical, dental and social histories reported, compile relevant data to record in the CRA form (**TABLE 2**, **COLUMNS 2** and **3**).
2. Talk to the caregiver (mother or other caregiver) to make sure all questions listed in the CRA form are answered (**TABLE 2**, **COLUMNS 2** and **3**). The discussion will include the risk factors and protective factors, leading to the subsequent clinical exam and later to a discussion of self-management goals.
3. Conduct a clinical examination in an age-appropriate way: knee to knee or with the child sitting on their own, ideally with the parent being able to be shown the findings. Start with detecting and recording presence of plaque, ideally with a visible plaque index score (VPI), and showing parents the problem areas. This answers the heavy-plaque question in **TABLE 2**, **COLUMN 2**. Follow with a toothbrush prophy to remove debris and clean surfaces for better visualization during the exam, showing parents the proper brushing technique. The use of a flosser for interdental plaque removal, when appropriate, should also be demonstrated.
4. From the intraoral examination, detect and record caries lesions from their earliest stages (white spots, which can be arrested or reversed by remineralization) to advanced caries (cavitation). From radiographical examination (if available depending on the child's age and cooperation), detect and record radiographic decay.
5. Assess and document the caries risk as low, moderate or high utilizing data from the complete CRA form with data included in Columns 1, 2 and 3 of **TABLE 2**. The procedure is further described later in this segment and in **TABLE 2**. With children aged 0 to 5 years, the questions will likely be answered prior to the clinical examination.
6. Produce and document a caries management plan that addresses all the risk factors that may contribute to the development or progression of disease for that specific patient, including lifestyle and behavior modification for caregivers and the child to achieve plaque control and diet improvements.
7. Prescribe and/or provide chemical therapy for the patient that includes fluoride, with or without antibacterial therapy, based upon the caries risk level and the age of the patient. Details are described later in this segment. Consider integrating motivational interviewing principles with caregivers and patients (when age appropriate) to set up achievable goals for home management plans.[6,7]
8. Develop a restorative treatment plan that takes into consideration age, behavior (cooperation for treatment delivery), health status and social determinants, favoring minimally invasive restorative procedures to conserve tooth structure whenever possible, restoring function and aiming at providing that patient with the means to achieve adequate plaque control.
9. Establish periodicity of recalls and review at intervals appropriate to the caries risk status to continue active surveillance of noncavitated lesions, provide in-office preventive measures and reinforce behavioral changes and adherence to

FIGURE 2A.

FIGURE 2B.

FIGURES 2. Images from two children, each of whom are at high risk of developing caries in the future. However, their clinical management would differ due to the extensive needs of the child in image **2B**.

TABLE 2

Updated CAMBRA* Caries Risk Assessment Form for Patients Aged 0 to 5 (January 2019)**
(Available in its original form as a patient download at cda.org/CAMBRA4 and on page 40.)

Caries risk component	Column 1	Column 2	Column 3
Biological or environmental risk factors*		Check if Yes**	
Frequent snacking (more than three times daily)			
Uses bottle/nonspill cup containing liquids other than water or milk			
Mother/primary caregiver or sibling has current decay or a recent history of decay (see high-risk description below)			
Family has low socioeconomic/health literacy status			
Medications that induce hyposalivation			
Protective factors**			Check if Yes**
Lives in a fluoridated drinking water area			
Drinks fluoridated water			
Uses fluoride-containing toothpaste at least two times daily – a smear for ages 0–2 years and pea sized for ages 3–6 years			
Has had fluoride varnish applied in the last six months			
Biological risk factors — clinical exam*		Check if Yes**	
Cariogenic bacteria quantity – **Not currently available**			
Heavy plaque on the teeth			
Disease indicators — clinical exam	Check if Yes**		
Evident tooth decay or white spots			
Recent restorations in last two years (new patient) or the last year (patient of record)			
Final Score:	Column 1 total	Column 2 total	Column 3 total
Yes in Column 1: Indicates high risk Yes in columns 2 and 3: Consider the caries balance			
Final overall caries risk assessment category **High ❒ Moderate ❒ Low ❒** ***CAMBRA is a registered trademark of the University of California, San Francisco			

*Biological and environmental risk factors are split into a) question items, b) clinical exam.
**Check the "yes" answers in the appropriate column. Shading indicates which column to place the appropriate "yes."

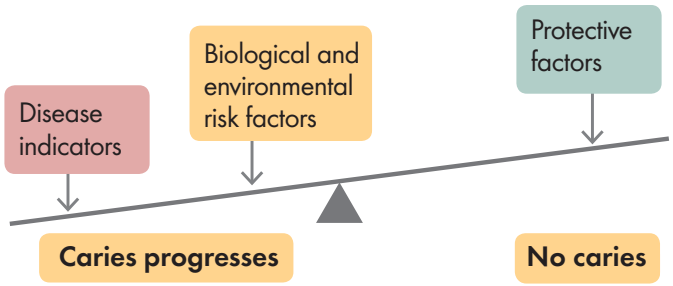
Determining the caries risk as high, moderate or low

1. High risk. If there is a "yes" in column 1 (one or both disease indicators), the patient is at high risk. Even if there are no "yes" disease indicators the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Mother or caregiver with current or recent dental decay most likely indicates high caries risk for the child. Use the "yes" checks for each of the risk factor and protective factor columns to visualize the caries balance as illustrated below. The balance clearly to the left indicates high caries risk, whereas clearly to the right the risk level is low.

2. Moderate risk. If there are no disease indicators and the risk factors and protective factors appear to be balanced, then a moderate caries risk determination is appropriate. If in doubt, move the moderate to a high classification.

3. Low risk. If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk.

Any items checked "yes" may also be used as topics to modify behavior or determine additional therapy. Use the following modified caries balance to visualize the overall result and determine the risk level:



Additional caries-related components for caregiver/patient counseling

- Frequency of use of fluoride toothpaste and amount
- Use of silver diamine fluoride in appropriate cases
- Dietary counseling to reduce frequency and amount of fermentable carbohydrates, especially sucrose, fructose (high-fructose corn syrup) and continual fruit juice (e.g., apple juice)
- Bottle used continually, bottle used in bed or nursing on demand
- Child has developmental problems/child has special care needs (CHSCN)
- Inadequate saliva flow and related medications, medical conditions or illnesses

Self-management goals (discussed and agreed with parent/caregiver)

1. _____

2. _____

FIGURE 3. Instructions for using the caries risk assessment form.

***CAMBRA is a registered trademark of the University of California, San Francisco

prescribed daily home regimes.

10. Reassess and document the caries risk level at each recall and modify the caries management plan as necessary.

Steps 1–4 comprise the CRA, which informs the development and implementation of a personalized caries management plan. Hence, CAMBRA is a two-phase process involving both CRA and management of caries as a biologically determined, clinical disease. Steps 1, 3 and 4 are familiar elements of any conventional oral examination for this age group and form the basis of the CRA. Step 2 compiles a few simple questions (as listed in the CRA form in **TABLE 2, COLUMNS 2** and **3**) to attempt to determine the cause of the ongoing disease or to determine whether it is under control. Those biological risk factors that have been shown to be statistically significantly related to ongoing caries in previous studies are included here.[29,31] **TABLE 2** is a ready-to-use CRA form that provides a visual summary of the factors that contribute to the overall caries risk assignment. Instructions for its use and definitions of terms follow here and are briefly summarized in the second page of the form (**FIGURE 3**).

Biological and Environmental Risk Factors (Pathological Factors) — TABLE 2, Column 2

Biological risk factors contribute directly to the initiation or progression of dental caries. They include an assessment of cariogenic bacteria and fermentable carbohydrates, the two required conditions for dental caries.[21–23,33] Additional factors such as frequency of ingestion of fermentable carbohydrates and salivary-reducing medications have been established as important (**TABLE 1**). The following are the risk factors utilized in the updated CRA form.

1. Frequent snacking on fermentable carbohydrates at least three times daily outside of meal times.

Frequent carbohydrate intake results in a prolonged acidic environment in the plaque that dissolves the tooth mineral and can act as a driving force to reinforce the overgrowth of cariogenic bacteria and the suppression of oral commensal (beneficial) bacteria, leading to future caries development.[34] Fermentable carbohydrates such as sucrose, fructose (high-fructose corn syrup), glucose and cooked starch are included. Fruit juice (e.g., apple juice) is an important but often overlooked source of fermentable carbohydrates among young children.

2. Use of bottle or nonspill cup containing liquids other than water or milk.

This provides a continuous ingestion of carbohydrates, such as from fruit juices, that leads to a continual acid environment in the plaque. It should be stressed that the use of milk in a bottle overnight and nursing on demand in the presence of cariogenic bacteria provide a prolonged acid challenge that increases the risk for caries and should be strongly discouraged.

3. Mother/primary caregiver or sibling has current decay or a recent history of decay.

Presence of recent decay indicates they have high levels of cariogenic bacteria, especially mutans streptococci (MS), which can be transmitted to the child. Early colonization of MS by age 3 will increase the child's risk for developing caries.[34,35] Current or recent decay in the parent or caregiver is an important indicator of potential high caries risk for the child. This becomes more important in infants with few teeth present, where signs of additional risk factors are not yet evident, and is supported by the strong correlation found in numerous studies.[36–39]

4. Family has low socioeconomic/health literacy status.

Low socioeconomic status cannot usually be changed and is not a biological contributor to the caries process. However, as a social determinant of health for many other diseases, it is one of several statistically significant factors associated with high caries risk.[29,31] Practitioners should account for a challenging family socioeconomic context in formulating a personalized caries management plan. Similarly, low health literacy is not a biological risk factor, but it is often associated with socioeconomic levels and contributes to increased risk of disease. Importantly, it is possible to educate the parent/primary caregiver regarding caries and caries prevention.

5. Use of medications that induce hyposalivation.

Hyposalivation is a side effect of some of the most commonly prescribed medications, such as those used to treat allergies, asthma, mental disorders and cancer.[40] The risk of dry mouth increases with the number of medications prescribed.

In the risk-assessment procedure, any items on this list with a positive response are marked with a "yes" (**TABLE 2, COLUMN 2**). Each yes adds to the risk level. Items 1 and 2 can be modified by behavioral management. A yes to item 3 may indicate a potentially very-high-risk patient who requires additional care and therapy.

Protective Factors — TABLE 2, Column 3

Protective factors are environmental factors or chemical therapy that help to swing the caries balance to caries prevention or reversal. The factors included in the newly proposed CRA form are:

1. Lives in a fluoridated drinking water area.

2. Drinks fluoridated water.

The beneficial effect of drinking fluoridated water is well established.

3. Uses a fluoride-containing toothpaste at least twice daily.

The beneficial effect of brushing with fluoridated toothpaste has been well established in numerous clinical trials and is a major factor in reductions in caries over recent decades.[41–44] The American Academy of Pediatric Dentistry (AAPD) recommends the use of a smear of fluoride toothpaste for ages 0 to 2 years and a pea-sized application for ages 3 to 6 years. For children aged 0 to 6 years, it is recommended that the parent/caregiver brushes the child's teeth or supervises toothbrushing twice a day. Parent-supervised toothbrushing with fluoride toothpaste at least twice daily provides considerable added benefit greater than once daily.[45,46]

4. Has had FV applied in the last six months.

The caries-reducing benefit of FV is well established, including when used in young children.[47,48]

Each of these items with a positive response receives a yes score in **TABLE 2, COLUMN 3**.

Note: Xylitol use by the caregiver is no longer listed as a protective factor in this revised CRA version as the evidence of its antimicrobial effects to achieve caries prevention is limited for adults or children.[49]

Biological Risk Factors — Clinical Exam — TABLE 2, Column 2

1. Cariogenic bacteria quantitative assessment.

There is ample evidence that cariogenic bacteria levels are strongly related to caries risk.[12,50–52] However, at the time of writing there is no validated chairside test commercially available for measuring cariogenic bacterial levels. Therefore, cariogenic bacteria counts have been eliminated from the CRA form in this revised version, although a placeholder has been retained in **TABLE 2** to allow for a quantitative bacteria test to be added back at a later date when an evidence-based test becomes available.

2. Heavy plaque on the teeth.

This simple measure, as observed by the clinician, has been shown in our clinical outcomes studies in children of all ages and in adults to be a strong indicator of cariogenic bacterial activity and it is strongly related to ongoing caries.[17,29–31] This factor may indicate a combination of items that include high levels of cariogenic bacteria, ineffective plaque removal, food accumulation and inadequate brushing with fluoride toothpaste. Gingivitis, or gums that bleed easily, can be a sign of consistent presence of heavy plaque in specific areas and a clinical risk indicator related to the presence of plaque.

In the risk-assessment procedure, any items on this list with a positive response are marked with a yes (**TABLE 2, COLUMN 2**). Each yes adds to the risk level. Item 2 can be modified by behavioral management.

Disease Indicators — Clinical Exam — TABLE 2, Column 1

This category replaces the "Clinical Indicators" category from the previous CRA form. Heavy plaque on the teeth is not an indicator of disease, but rather is a biological risk factor as described previously and likely indicates high levels of cariogenic bacteria as well as poor oral-hygiene practices. Therefore, it moves to the group of biological risk factors identified in the clinical exam.

Disease indicators are the clinically observed results of previous and/or ongoing dental caries destruction of the tooth mineral. They do not contribute to the disease; they are simply manifestations and clinical signs of the effects of dental caries at different stages. Disease indicators fit into two overall descriptions as evaluated in the outcomes assessments over several years of the original CAMBRA CRA form. They are strong indicators of ongoing disease.

1. Evident tooth decay or white spots. This descriptor includes:

a. Observed cavitation or radiographic evidence of progression into dentin.
b. White spot lesions (that are new or active) on smooth surfaces.
c. Radiographic or visual evidence of noncavitated demineralization into the enamel (usually by bitewing radiographs).

2. Existing restorations.

These are restorations that were placed due to caries in the last two years for a new patient or in the last year for a patient of record. For a new-patient visit, one or more of these disease indicators signals "high caries risk." For a patient of record at a follow-up visit, any *new* appearance of indicators 1 or 2 signals "high caries risk." If present, hyposalivation will require additional care and therapy.

Determining the Caries Risk as Low, Moderate or High

1. *High risk.* One or more disease indicators signals high risk. Even if there are no "yes" disease indicators, the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Think of the caries balance: Visualize the modified caries balance as shown in **FIGURE 3**. If the balance is clearly to the left, then the patient is at high caries risk. Mother or primary caregiver with current or recent dental decay most likely indicates high caries risk for the child.
2. *Moderate risk.* If there are no disease indicators and the risk factors and protective factors appear to be balanced, then

neither a high-risk nor a low-risk assignment is clear. In this case, a moderate determination is appropriate. If in doubt, move the moderate to a high classification.

3. *Low risk.* If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk. If the balance is clearly swung to the right, the risk level is low. When evidence-based chairside quantitative cariogenic bacteria tests become available, a high cariogenic bacterial count will push a low-caries-risk individual to the high-risk category.

The yes indications are also used to modify behavior or determine additional therapy (as follows).

Caries Management Based on Risk Assessment

CAMBRA therapies for older children and adults place special importance on chemical therapy, because placing restorations can restore tooth form and function but does not affect the risk factors that caused the disease, such as a cariogenic diet or high levels of cariogenic bacteria in the rest of the mouth.[4,53,54] The most evident antimicrobial chemical therapy in children aged 6 years and older and in adults is chlorhexidine mouth rinse.[17,53] However, use of chemotherapeutic agents in infants and toddlers requires special considerations due to toxicity/safety and behavioral acceptance issues. For this reason, in this age group, most of the recommendations within a caries management plan rely heavily on a chronic-disease management model, where different strategies, such as education about the disease process, motivational interview-style counseling (to change diet practices and plaque-control routines) and periodic evaluation of self-management goals in conjunction with chemical therapy to modify the oral pH environment, are used to target the individual risk factors that can trigger the disease process on the individual patient (frequent snacking, bottle feeding, visible plaque accumulation, etc.).[6,7,16] Several publications describe in detail this style of counseling and surveillance.[6,7,19,32,55]

When addressing oral health in high-risk groups, early intervention and strategic disease management are key. The Disease Management and Risk Assessment module used in the UCLA and UCSF pediatric dentistry curricula stresses the importance of early assessment, diagnosis and intervention as a means of oral disease prevention management.[6,7,19,32,55] Early intervention and education are the most effective ways to prevent problems that traditional infectious-disease models fail to address, such as the epidemic of ECC. The UCLA and UCSF module provides pediatric dentistry residents with a background in minimally invasive pediatric dentistry, individual oral health assessment and treatment for pregnant women, infants, children and caregivers. Central to this is the use of the CAMBRA tool, which provides a method of assessing caries risk in young children, thereby informing treatment plans, self-management goals and recall schedules.

When addressing oral health in high-risk groups, early intervention and strategic disease management are key.

In evidence-based minimally invasive dentistry, which includes the use of CAMBRA, fluoride, sealants, remineralization substances such as casein phosphopeptide, prevention of early cariogenic bacteria colonization by xylitol product use for family members with caries and acid-neutralization agents such as baking soda wiping after meals/snacks, the patient/caregiver is encouraged to assume responsibility for the level of infection and is educated, instructed and monitored in the proper control techniques. It is the child who has the disease, but it is the health professional's responsibility to provide the patient and parent/caregiver the appropriate tools to overcome it.

The following care pathways are summarized in **TABLE 3**.

Low-Caries-Risk Management Protocol

If the plaque levels are low as an indication of adequate home care and fluoride exposure has prevented signs of disease under their current dietary conditions, patients should be praised and advised to continue their daily routine. Chemical therapy indicated for infants and toddlers, namely in the form of fluoride toothpaste, must be included in the treatment plan for all patients (even low-risk patients)[41] in the appropriate amount (a smear or the size of a grain of rice for children 0 to 2 years and a pea-sized application for 3 to 6 years),[42,43] as it is likely to be sufficient to maintain a healthy caries balance in low-risk patients. Fluoride-free "training toothpaste" should not be recommended as its use has not proven to have the same therapeutic effect as full-strength fluoride toothpaste. Recalls for periodic reevaluation should be set for every six months, where their preventive home-care

TABLE 3

Summary of Care Paths for Caries Management Based on Risk for Children Aged 0 to 5 (modified from Ramos-Gomez et al., 2010[7])

Risk category	Diagnostic		Preventive interventions				Restoration
	Periodic oral exams	Radiographs	Fluoride	Diet counseling	Self-management goals	Sealants	Existing lesions
Low	6–12 mos	2–24 mos	Brush twice daily with F toothpaste¥	No	No	No	
Moderate	6 mos	6–12 mos	Brush twice daily with F toothpaste¥ optimize F intake£ FV every 6 mos	Yes	Yes	On enamel defects and pits and fissures at risk	Active surveillance for developing lesions
High	3 mos	6 mos	Brush twice daily with F toothpaste¥ optimize F intake£ FV every 3 mos	Yes	Yes	On enamel defects and pits and fissures at risk	Remineralize enamel-only lesions with FV; restoration of cavitated lesions or nonsurgical caries management with ITR or SDF as appropriate
High with extensive existing disease	monthly	6 mos	Brush three times daily with F toothpaste¥ optimize F intake£ FV every 1–3 mos Consider additional therapies for caries control*	Yes	Yes	All pits and fissures	Consider caries control prior to surgical tx; remineralize enamel-only lesions with FV; restoration of cavitated lesions or nonsurgical caries management with ITR or SDF as appropriate

¥ Smear of fluoride toothpaste for 0- to 2-year-olds, pea-size of fluoride toothpaste for 3- to 6-year-olds.
£ Recommend drinking fluoridated water (from tap or bottled), parental brushing, spit and don't rinse toothpaste.
* Wipe with baking soda/xylitol, use casein phosphopeptide – amorphous calcium phosphate (ACP/CPP) paste.
Abbreviations: FV = fluoride varnish; ITR = interim therapeutic restoration; SDF = silver diamine fluoride; mos = months.

routine should be reinforced. Low-risk patients do not benefit from in-office fluoride applications.[56,57] Radiographic examinations, if necessary (contact areas closed and not visible) and feasible (if patient's cooperation allows), should be performed at 12- to 24-month intervals as per AAPD and ADA guidelines.[58,59]

Moderate-Caries-Risk Management Plan

With no signs of caries lesions at any stage, moderate-risk children will present with several risk factors that indicate that their lifestyle routines can lead them to develop caries in the near future and that additional chemical therapy could prevent frequent acid exposure from tipping the balance to the establishment of disease. Caregivers and children (when appropriate) should be informed on the caries process and counseled on strategies to improve their individual dietary or home-care routines. Fluoride-toothpaste recommendations indicated previously should be stressed, additional forms of fluoride exposure (fluoride in drinking water) should be promoted and children at moderate risk should be recalled at six-month intervals for monitoring of adherence to the improvement of diet and home-care routines. These patients will also benefit from in-office FV applications at six-month intervals. Radiographic examinations should be performed every six to 12 months.

High-Caries-Risk Management Plan

Children with obvious signs of caries at any stage and children with several risk factors and minimal fluoride exposure are at high risk of developing more lesions in the future (**FIGURE 2**). In addition to the chemical therapy (fluoride-toothpaste recommendations and promotion of other forms of fluoride exposure as well as the use of agents that enhance remineralization and acid neutralization or inhibit MS transmission) and behavioral counseling to improve lifestyle changes as mentioned previously, patients at high risk benefit from additional in-office FV applications at three- to six-month intervals. Therefore, three- to six-month recall visits should include FV application, reinforce self-management goals to reduce specific risk factors, promote protective factors and perform active surveillance of lesions at all stages.

The caries management plan should include a restorative treatment plan that aims to limit tissue destruction, diminish sensitivity to allow adequate plaque-control measures and restore

function and form, taking into consideration the cooperation and health status of the patient as well as the family situation. Following principles of minimally invasive dentistry,[6] the choice of restorative treatment (which is typically needed in high-risk patients) could include traditional restorative treatment or nonsurgical therapies (interim therapeutic restorations with glass ionomer, caries arrest with silver diamine fluoride (SDF), etc.) after careful discussion explaining to the parents the risk and benefits of each option and trying to delay or defer more complicated and risky procedures like sedation and/or general anesthesia. The informed consent of the parent is essential following this discussion and the laying out of recommended options.

High-Risk Patients With Extensive Treatment Needs — Additional Guiding Principles

The outcomes studies described previously[29] and the results of our studies of patients aged 6 years through adult[17] show that in-office topical fluoride applications and home fluoride-toothpaste use may not be sufficient to prevent future caries in high-risk patients. A prolonged acidic environment in the plaque created by a frequent sugary/carbohydrate diet and poor oral hygiene leads to microbial dysbiosis and serves as the driving force for caries formation in children,[34,60] resulting in high caries recurrence in high-risk children.[3–5] Therefore, home-care behavior modification can be the key to caries management in children.

Children at high risk who already require extensive restorative treatment (more than four restorations, as illustrated in **FIGURE 2B**) may benefit from intensive care including protective sealants in surfaces at risk. As studies show that supervised brushing achieves much higher prevention results than brushing alone,[45,46] supervised brushing should be a major point in the counseling sessions. Brushing three times a day (after every meal) and spitting the toothpaste with no rinsing[61] are simple strategies that may maximize the protective action of fluoride in these children.

Additional possible antimicrobial regimens to consider are wiping/brushing teeth with xylitol[62–64] and/or baking soda[65–67] after feedings or meals. Xylitol is noncariogenic and baking soda is an effective acid-naturalizing agent, which can effectively neutralize the oral environment and have antiplaque and antimicrobial effects in children and adults.[65–67]

For children with numerous cavitated lesions who may need multiple visits to complete restorative care and/or may have limited cooperation for treatment, SDF therapy to achieve caries arrest and desensitization of lesions with no pulpal involvement can be followed at subsequent visits by glass ionomer interim restorations to prevent plaque accumulation and combined with FV at three-month intervals to prevent new lesions.[68–71] This combination therapy can help to delay or defer more complicated and risky procedures like sedation or treatment under general anesthesia, which is especially important for children under 3 years of age.

Conclusions

Successful management of ECC requires a risk-based approach to formulate an individualized treatment plan using a chronic disease management model, which aims at targeting the risk factors (biological, environmental and social) that contribute to the establishment and progression of this multifactorial disease. This paper provides a practical evidence-based updated CRA tool for the clinician to use in practice for young children aged 0 to 5 years. This updated CRA tool incorporates evidence from recent implementation studies to be used as the basis of such a risk-based caries management treatment plan that aims to restore oral health, as fluoride therapy alone is insufficient for high-risk patients. This approach is considered standard of care for children's oral health. ■

ACKNOWLEDGMENTS

The many people who have contributed to the development, utilization and the outcomes studies that have provided the evidence for the CAMBRA approach cited here are thanked sincerely. Thousands of patients have benefited to date. The authors would like to acknowledge their pediatric dental programs at UCSF and UCLA that are teaching these modalities to the new generation of pediatric dentists in California, across the U.S. and globally.

REFERENCES

1. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft: The human and economic cost of early childhood caries. *J Am Dent Assoc* 2009;140(6):650–7.
2. Tinanoff N, Reisine S. Update on early childhood caries since the surgeon general's report. *Acad Pediatr* 2009;9(6):396–403.
3. Amin MS, Bedard D, Gamble J. Early childhood caries: Recurrence after comprehensive dental treatment under general anesthesia. *Eur Arch Paediatr Dent* 2010;11(6):269–73.
4. Zhan L, Featherstone JD, Gansky SA, et al. Antibacterial treatment needed for severe early childhood caries. *J Public Health Dent* 2006;66(3):174–9.
5. Foster T, Perinpanayagam H, Pfaffenbach A, Certo M. Recurrence of early childhood caries after comprehensive treatment with general anesthesia and follow-up. *J Dent Child (Chic)* 2006;73(1):25–30.
6. Ramos-Gomez FJ, Crystal YO, Domejean S, Featherstone JD. Minimal intervention dentistry: Part 3. Paediatric dental care — prevention and management protocols using caries risk assessment for infants and young children. *Br Dent J* 2012;213(10):501–8.
7. Ramos-Gomez FJ, Crystal YO, Ng MW, Crall JJ, Featherstone JD. Pediatric dental care: Prevention and management protocols based on caries risk assessment. *J Calif Dent Assoc* 2010;38(10):746–61.
8. Emilson CG, Krasse B. Support for and implications of the specific plaque hypothesis. *Scand J Dent Res* 1985;93(2):96–104.
9. Rask PI, Emilson CG, Krasse B, Sundberg H. Effect of preventive measures in 50-60-year-olds with a high risk of dental caries. *Scand J Dent Res* 1988;96(6):500–4.
10. Beck JD, Weintraub JA, Disney JA, et al. University of North Carolina Caries Risk Assessment Study: Comparisons of high risk prediction, any risk prediction and any risk etiologic models. *Community Dent Oral Epidemiol* 1992;20(6):313–21.

11. Disney JA, Graves RC, Stamm JW, et al. The University of North Carolina Caries Risk Assessment study: Further developments in caries risk prediction. *Community Dent Oral Epidemiol* 1992;20(2):64–75.
12. Gao X, Di Wu I, Lo EC, et al. Validity of caries risk assessment programmes in preschool children. *J Dent* 2013;41(9):787–95.
13. Gao XL, Hsu CY, Xu Y, et al. Building caries risk assessment models for children. *J Dent Res* 2010;89(6):637–43.
14. Featherstone JD, Domejean-Orliaguet S, Jenson L, Wolff M, Young DA. Caries risk assessment in practice for age 6 through adult. *J Calif Dent Assoc* 2007;35(10):703–7,10–3.
15. Jenson L, Budenz AW, Featherstone JD, et al. Clinical protocols for caries management by risk assessment. *J Calif Dent Assoc* 2007;35(10):714–23.
16. Ramos-Gomez FJ, Crall J, Gansky SA, Slayton RL, Featherstone JD. Caries risk assessment appropriate for the age 1 visit (infants and toddlers). *J Calif Dent Assoc* 2007;35(10):687–702.
17. Featherstone JDB, Chaffee BW. The Evidence for Caries Management by Risk Assessment (CAMBRA(R)). *Adv Dent Res* 2018;29(1):9–14.
18. Ramos-Gomez F, Askaryar H, Garell C, Ogren J. Pioneering and Interprofessional Pediatric Dentistry Programs Aimed at Reducing Oral Health Disparities. *Front Public Health* 2017;5:207.
19. Ramos-Gomez FJ, Silva DR, Law CS, et al. Creating a new generation of pediatric dentists: A paradigm shift in training. *J Dent Educ* 2014;78(12):1593–603.
20. Featherstone JD. The continuum of dental caries — evidence for a dynamic disease process. *J Dent Res* 2004;83 Spec No C:C39–42.
21. Featherstone JD. Dental caries: A dynamic disease process. *Aust Dent J* 2008;53(3):286–91.
22. Featherstone JD. The caries balance: Contributing factors and early detection. *J Calif Dent Assoc* 2003;31(2):129–33.
23. Featherstone JD. The caries balance: The basis for caries management by risk assessment. *Oral Health Prev Dent* 2004;2 Suppl 1:259–64.
24. Featherstone JD. The science and practice of caries prevention. *J Am Dent Assoc* 2000;131(7):887–99.
25. Featherstone JD. Prevention and reversal of dental caries: Role of low level fluoride. *Community Dent Oral Epidemiol* 1999;27(1):31–40.
26. Fontana M. The Clinical, Environmental, and Behavioral Factors That Foster Early Childhood Caries: Evidence for Caries Risk Assessment. *Pediatr Dent* 2015;37(3):217–25.
27. Okunseri C, Gonzalez C, Hodgson B. Children's Oral Health Assessment, Prevention and Treatment. *Pediatr Clin North Am* 2015;62(5):1215–26.
28. Chaffee BW, Cheng J, Featherstone JD. Baseline caries risk assessment as a predictor of caries incidence. *J Dent* 2015;43(5):518–24.
29. Chaffee BW, Featherstone JDB, Zhan L. Pediatric Caries Risk Assessment as a Predictor of Caries Outcomes. *Pediatr Dent* 2017;39(3):219–32.
30. Domejean S, White JM, Featherstone JD. Validation of the CDA CAMBRA caries risk assessment — a six-year retrospective study. *J Calif Dent Assoc* 2011;39(10):709–15.
31. Chaffee BW, Featherstone JD, Gansky SA, Cheng J, Zhan L. Caries Risk Assessment Item Importance: Risk Designation and Caries Status in Children Under Age 6. *JDR Clin Trans Res* 2016;1(2):131–42.
32. Ramos-Gomez F, Crystal YO, Ng MW, Tinanoff N, Featherstone JD. Caries risk assessment, prevention and management in pediatric dental care. *Gen Dent* 2010;58(6):505–17; quiz 18-9.
33. Featherstone JD. Caries prevention and reversal based on the caries balance. *Pediatr Dent* 2006;28(2):128–32; discussion 92–8.
34. Zhan L. Rebalancing the Caries Microbiome Dysbiosis: Targeted Treatment and Sugar Alcohols. *Adv Dent Res* 2018;29(1):110–16.
35. Lin HK, Fang CE, Huang MS, et al. Effect of maternal use of chewing gums containing xylitol on transmission of mutans streptococci in children: A meta-analysis of randomized controlled trials. *Int J Paediatr Dent* 2016;26(1):35–44.
36. Dye BA, Vargas CM, Fryar CD, Ramos-Gomez F, Isman R. Oral health status of children in Los Angeles County and in the United States, 1999–2004. *Community Dent Oral Epidemiol* 2017;45(2):135–44.
37. Ng MW, Ramos-Gomez F, Lieberman M, et al. Disease Management of Early Childhood Caries: ECC Collaborative Project. *Int J Dent* 2014;2014:327801.
38. Pitts NB, Zero DT, Marsh PD, et al. Dental caries. *Nat Rev Dis Primers* 2017;3:17030.
39. Ramos-Gomez FJ, Weintraub JA, Gansky SA, Hoover CI, Featherstone JD. Bacterial, behavioral and environmental factors associated with early childhood caries. *J Clin Pediatr Dent* 2002;26(2):165–73.
40. Guggenheimer J, Moore PA. Xerostomia: Etiology, recognition and treatment. *J Am Dent Assoc* 2003;134(1):61–9; quiz 118–9.
41. Wong MC, Clarkson J, Glenny AM, et al. Cochrane reviews on the benefits/risks of fluoride toothpastes. *J Dent Res* 2011;90(5):573–9.
42. American Dental Association Council on Scientific A. Fluoride toothpaste use for young children. *J Am Dent Assoc* 2014;145(2):190–1.
43. Wright JT, Hanson N, Ristic H, et al. Fluoride toothpaste efficacy and safety in children younger than 6 years: A systematic review. *J Am Dent Assoc* 2014;145(2):182–9.
44. dos Santos AP, Nadanovsky P, de Oliveira BH. A systematic review and meta-analysis of the effects of fluoride toothpastes on the prevention of dental caries in the primary dentition of preschool children. *Community Dent Oral Epidemiol* 2013;41(1):1–12.
45. Curnow MM, Pine CM, Burnside G, et al. A randomised controlled trial of the efficacy of supervised toothbrushing in high-caries-risk children. *Caries Res* 2002;36(4):294–300.
46. Pine CM, Curnow MM, Burnside G, Nicholson JA, Roberts AJ. Caries prevalence four years after the end of a randomised controlled trial. *Caries Res* 2007;41(6):431–6.
47. Marinho VC. Cochrane reviews of randomized trials of fluoride therapies for preventing dental caries. *Eur Arch Paediatr Dent* 2009;10(3):183–91.
48. Weintraub JA, Ramos-Gomez F, Jue B, et al. Fluoride varnish efficacy in preventing early childhood caries. *J Dent Res* 2006;85(2):172–6.
49. Riley P, Moore D, Ahmed F, Sharif MO, Worthington HV. Xylitol-containing products for preventing dental caries in children and adults. *Cochrane Database Syst Rev* 2015(3):CD010743.
50. Edelstein BL, Ureles SD, Smaldone A. Very High Salivary Streptococcus Mutans Predicts Caries Progression in Young Children. *Pediatr Dent* 2016;38(4):325–30.
51. Leverett DH, Featherstone JD, Proskin HM, et al. Caries risk assessment by a cross-sectional discrimination model. *J Dent Res* 1993;72(2):529–37.
52. Leverett DH, Proskin HM, Featherstone JD, et al. Caries risk assessment in a longitudinal discrimination study. *J Dent Res* 1993;72(2):538–43.
53. Featherstone JD, White JM, Hoover CI, et al. A randomized clinical trial of anticaries therapies targeted according to risk assessment (caries management by risk assessment). *Caries Res* 2012;46(2):118–29.
54. Hughes CV, Dahlan M, Papadopolou E, et al. Aciduric microbiota and mutans streptococci in severe and recurrent severe early childhood caries. *Pediatr Dent* 2012;34(2):e16–23.
55. Ramos-Gomez F, Ng MW. Into the future: Keeping healthy teeth caries free: Pediatric CAMBRA protocols. *J Calif Dent Assoc* 2011;39(10):723–33.
56. American Dental Association Council on Scientific A. Professionally applied topical fluoride: Evidence-based clinical recommendations. *J Am Dent Assoc* 2006;137(8):1151–9.
57. Weyant RJ, Tracy SL, Anselmo TT, et al. Topical fluoride for caries prevention: Executive summary of the updated clinical recommendations and supporting systematic review. *J Am Dent Assoc* 2013;144(11):1279–91.
58. AAPD Best Practices: Prescribing Dental Radiographs for Infants, Children, Adolescents and Individuals With Special Health Care Needs
www.aapd.org/media/Policies_Guidelines/BP_Radiographs.pdf. Accessed Oct. 31, 2018.
59. FDA, ADA, HHS. Dental radiographic examinations for patient selection and limiting radiation exposure, 2012. www.ada.org/~/media/ADA/Publications/ADA%20News/Files/Dental_Radiographic_Examinations_2012.pdf?la=en. Accessed Oct. 31, 2018.
60. Tanner ACR, Kressirer CA, Rothmiller S, Johansson I, Chalmers NI. The Caries Microbiome: Implications for Reversing Dysbiosis. *Adv Dent Res* 2018;29(1):78–85.
61. Sjogren K, Birkhed D, Rangmar B. Effect of a modified toothpaste technique on approximal caries in preschool children. *Caries Res* 1995;29(6):435–41.
62. Zhan L, Featherstone JD, Lo J, et al. Clinical efficacy and effects of xylitol wipes on bacterial virulence. *Adv Dent Res* 2012;24(2):117–22.
63. Zhan L, Cheng J, Chang P, et al. Effects of xylitol wipes on cariogenic bacteria and caries in young children. *J Dent Res* 2012;91(7 Suppl):85S–90S.
64. Marghalani AA, Guinto E, Phan M, Dhar V, Tinanoff N. Effectiveness of Xylitol in Reducing Dental Caries in Children. *Pediatr Dent* 2017;39(2):103–10.
65. Legier-Vargas K, Mundorff-Shrestha SA, Featherstone JD, Gwinner LM. Effects of sodium bicarbonate dentifrices on the levels of cariogenic bacteria in human saliva. *Caries Res* 1995;29(2):143–7.
66. Zero DT. Evidence for biofilm acid neutralization by baking soda. *J Am Dent Assoc* 2017;148(11S):S10–S14.
67. Myneni SR. Effect of baking soda in dentifrices on plaque removal. *J Am Dent Assoc* 2017;148(11S):S4–S9.
68. Crystal YO, Chaffee BW. Silver Diamine Fluoride Is Effective in Arresting Caries Lesions in Primary Teeth. *J Evid Based Dent Pract* 2018;18(2):178–80.
69. Crystal YO, Janal MN, Hamilton DS, Niederman R. Parental perceptions and acceptance of silver diamine fluoride staining. *J Am Dent Assoc* 2017;148(7):510–18 e4.
70. Crystal YO, Marghalani AA, Ureles SD, et al. Use of Silver Diamine Fluoride for Dental Caries Management in Children and Adolescents, Including Those With Special Health Care Needs. *Pediatr Dent* 2017;39(5):135–45.
71. Crystal YO, Niederman R. Silver Diamine Fluoride Treatment Considerations in Children's Caries Management. *Pediatr Dent* 2016;38(7):466–71.

THE CORRESPONDING AUTHOR, John D. B. Featherstone, MSc, PhD, can be reached at john.featherstone@ucsf.edu.

Appendix

Self-management goals pictorial check sheet
and caries risk assessment forms

Updated CAMBRA* Caries Risk Assessment Form for Patients Aged 6 Through Adult (January 2019) (Refer to the second page of this form for details and instructions for use.)

Patient name: Reference number:
Provider name: Date:

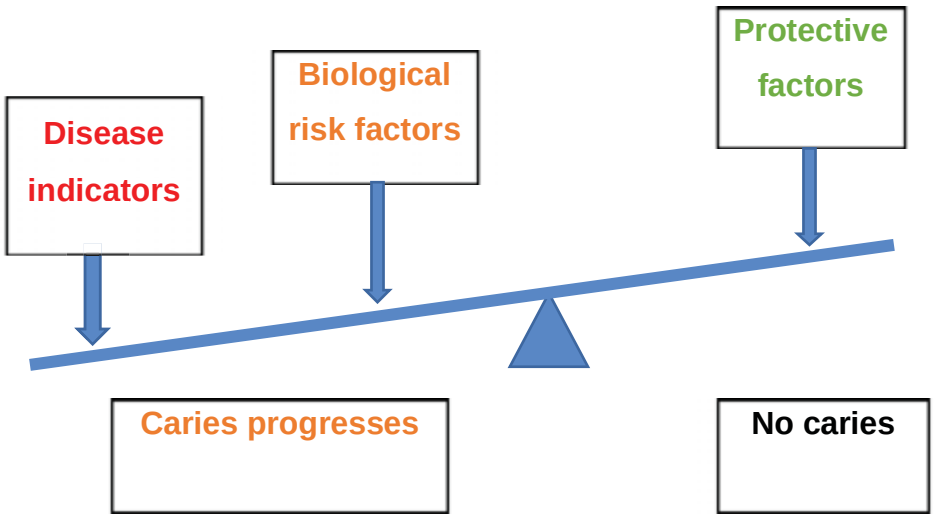
Caries risk component			
Disease indicators	Check if Yes		
1. New cavities or lesion(s) into dentin (radiographically)			
2. New white spot lesions on smooth surfaces			
3. New noncavitated lesion(s) in enamel (radiographically)			
4. Existing restorations in last three years (new patient) or the last year (patient of record)			
Biological or environmental risk factors		Check if Yes	
1. Cariogenic bacteria quantity — **not currently available**			
2. Heavy plaque on the teeth			
3. Frequent snacking (> 3 times daily)			
4. Hyposalivatory medications			
5. Reduced salivary function (measured low flow rate)**			
6. Deep pits and fissures			
7. Recreational drug use			
8. Exposed tooth roots			
9. Orthodontic appliances			
Protective factors			Check if Yes
1. Fluoridated water			
2. F toothpaste once a day			
3. F toothpaste 2X daily or more			
4. 5000 ppm F toothpaste			
5. F varnish last six months			
6. 0.05% sodium fluoride mouthrinse daily			
7. 0.12% chlorhexidine gluconate mouthrinse daily seven days monthly			
8. Normal salivary function			
	Column 1	Column 2	Column 3
Final Score: **Yes in Column 1: Indicates high or extreme risk** **Yes in columns 2 and 3: Consider the caries balance** **** Hyposalivation plus high risk factors = extreme risk**			
Final overall caries risk assessment category (check) determined as per guidelines on next page **EXTREME** ☐ **HIGH** ☐ **MODERATE** ☐ **LOW** ☐			

*CAMBRA is a registered trademark of the University of California

Caries Risk Assessment Form for Patients Aged 6 Through Adult (continued)

Determining the caries risk as low, moderate, high or extreme

Add up the number of "yes" checks for each of the disease indicators (Column 1) and risk factors (Column 2). Offset this total by the total number of "yes" checks for protective factors (Column 3). Use these numbers to determine whether the patient has a higher risk factor score than a protective factor score or vice versa. Use the caries balance to visualize the overall result and determine the risk level:



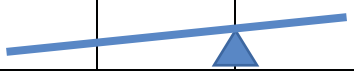
This enables a determination of low, moderate or high risk, determined by the balance between disease indicators/risk factors and protective factors. The "yes" indications are also used to modify behavior or determine additional therapy.

In addition to counting the "yes" checks as described above, the following three modifiers apply:

1. *High and extreme risk.* One or more disease indicators signals at least high risk. If there is also hyposalivation, the patient is at extreme risk. Even if there are no positive disease indicators the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Think of the caries balance: visualize the balance diagram as illustrated above.
2. *Low risk.* If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk. Usually this is obvious.
3. *Moderate risk.* If the patient is not obviously at high or extreme risk and there is doubt about low risk, then the patient should be allocated to moderate risk and followed carefully, with additional chemical therapy added. An example would be a patient who had a root canal as a result of caries four years ago and has no new clinical caries lesions, but has exposed tooth roots and only uses a fluoride toothpaste once a day.

Updated CAMBRA*** Caries Risk Assessment Form for Patients Aged 0 to 5 (January 2019)
(Refer to the second page of this form for instructions for use.)

Patient name: Reference number:
Provider name: Date:

Caries risk component	Column 1	Column 2	Column 3
Biological or environmental risk factors*		**Check if Yes****	
1. Frequent snacking (more than three times daily)			
2. Uses bottle/nonspill cup containing liquids other than water or milk			
3. Mother/primary caregiver or sibling has current decay or a recent history of decay (see high-risk description on next page)			
4. Family has low socioeconomic/health literacy status			
5. Medications that induce hyposalivation			
Protective factors**			**Check if Yes****
1. Lives in a fluoridated drinking water area			
2. Drinks fluoridated water			
3. Uses fluoride-containing toothpaste at least two times daily — a smear for ages 0–2 years and pea sized for ages 3–6 years			
4. Has had fluoride varnish applied in the last six months			
Biological risk factors — clinical exam*		**Check if Yes****	
1. Cariogenic bacteria quantity — **Not currently available**			
2. Heavy plaque on the teeth			
Disease indicators — clinical exam	**Check if Yes****		
1. Evident tooth decay or white spots			
2. Recent restorations in last two years (new patient) or the last year (patient of record)			
	Column 1 total	**Column 2 total**	**Column 3 total**
Yes in Column 1 indicates high risk **Yes in columns 2 and 3: Consider the caries balance as illustrated on next page**			

Final overall caries risk assessment category (check) determined as per guidelines on next page

HIGH ☐ **MODERATE** ☐ **LOW** ☐

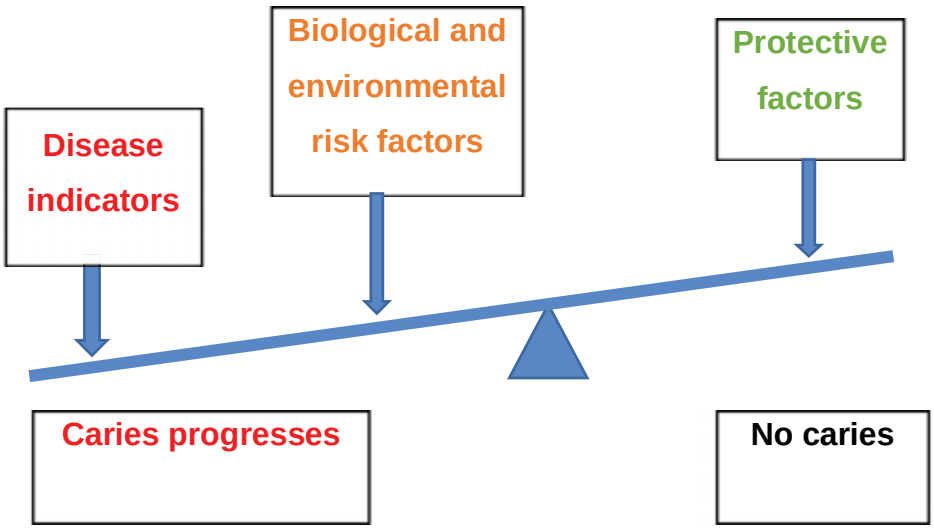
***Biological and environmental risk factors are split into a) question items, b) clinical exam.**
****Check the "yes" answers in the appropriate column. Shading indicates which column to place the appropriate "yes."**

Caries Risk Assessment Form for Patients Aged 0 to 5 (continued)

Determining the caries risk as high, moderate or low

1. ***High risk.*** If there is a "yes" in Column 1 (one or both disease indicators), the patient is at high risk. Even if there are no "yes" disease indicators the patient can still be at high risk if the risk factors definitively outweigh the protective factors. Mother or caregiver with current or recent dental decay most likely indicates high caries risk for the child. Use the "yes" checks for each of the risk factor and protective factor columns to visualize the caries balance as illustrated below. The balance clearly to the left indicates high caries risk, whereas clearly to the right the risk level is low.
2. ***Moderate risk.*** If there are no disease indicators and the risk factors and protective factors appear to be balanced, then a moderate caries risk determination is appropriate. If in doubt, move the moderate to a high classification.
3. ***Low risk.*** If there are no disease indicators, very few or no risk factors and the protective factors prevail, the patient is at low risk.

Any items checked "yes" may also be used as topics to modify behavior or determine additional therapy. Use the following modified caries balance to visualize the overall result and determine the risk level:



Additional caries-related components for caregiver/patient counseling
Frequency of use of fluoride toothpaste and amount
Use of silver diamine fluoride in appropriate cases
Dietary counseling to reduce frequency and amount of fermentable carbohydrates, especially sucrose, fructose (high-fructose corn syrup) and continual fruit juice (e.g., apple juice)
Bottle used continually, bottle used in bed or nursing on demand
Child has developmental problems/child has special care needs (CHSCN)
Inadequate saliva flow and related medications, medical conditions or illnesses

Self-management goals (discussed and agreed with parent/caregiver)

1. _____
2. _____

Caries Self-Management Menu of Options (Also available as a download at cda.org/CAMBRA2.)

Protective factors

- Use an antibacterial mouthrinse/ fluoride mouthwash
- Drink fluoridated tap water or fluoridated bottled water
- 2 tsp. baking soda in 8 oz. water for buffering
- Brush at least 2x daily with a fluoridated toothpaste

Fermentable carbohydrate changes

- Reduce frequency of processed starchy snacks
- Substitute xylitol-based products for fermentable carbohydrates
- Limit snacking on fermentable carbohydrates to 2x or less outside of meal time
- Reduce frequency of sugary snacks

Sugar control options

- Drink water or milk instead of sugar-sweetened beverages; limit to meal time if at all
- Do not add sugar to beverages
- Dilute juice with water; exercise portion control; limit to meal time if at all
- Read nutrition labels for sugar content

Oral health lifestyle reinforcements

- Daily plaque removal
- Choose healthful snacks
- Keep all oral health appointments
- Track goal progress

Self-management goals

Select two goals, such as buffering or limiting sugary drinks, and number each goal.

- Goal 1: How important it is _____ (1–10) How likely to accomplish it _____ (1–10)
- Goal 2: How important it is _____ (1–10) How likely to accomplish it _____ (1–10)