Caries Risk and Predictive Models in Children: A Scoping Review

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ABSTRACT

Purpose: This scoping review synthesized evidence on the diagnostic accuracy, predictive validity, and clinical utility of caries risk assessment (CRA) tools and predictive models for children and adolescents. The objective was to evaluate the performance of established instruments and assess advances in computationally informed approaches.

Methods: A structured PubMed/MEDLINE search identified English language publications through February 2025 using predefined terms related to dental caries, risk assessment, predictive modeling, and pediatric populations. 77 records were retrieved, with 29 studies meeting inclusion criteria after screening. Extracted data included tool characteristics, validation methodology, performance metrics, and implementation considerations. Reference lists of key studies were also reviewed to ensure comprehensive coverage.

Results: Established CRA tools, including the Cariogram, age modified programs, and simplified checklists, demonstrated moderate predictive validity, with AUC values generally ranging from 0.65 to 0.75. Performance varied across age groups and settings. Emerging approaches incorporating salivary biomarkers, microbiomic profiling, and machine learning algorithms showed higher predictive potential, often achieving AUC values above 0.80 in development cohorts. However, these innovations remain limited by insufficient validation, inconsistent methodology, and uncertain feasibility for broad clinical use. Implementation analyses identified barriers involving workflow integration, clinician training, cost, and acceptance.

Conclusions: CRA methodologies in pediatric dentistry range from clinical instruments to computational models. While traditional tools offer imperfect but useful stratification, emerging approaches may improve predictive precision. Continued progress requires external validation across diverse populations, cost effectiveness analyses, and implementation frameworks that support translation into clinical practice.

INTRODUCTION

Dental caries remains the most prevalent chronic disease among children globally, with substantial implications for oral health, systemic well-being, and quality of life. The contemporary management paradigm has transitioned from a predominantly restorative model to a preventive, risk-based approach that prioritizes early identification of susceptibility and individualized intervention strategies. Within this framework, caries risk assessment (CRA) serves as a foundational component, designed to stratify individuals according to their probability of developing future carious lesions.

Current tools ranges from basic checklists to multifactorial algorithms. Concurrently, a new generation of models utilizing salivary proteomics, microbiome characterization, and machine learning (ML) is emerging. This scoping review aims to map and synthesize the current evidence on modern CRA tools and predictive models for children and adolescents, evaluating their reported accuracy, validity, and clinical utility to inform practice and highlight research priorities.

MATERIALS AND METHODS

A strategic search of PubMed/MEDLINE was conducted for literature published up to February 2025. The search was limited to English articles. From 77 initial records, screening identified 29 core studies for analysis after exclusions (Figure 1). Data on tool type, population, validation design, performance metrics, and implementation factors were analyzed.

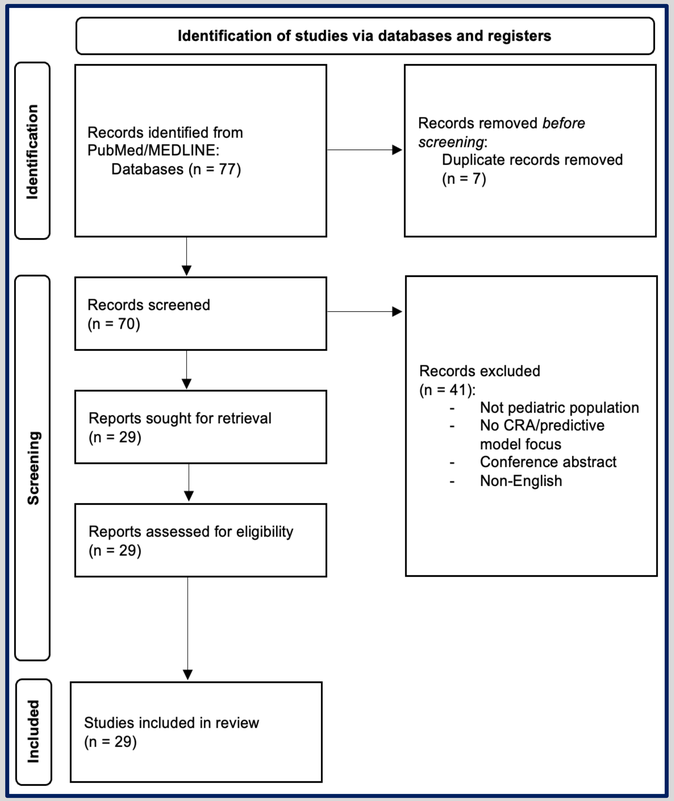

Figure 1. PRISMA-ScR Flow Diagram

RESULTS

Traditional CRA tools combine sociodemographic, dietary, clinical, and microbiological variables.

As summarized in Table 1, predictive validity varies across age groups and tools. Tools for adolescents show better performance, when compared to performance for preschool-aged children. Numerous studies stated that several different CRA tools would be needed for different populations. A systematic review concluded that high-quality validation in diverse populations for early childhood caries (ECC) tools is still needed.

Recent research has advanced towards biological and computational models, as summarized in Table 2.

An additional predicative factor for increased carious risk continues to be high levels of mutans streptococci and lactobacilli, and plaque content, which will likely be used for future CRA tools.

Tool Name	Target Population	Key Components	Reported Performance
Cariogram (Various settings)	Mixed ages (mostly school-age)	Multifactorial algorithm (diet, bacteria, susceptibility, circumstances, plaque)	Performance highly dependent on chosen risk thresholds. Moderate validity. Higher than Bangkok checklist; lower than CAMBRA.
Bangkok Checklist	Preschool children	Simplified clinical and behavioral checklist	Low to moderate validity. Highly sensitive, moderate specificity.
MyRisk Mobile CRA App	General pediatric	Digital adaptation integrating core risk factors into a clinical app	Developed for feasibility and clinical integration; validation studies ongoing still.
Nomogram for 7-year-olds	School children	Statistical model based on demographic and clinical variables	Promising validity in Filipino and Chinese children but lacking extensive research.

Table 1. Characteristics and Reported Performance of Select Validated Caries Risk Assessment (CRA) Tools for Children

Approach	Method	Predictive Potential	Stage of Development
Salivary Microbiome	16S rRNA sequencing; microbial signatures; easy and non-invasive source for biomarkers	High predictive value for ECC onset; association with future caries	Advanced research present; standardization needed for clinical use
Salivary Proteomics	Mass spectrometry; protein/metabolite panels	Questionable due to differential expression	Early research phase and requires further research
Machine Learning	Classification trees; algorithms using clinical data	Reported superior accuracy; can handle complex data interactions; reported high AUC values (>0.80).	Early research phase and requires further research
Public Prediction Platforms	Web-based or digital tools with user data input	Dependent on user input data	Initial development present with mobile apps and public platforms

Table 2. Overview of Emerging Biological and Computational Approaches for Caries Risk Prediction

RESULTS

We apply the Consolidated Framework for Implementation Research to systematically analyze barriers and facilitators.

Intervention Characteristics: Simple checklists have low complexity, which aids in adoption. ML models face challenges with possible cost and unproven advantages.

Outer Setting: High ECC prevalence creates patient need, but supportive reimbursement policies on interventions are often lacking.

Inner Setting: Compatibility with existing clinic workflow and required time and training are critical to adoption.

Characteristics of Individuals: Clinician knowledge, tool's validity, and perception of a tool's potential value determine buy-in.

A critical barrier is generalizability; tools validated in one demographic often fail in another due to differing risk factor prevalence and access to care, limiting their global clinical utility.

DISCUSSION

This review highlights the transition of CRA tools from clinical checklists to more robust, analytical models. While established tools provide a useful framework, their moderate and variable accuracy limits reliable prediction for individual patients. Clinical utility is a balance between sensitivity to identify true high-risk individuals and specificity to avoid over-treatment of low-risk individuals.

Innovations in biomarkers and ML offer promise for enhanced precision. These models remain primarily in research. Challenges related to cost, technology, and the need for validation in diverse populations must be solved for clinical implementation.

A persistent theme is that the accuracy of the CRA tools is influenced by a particular population and location. Future research must prioritize clinical trials evaluating impact on clinical interventions as well.

CONCLUSION

Clinical utility is a balance between sensitivity to identify true high-risk individuals and specificity to avoid over-treatment of low-risk individuals. Established tools offer imperfect but very useful stratification. Emerging technologies hold potential for enhanced accuracy through personalized profiling and advanced analytics. To achieve clinical impact, future work must focus on external validation across diverse populations, cost-effectiveness analysis, and implementation strategies. We propose an international conversation to help standardize protocols, share datasets from varied population groups, and conduct broader trials. This will help work towards more equitable and personalized preventive pediatric dental care.

REFERENCES

Please scan the associated QR code for a list of references.