**REVIEW ARTICLE**

# EVIDENCE OF THE EFFECTIVENESS OF CARIES RISK MANAGEMENT MODELS

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**Highlights: (**1) Caries risk management models enable the personalization of dental care. (2) The main focus is to prevent dental caries, avoiding more invasive and painful treatments in the future. (3) Risk management strategies are evidence-based, ensuring the effectiveness of interventions.

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## ABSTRACT

The search for a more comprehensive approach to oral health has led to the analysis of care models that integrate biophysical, psychological, and social dimensions, recognizing the complex interaction among these factors. Objective: To analyze the evidence regarding the effectiveness of caries risk management models for the adult population. Methods: This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search was carried out in the PubMed, SciELO, Scopus, and Web of Science databases in November 2024.Results: A total of 1,695 articles were identified, of which 1,652 were excluded during the screening process, resulting in 13 studies included in this review. The studies applied caries risk management software to 8,641 participants. The most commonly used software for the adult population was Cariogram. A direct association was observed between Cariogram risk categories and the prevalence, experience, and severity of dental caries. Risk factors such as previous history of the disease, salivary flow rate, levels of *Streptococcus mutans*, and dietary and oral hygiene habits were considered strong predictors of future caries incidence. Genetic factors, specific medical conditions, unique microbial characteristics, and even individual responses to treatment may significantly influence caries risk. Conclusion: Caries risk management is a promising approach for the prevention and control of this disease. The use of software and applications may facilitate risk assessment and the development of personalized treatment plans.

**Keywords:** Dental caries; Risk management; Disease prevention; Oral health.



## INTRODUCTION

Public health problems associated with oral health have become a significant burden for countries worldwide[1]. In several high-income countries, oral health has improved following the implementation of prevention programs. However, the adoption of unhealthy lifestyles, including risk factors common to most chronic diseases, has led to a concerning increase in oral diseases, influenced by behaviors such as high-sugar

diets and poor oral hygiene habits[1]. Recent data reveal that nearly 30% of the world's adult population presents untreated dental caries in permanent teeth, representing an oral health problem that affects millions of people globally[2].

Over recent years, health models and concepts have been increasingly analyzed and expanded in an effort to integrate biophysical, psychological, and social dimensions, thereby promoting stronger foundations for improving the population's oral health quality[3]. Epidemiology contributes to this process by enabling the aggregation of clinical measures and indicators to support decision-making regarding the type of treatment provided to individuals[3].

Health and illness are complex and multifaceted experiences that vary from person to person[3]. Recognizing this uniqueness is essential for providing high-quality healthcare. However, healthcare practices are still largely based on biomedical models that prioritize disease, making it difficult to build more humanized therapeutic relationships and to promote comprehensive health care[1,3]. Each individual experiences illness in a unique way, influenced by biological, psychological, social, and cultural factors. In Dentistry, this practice is common. Even today, the most frequently used method for assessing oral health status is based on the clinical evaluation performed by professionals, often without considering other social and personal aspects related to oral health[2].

Among the major oral diseases, dental caries is the most prevalent and develops through a complex and multifactorial sequence of events involving clinical, microbiological, behavioral, and social factors. This chain of events, which may extend over several years, requires a multidisciplinary approach for its prevention[4]. By identifying and addressing risk factors at each stage of this process, it is possible to interrupt disease progression and promote oral health. Scientific evidence demonstrates that prevention is the key to controlling this disease[5].

In recent years, a set of tools and clinical criteria has emerged, enabling oral health professionals to plan personalized and preventive treatments. However, the transition toward a prevention-centered model of care remains a significant challenge requires a paradigm shift, with greater emphasis on early detection, individual risk assessment, and personalized interventions[6].

Among the various tools available for caries risk assessment, four are most commonly used: CAMBRA, Cariogram, and the guidelines established by the American Dental Association (ADA) and the American Academy of Pediatric Dentistry (AAPD)[7]. Each of these tools provides a specific approach to identifying individual risk factors and supporting disease prevention[7].

Therefore, the aim of this study was to analyze the scientific evidence regarding the effectiveness of caries risk management models for the adult population.

## MATERIALS AND METHODS:

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[8] and was registered in the PROSPERO database under registration number CRD42024498785.

The review was guided by a research question based on the study problem: *What is the evidence regarding the effectiveness of caries risk management models in the adult population?* This question guided the organization of the review, the definition of the search strategies, and the exploration of the electronic databases used in this study.

Descriptors and Search Strategies:The PICO acronym was used to define the research descriptors (Table 1).

Table 1. Acronym used to define the search descriptors

| Definition | Descriptors |
|---|---|
| P - Population | Adult population (young adults and adults, 19 to 55 years old) |
| I - Intervention | Risk management models |
| C - Comparison | Not applicable in this context |
| O - Outcome | Dental caries |

**Source:** Prepared by the researchers.

Although the objective of this review was to analyze the effectiveness of caries risk management models, the guiding research question did not include an explicit comparator (C) within the acronym. This decision was made due to the absence of controlled clinical trials in the literature comparing the application of these models with a control group.

he search was conducted in the following databases: PubMed from the *Medical Literature Analysis and Retrieval System Online* (MEDLINE) PubMed/MEDLINE; *Scientific Electronic Library Online* (SciELO) SciELO; Scopus; and Web of Science. The article search strategy included MeSH and DeCS terms to structure the search, and the Boolean operators “OR” and “AND” were also applied (Table 2).

**Table 2. Search strategies used in the selected databases**

| | Search strategies |
|---|---|
| PubMed<br>n=537 | ((dentistry) OR (dental caries) OR (caries)) AND ((caries risk assessment) OR (Cariogram) OR (CAMBRA) OR (AAPD) OR (CAT) OR (ADA) OR (nuscra) OR (NUS-CRA) OR (PreViser)) AND ((cross-sectional studies) OR (cohort analysis risk) OR (cohort studies) OR (clinical trial) OR (clinical study) OR (controlled clinical trial) OR (observational study))<br>((dentistry) OR (dental caries) OR (caries)) AND ((caries risk assessment) OR (Cariogram) OR (CAMBRA) OR (AAPD) OR (CAT) OR (ADA) OR (nuscra) OR (NUS-CRA) OR (PreViser)) AND ((cross-sectional studies) OR (cohort analysis risk) OR (cohort studies) OR (clinical trial) OR (clinical study) OR (controlled clinical trial) OR (observational study) AND (adults)) |
| Web of Science (WoS)<br>n= 1.090 | ((dentistry) OR (dental caries) OR (caries)) AND ((caries risk assessment) OR (Cariogram) OR (CAMBRA) OR (AAPD) OR (CAT) OR (ADA) OR (nuscra) OR (NUS-CRA) OR (PreViser)) AND ((cross-sectional studies) OR (cohort analysis risk) OR (cohort studies) OR (clinical trial) OR (clinical study) OR (controlled clinical trial) OR (observational study) AND (adults)) |
| Scopus<br>n=68 | (TITLE-ABS-KEY ( (dentistry) OR (dentalANDcaries) OR (caries) ) AND ALL (dentistry AND oral AND medicine) AND TITLE-ABS-KEY (dental caries") AND TITLE-ABS-KEY ("caries risk assessment") AND TITLE-ABS-KEY (adult) ) |

Source: Prepared by the researchers.

To improve the comprehensiveness of the review and identify potentially eligible studies that were not retrieved from the selected databases, forward and backward citation searches were performed. In other words, all references cited in the studies eligible for inclusion were inspected (backward citation search), and all articles that cited the studies eligible for inclusion were also examined (forward citation search)[9].

**Inclusion and Exclusion Criteria:**

Original articles investigating caries risk management or assessment models (e.g., Cariogram, CAMBRA, ADA, and AAPD) applied to the adult population (19–55 years old) were included in this review. Only studies reporting outcomes related to the prevalence, experience, increment, or severity of dental caries were considered. Articles published in English, Portuguese, or Spanish, available in peer-reviewed journals and indexed in the PubMed, SciELO, Scopus, and Web of Science databases, as well as those retrieved through manual searches of references and citations, were included.

Duplicate articles, studies involving populations outside the age range defined in the inclusion criteria, studies that did not use caries risk assessment models, publications without sufficient data to answer the research question, as well as qualitative studies, letters to the editor, editorials, and conference abstracts were excluded.

The bibliographic search was conducted in November 2024 and included articles published between 2000 and 2024. The retrieved data were exported to the Rayyan platform, where duplicate articles were removed. Subsequently, titles and abstracts were subjected to blinded screening by two independent reviewers to assess their eligibility according to the predefined inclusion and exclusion criteria. Disagreements between reviewers were resolved by consensus. After the initial screening, potentially relevant articles were selected for full-text reading.

**Data Collection:**

The data of interest were collected using a spreadsheet in Microsoft Excel® containing the following information: author(s)/year of publication, outcome, number of participants, indices, model, and statistical significance.

**Data Analysis:**

Data regarding the main information related to the study objective were collected, summarized, and narratively reported using text synthesis, with the results presented in tables and graphs. The methodological quality and risk of bias of each included study were assessed to ensure the validity of the results and confidence in the evidence. The assessment was conducted by two independent reviewers using the critical appraisal tools of the Joanna Briggs Institute (JBI), which are specific to different study designs. Disagreements were resolved by consensus. The risk of bias was categorized as "low," "moderate," or "high" based on the score obtained with each appraisal tool[10].

## RESULTADOS

The bibliographic search conducted in the selected databases (PubMed, SciELO, Scopus, and Web of Science) identified a total of 1,695 records. After the removal of 35 duplicate articles using the Rayyan platform, 1,660 studies were subjected to title and abstract screening. Of these, 1,425 were excluded for not meeting the previously established inclusion criteria. Thus, 235 articles were considered potentially relevant and assessed during the initial screening phase.

After reviewing titles and abstracts, 189 studies were excluded for not focusing on caries risk management models in adults. The subsequent stage resulted in 46 articles selected for full-text reading. Of these, 38 were excluded for not answering the research question or for not providing sufficient data. Additionally, 5 articles were retrieved through forward and backward citation searches, in accordance with methodological recommendations.

In the end, 13 studies met all eligibility criteria and were included in the qualitative synthesis of this systematic review. The process of study identification, screening, eligibility, and inclusion is detailed in the PRISMA flowchart (Figure 1), according to the recommendations of the Joanna Briggs Institute (JBI)[11] and the adapted checklist from the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA)[7].

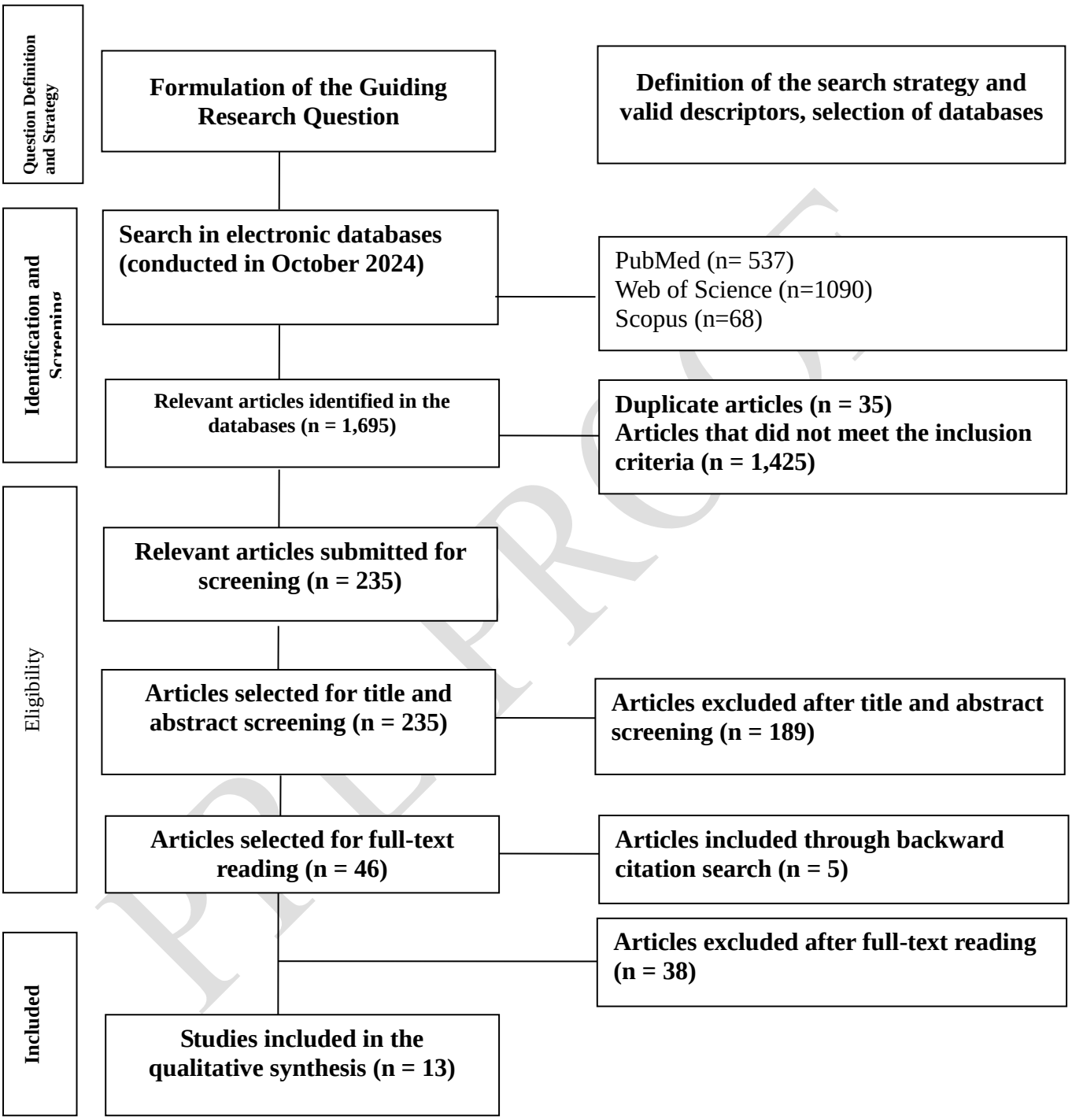


Figure 1 – Article selection flowchart

Source: Adapted from PRISMA-ScR

The studies applied caries risk management software to 8,641 participants. The characteristics of the studies analyzed in this review are described in Table 1.

**Table 1. Characteristics of the Studies Included in the Review**

| Authors/Year | Outcome | Participants | Model | Statistical Significance | Risk of Bias (JBI) | Justification for the Assessment |
|---|---|---|---|---|---|---|
| Petersson (2003) | Caries increment | 208 | Cariogram | $p < 0.05$ | Low | Prospective cohort study with long-term follow-up. |
| Sonbul (2008) | Current caries status | 175 | Complete Cariogram | $p < 0.05$ | Moderate | Cross-sectional study, not allowing the establishment of causality. |
| Ruiz Miravet (2007) | Current caries status | 48 | Cariogram | $p < 0.05$ | High | Small sample size and cross-sectional study design. |
| Peker (2012) | Current caries status | 90 | Complete Cariogram | $p < 0.05$ | Moderate | Cross-sectional study with a moderate sample size. |
| Petersson (2015) | Caries increment | 1295 | Complete Cariogram | $p \leq 0.01$ | Low | Long-term cohort study with a large number of participants. |
| Chafee (2015) | Caries | 4468 | CAMBRA | $p < 0.05$ | Low | Large |

**Table 1. Characteristics of the Studies Included in the Review**

| Authors/Year | Outcome | Participants | Model | Statistical Significance | Risk of Bias (JBI) | Justification for the Assessment |
|---|---|---|---|---|---|---|
| | increment | | | | | prospective cohort with clearly defined outcomes. |
| Dou et al. (2018) | Caries increment | 192 | Complete Cariogram and a model without salivary tests | $p < 0.05$ | Moderate | Comparative study, but without an external control group. |
| Carta et al. (2015) | Caries increment | 480 | Cariogram | $p \leq 0.01$ | Low | Cohort study with adequate follow-up and clearly defined outcomes. |
| Petersson et al. (2013) | Current caries status | 1295 | Cariogram | $p \leq 0.01$ | Low | Cohort study with a large sample and standardized assessment. |
| Lee (2013) | Current caries status | 80 | Complete Cariogram; 7/8-factor Cariogram | $p < 0.05$ | Moderate | Cross-sectional study, not allowing the establishment of causality. |
| Chang and Kim (2014) | Current caries | 110 | Complete Cariogram | $p < 0.05$ | Moderate | Cross-sectional study |

**Table 1. Characteristics of the Studies Included in the Review**

| Authors/Year | Outcome | Participants | Model | Statistical Significance | Risk of Bias (JBI) | Justification for the Assessment |
|---|---|---|---|---|---|---|
| | status | | | | | assessing only the current caries condition. |
| Doitchinova et al. (2020) | Caries increment | 100 | Cariogram | $p < 0.05$ | Moderate | Small sample size and observational study design. |
| Celik et al. (2012) | Caries increment | 100 | Cariogram | $p < 0.05$ | Moderate | Small sample size and observational study design. |

**Source:** Prepared by the researchers.

Among the 13 studies included in this review, six were rated as having a low risk of bias according to the JBI critical appraisal criteria[12,13,16,17,19,20]. Six studies were classified as having a moderate risk of bias[15,18,21,22,23,24]. while only one study was considered to have a high risk of bias[14]. Notably, very small sample sizes may reduce statistical power and limit the detection of significant differences between groups.

## DISCUSSION

By identifying patients with a higher likelihood of developing new carious lesions, dental professionals can provide more personalized and effective preventive care. The most frequently used caries risk management model among the studies included in this review was the Cariogram. Several studies conducted among young adults demonstrated a direct association between Cariogram risk categories and caries prevalence, experience, and severity [12–18].

Petersson et al. (2003) evaluated the effectiveness of the Cariogram, a computerized program designed to assess an individual's risk of developing dental caries, in a population of older adults. The primary objective was to determine whether the program could accurately identify individuals at greater risk of developing new carious lesions[12]. Similarly, Sonbul, Al-Otaibi, and Birkhed evaluated the effectiveness of the Cariogram in identifying adults at high risk of developing future caries, particularly those with a previous history of caries, as indicated by the presence of multiple restorations [13].

The Cariogram is a multifactorial risk assessment tool that integrates several variables, including dietary habits, oral hygiene practices, fluoride exposure, and individual biological characteristics, to estimate the probability of future caries development [12,13]. The findings of these studies demonstrated that the model was able to discriminate individuals with a higher likelihood of developing new carious lesions, enabling oral health professionals to target preventive interventions toward those most in need[12,13].

The study analyzed factors such as previous caries experience, *Streptococcus mutans* counts, access to fluoridated water, and salivary buffering capacity. In addition, factors not directly included in the Cariogram model, such as the Decayed, Missing, and Filled Teeth (DMFT) index and the plaque index, also showed a strong correlation with caries risk. Linear regression analysis revealed that the most significant predictors of caries risk were *Streptococcus mutans* counts, the DMFT index, and salivary buffering capacity[14]. By identifying individuals at high risk, caries risk management enables the personalization of treatment plans, directing preventive measures toward those who need them most[14].

Caries risk management models also improved communication with patients. By presenting Cariogram results to patients, oral health professionals can clearly explain individual risk factors and emphasize the importance of adopting healthy behaviors to prevent the development of new carious lesions[13].

A study that evaluated the accuracy of the Cariogram model in predicting caries risk among young adults over a three-year period found that the risk factors included in the model, such as previous caries experience, oral hygiene habits, and sugar

consumption, remained important predictors of new carious lesion development[15]. The tool demonstrated relative stability over time, suggesting that the Cariogram may be useful for long-term monitoring of caries risk[15]. A strong association was observed between Cariogram risk categories and three-year caries increment at the tooth-surface level; however, the predictive values were modest. High- and very high-risk categories showed high specificity (>90%) but low sensitivity [15].

Both the Cariogram and the CAMBRA model demonstrated effectiveness in stratifying caries risk among young adults. In studies with follow-up periods of two and three years, individuals classified as being at very high risk according to the Cariogram exhibited a significantly greater increase in carious lesions compared with those classified as being at very low risk[16,17]. Only one study evaluated the CAMBRA model, which, similarly to the Cariogram, showed that individuals classified as high risk experienced more than a threefold increase in the development of new carious lesions[16,17]. Baseline caries risk assessment using CAMBRA, which considered factors such as salivary flow rate, *Streptococcus mutans* levels, and dietary habits, was found to be a strong predictor of future caries incidence[17].

The exclusion of salivary tests from the Cariogram model did not significantly compromise its ability to predict caries development in young adults with a previous history of the disease[18]. Both the complete and reduced versions of the model proved to be reliable tools for caries risk management in clinical settings. Although the complete Cariogram performed well, the reduced version demonstrated superior predictive performance while requiring less time and fewer resources, making it a more practical option for individual risk assessment[17,18].

Caries risk profiles among Italian adults were investigated using a computer-based caries risk assessment system and the International Caries Detection and Assessment System (ICDAS) to evaluate the relationship between sociodemographic and behavioral factors, caries status, and caries risk in an adult population[19]. Smoking habits, toothbrushing frequency, and the frequency of dental examinations were significantly associated with Cariogram scores[19].

The studies included in this review present some limitations inherent to risk assessment study designs. Small sample sizes may reduce statistical power, thereby

limiting the ability to detect weaker associations. In addition, some models may have limited predictive accuracy[15]. The sensitivity and specificity of the Cariogram model were reported in one study[16]. Both the complete and reduced versions of the Cariogram were considered reliable risk management tools for predicting caries increment in clinical dental practice and community-based populations. The reduced Cariogram demonstrated superior predictive performance while requiring less time and fewer resources, making it a more practical option for individual risk assessment[16].

The studies included in this review consistently demonstrated an association between Cariogram risk categories and the prevalence, experience, and severity of dental caries among young adults[14,15,20]. Individuals classified as being at high risk presented significantly higher caries levels than those classified in lower-risk categories[13,21]. Comparative analyses of different Cariogram versions, including models based on seven and eight factors, showed that all versions were able to identify risk levels that were statistically associated with caries experience[21].

Simplified versions of the Cariogram also demonstrated statistically significant associations with caries outcomes in both cross-sectional and longitudinal studies[21,24]. These findings suggest that, even with a reduced number of variables, the model retains its ability to identify individuals at greater risk of developing carious lesions[21,24].

Studies conducted among Italian adults further showed that more severe caries lesions (ICDAS scores 5–6) and a greater number of missing teeth were significantly associated with higher Cariogram scores[19].

Os principais fatores de risco para o desenvolvimento de cárie, considerados pelos modelos analisados foram: hábitos alimentares, higiene bucal, exposição ao flúor, história prévia da doença, o número de *estreptococos mutans* e lactobacilos, capacidade tampão e taxa de secreção, e hábitos alimentares e exposição ao flúor demonstrando a importância de uma avaliação multifatorial para a identificação do risco[12,13,14,16,16,17,18,1920,21,22,23,24]. Observou-se também que a avaliação do risco de cáries pode prever a incidência de cáries futuras também na odontologia hospitalar[22]. Experiências anteriores com cáries e manutenção inadequada da higiene oral foram amplamente relacionadas ao desenvolvimento de cáries em pacientes com necessidades especiais[22].

Doitchinova et al. (2020) identificaram o risco de cárie em pacientes adultos usando o produto de software sueco Cariogram e observaram que os fatores de risco mais importantes foram os seguintes: CPOD, (n (100) = 0,358, p < 0,001), níveis de Lactobacilos (n=(100) = 0,321, p < 0,001), níveis de *Streptococcus mutans* (n=(100) = 0,302, p < 0,05), quantidade de placa (n=(100) = 0,291, p < 0,05), frequência de ingestão alimentar (n=(100) = 0,252, p < 0,05) e conteúdo da dieta (n=(100) = 0,220, p < 0,05).

Diet frequency, plaque accumulation, and salivary secretion rate were significantly associated with caries increment ($p < 0.05$)[23].

Risk assessment models are used to predict and identify risk factors in order to develop the most effective prevention and treatment strategies[24]. By identifying patients at high risk, dentists can recommend more frequent dental examinations, additional fluoride treatments, or dietary modifications to help prevent dental caries[23]. Evidence has shown that baseline caries risk is predictive of future caries development, supporting the use of caries risk assessment to identify patients who may benefit from more intensive preventive interventions[24].

Accurate identification of individuals at increased risk of future caries allows the implementation of targeted preventive strategies, including more frequent dental check-ups, fluoride-based therapies, and dietary counseling. Multifactorial approaches to caries risk assessment enable oral health professionals to provide individualized care, contributing to improved oral health outcomes[25].

An inherent limitation of caries risk management models lies in their reliance on population-based data. Although these models provide valuable estimates of caries risk, they may not fully capture the complexity of individual patients. Genetic factors, specific medical conditions, unique microbial characteristics, and individual responses to treatment can substantially influence caries risk in ways that statistical models are unable to completely account for. This individual variability may result in the overestimation or underestimation of risk in certain cases, highlighting the need for careful clinical judgment and complementary patient assessment.

Several methodological aspects of caries risk assessment also warrant consideration. First, the definition of dental caries adopted by most risk assessment models excludes white spot lesions, arrested lesions, and lesions confined to the enamel. Early carious lesions represent a critical stage in the disease process and offer the greatest opportunity for preventive intervention. Their exclusion may therefore limit the ability of risk assessment models to fully reflect the spectrum of disease activity.

The heterogeneity of the studies included in this review limits the generalizability of the findings and the development of more precise recommendations. The lack of standardization across study populations, the use of different risk management models, and variations in caries assessment indices precluded the performance of a meta-analysis. Consequently, it was not possible to generate more robust conclusions regarding the effectiveness and applicability of caries risk assessment models.

This review highlights the need for greater standardization in caries risk assessment. The complexity of the caries process, individual variability, and the lack of consensus regarding the most appropriate risk assessment model remain important challenges. The adoption of standardized clinical protocols and validated assessment tools may improve the accuracy and reliability of identifying individuals at increased risk of caries, thereby supporting the implementation of more effective preventive strategies.

Prevention remains the cornerstone of caries management. Treatment plans should be individualized and focused on reducing risk factors while strengthening protective factors. Minimally invasive restorative dentistry may complement preventive approaches by promoting the long-term preservation of oral health. In addition, data collection processes used to support clinical decision-making should be efficient, cost-effective, and acceptable to the target population.

The overall body of evidence cannot be considered uniformly high in quality. Although six studies were classified as having a low risk of bias, six others were assessed as having a moderate risk of bias, limiting confidence in the overall findings.

Furthermore, substantial heterogeneity was observed among the included studies, including the presence of very small sample sizes and the lack of standardized assessment criteria. These limitations precluded the performance of a meta-analysis and restricted the generalizability of the conclusions.

Considering the findings of this review and the limitations identified, the evidence supporting caries risk management models may be classified as providing a moderate level of recommendation (Grade B). This classification is justified by the overall balance and consistency of the findings reported across the included studies. The available evidence demonstrates a consistent association between Cariogram risk categories and the prevalence, experience, and severity of dental caries. However, further research is needed to strengthen the evidence base.

Future studies should include controlled clinical trials comparing caries risk management models with standard dental care, as well as investigations involving larger sample sizes and standardized risk assessment methods. Such studies would facilitate the validation and comparison of different risk assessment models across diverse clinical and population settings. In addition, future research should explore the integration of these digital risk assessment systems into public oral health policies and evaluate their effectiveness when implemented on a larger scale.

## CONCLUSION

The findings of this systematic review indicate that caries risk management models, particularly Cariogram and CAMBRA, have the potential to identify adult individuals at increased risk of developing new carious lesions, thereby supporting the personalization of preventive strategies and clinical decision-making. The use of digital software and applications appears to be a promising approach for assisting dental professionals in risk stratification and individualized care planning.

However, the methodological heterogeneity of the included studies, variations in the outcomes assessed, and the predominance of small sample sizes limit the strength of

the available evidence. Furthermore, the lack of standardized assessment criteria hinders comparisons across models and restricts the generalizability of the findings.

In summary, caries risk management represents an important advancement in preventive dental care. Nevertheless, stronger scientific evidence is still required to support its systematic implementation in clinical practice and public oral health programs.

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