A systematic review to inform the development of a Canadian caries risk assessment tool for use by primary health care providers

Keywords: caries risk assessment, community paediatric dentistry, preschool children, screening tool

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Abstract

Background: Caries risk assessment (CRA) tools may assist in identifying children at risk of early childhood caries.

Aim: To complete a systematic review of CRA and develop a Canadian CRA tool for preschool children for use in non-dental clinical settings.

Design: Systematic searches of relevant databases were conducted. Potential variables were based on strength of associations (odd ratios, relative risk, hazard ratios, etc.), frequency of occurrence, and existing CRA tools. Quality of the evidence assessments were performed by at least two review teams through consensus following GRADE.

Results: Overall, 25 publications met the inclusion criteria, all prospective in design. Based on this review variables to be considered when developing a new CRA tool for use with preschool children: age, socioeconmic status (SES), family toothbrushing habits, fluoride exposure, infant feeding practices, dietary habits/behaviours, dental home, caries experience, visible plaque, and enamel defects. The environmental scan identified 22 CRA tools suggesting other additional variables to consider including in a CRA tool, including special health care needs, enamel defects, and dental attendance.

Conclusions: This review informed the development of a Canadian CRA tool for use by primary health care professionals, which may improve access to oral health assessments and increase interprofessional collaboration.

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Introduction:

Despite all the advancements in dental prevention over the past decades, the problem of early childhood caries (ECC) still exists. Evidence suggests that while the prevalence of caries among older children, youth and adults has declined, the prevalence of ECC in the preschool population has increased.[1-3] For many children with ECC, dental surgery under general anesthesia is the only treatment option.[4] In-hospital day surgery to treat ECC is the most common day surgical procedure in Canada.[5] A 2013 report from the Canadian Institute of Health Information revealed that the rate of dental surgery to treat ECC in Canada is 12.5/1000 children aged 1-5 years.[5] Furthermore, evidence suggests that dental surgery rates are higher in children living in rural regions, from lower income households, and Indigenous communities.[5] The rates of dental surgery for ECC are even higher in northern regions of Canada (up to 227/1000 children), where many First Nations and Inuit communities are located.[5, 6] Unfortunately, this surgical approach fails to address the underlying risk factors for ECC, as many children develop new or recurrent caries within months of surgery.[4] This highlights the importance of implementing an effective prevention regimen to complement restorative care and adopting a risk-based approach to caries management.

The goal of caries risk assessment (CRA) is to develop and provide patient-centered caries prevention and management strategies for the individual. What makes caries risk-based care unique over traditional surgical/restorative approaches to dealing with caries lesions is that there is emphasis on intervening before there is irreversible damage to teeth.[7-9] CRA tools can also be used by non-dental professionals to screen children, determine caries-risk, and provide prevention services, including fluoride varnish, oral hygiene instruction, and anticipatory guidance.

Several organizations have developed tools that can be used to help guide practitioners in determining an individual's likelihood of developing caries. These tools provide a means to identify risk factors and behaviours that can promote caries along with protective factors known to minimize the risk of onset.[10] Risk tools help identify whether a child is at low or high

likelihood of developing caries, and can guide providers to implement preventive interventions and practices that can help minimize caries risk. These tools help guide the conversation between the dental provider and the parent or caregiver so that key information is obtained to assist in identifying many of the protective and caries causing factors.

However, one of the limitations of CRA tools is that the majority have not been validated, especially across different population groups. The validity of a tool can be determined by assessing the sensitivity and specificity of the instrument.[11-13] Sensitivity in the context of CRA refers to the capability of the tool to predict future caries risk in someone who does develop caries lesions. It has been suggested that for a CRA tool to be useful, it should have a combined sensitivity and specificity score of at least 160%, and should be relatively well-balanced between these two measures.[11] Well-designed and contemporary CRA tools can facilitate clinical dental examinations as they help guide clinicians to review and query parents regarding a multitude of factors that contribute to disease development and progression.[11]

The purpose of this project was to complete a systematic review of caries risk assessment (CRA) and develop a Canadian CRA tool for preschool children for use by non-dental primary health care providers and dental providers in non-dental clinical settings.

Methods:

The search strategy was informed by previous search strategies used in other systematic reviews on CRA.[11, 12, 14-16] Systematic searches were conducted in MEDLINE Ovid, Cochrane Library, Embase Ovid, and Scopus in August 2017. Searches were devised using controlled vocabulary where available and keyword terms for three concepts; Dental Caries, Risk Assessment and Children. A total of 1921 results were gathered and de-duplicated in EndNote, with a final tally of 980 unique articles. All abstracts were reviewed by three teams. Inclusion criteria for selection of articles appear in Table 1. Articles were fully reviewed if an abstract was selected by a minimum of two review teams. For the purpose of this review, only those articles involving children < 72 months of age were selected (65 articles). Potential variables to include in the draft caries risk assessment tool for use were based on strength of associations (e.g., odd ratios, relative risk, hazard ratios, etc.), frequency of occurrence in the identified studies and existing caries risk assessment tools, as well as factors that were feasible to include.

Quality of the evidence assessments were performed by at least two review teams through consensus following GRADE.[17] A modified version of a table developed by Gao et al[12]

was created to identify and characterize the different variables and factors included in the reviewed CRA tools. Once the initial report was completed, the Office of the Chief Dental Officer (OCDO) of Canada struck a working group of experts and potential users which examined the body of evidence and critically appraise the report. The working group debated and ultimately recommend factors to include in the drafted CRA tool with the appropriate target audience of primary care providers. Agreement was achieved through consensus. The working group of experts were credentialed members from the Canadian Paediatric Society (CPS), Canadian Academy of Pediatric Dentistry, and the Canadian Association of Public Health Dentistry. Representatives from the Canadian Dental Association, Canadian Dental Hygienists Association, Canadian Dental Assistants Association, Saskatchewan Dental Therapists Association, and the College of Family Physicians of Canada attended as observers. This included a pediatrician, a family physician, two pediatric dentists, four public health dentists, among other dental professionals along with the Chief Dental Officer and the Senior Policy Advisor in the OCDO. A timeline of the activities in the project are outlined in Table 2.

Results:

A total of 25 publications met the inclusion criteria (Table 3).[12, 18-40] All were prospective in design, beginning during early childhood or prenatally. Key findings from multivariate analyses in these publications as well as quality assessments appear in Table 3 and Table 4.

Sociodemographic and Family Factors:

Out of 11 studies that included age as a predictor, five reported that age was significantly associated with future caries risk with odds ratios ranging from 1.1-5.0.[22, 25, 31-33] This would justify including "age" as a variable in a CRA tool.

Three of 16 studies assessing sex reported that males were at greater risk for caries development (HR 1.1, RR 3.0) and one reported that males were at lower risk (HR 0.8).[24, 26, 38] Thus, there is very limited evidence to suggest including "sex" as a variable in a CRA tool. Additionally, only three of five publications that examined ethnicity indicated that ethnicity was associated with increased caries risk.[24, 31, 33] One study suggested that both Hispanic (HR 1.8) and African American (HR 1.8) children were at risk, while two indicated that Malay (both OR 1.8) children were at risk. Given the limited information on ethnicity and the considerable

variability that exists in determining ethnic background of children there is limited evidence to suggest its inclusion as a variable in a CRA tool.

Six of 11 studies identified that household socioeconomic factors, including low socioeconomic status (SES) (2.38X, OR 10.4)[30, 35], deprivation[27], parental employment status (RRI 11)[26, 32], and income (OR 3.3 < $200,000/year)[41] were significantly associated with caries risk. High SES and having a high household income were protective against caries.[30, 41] Based on this evidence, low SES or other indicators of household income and employment should be considered. Only one of three studies reported that the type of housing was associated with caries risk[27], which may be a proxy for family SES. Another identified that household drinking water sourced from rain, well water, or other non-traditional sources was associated with increased caries risk (OR 2.0).[41] However, this may be a proxy measure of both access to fluoridated drinking water and SES. Four of seven articles identified parental education level as a risk factor for future caries development; two revealed associations with maternal education (OR 2.5 high school, OR 3.2 > high school) and two with paternal education (OR 0.6, OR 0.7).[31-34, 41] Given that parental educational attainment is likely reflected in household SES, there is limited evidence to suggest it should be incorporated separately into a CRA tool.

Only one of three studies reported on the age of the child's mother with children whose mothers were < 25 years of age (RRI 17) and those ≥ 35 years of age (RRI 2) being at higher risk for caries.[26] Therefore, there is limited evidence to support including maternal age as a variable in a CRA tool. Meanwhile, three of four studies reported an association with parental smoking; one reported that maternal smoking and two reported that parental smoking was associated with increased caries risk (RRI 15 at 3 years of age).[26, 27, 32] Overall, there appears to be limited evidence to support the inclusion of parental smoking into a CRA tool.

Few studies reported on the association between special health needs of the child and caries risk. One revealed that acute otitis media and respiratory tract infection at 0-12 months were associated with increased caries risk.[24] Meanwhile, two indicated that children without health problems were at increased risk.[31, 33] Four studies reported on the association between prenatal and birth characteristics and caries risk in young children. One study identified that low prenatal vitamin D concentrations during pregnancy were associated with caries in infants (OR 2.0).[22] Another reported that premature delivery (< 37 weeks) was associated with lower risk for caries (OR 0.2).[36] Two of five studies revealed that birth weight may be associated with

increased caries risk.[26, 32] One of these studies reported that low birth weights (< 2,500 g) (RRI 5) and birthweights ≥ 4,000 g are associated with caries (RRI 19).[26] These findings suggest there is limited evidence to support including any of these variables in a CRA tool.

Parental attitudes and knowledge can also influence childhood oral health. For instance, parents believing that caries is a result of a "tooth worm" was found to lessen the risk for caries in their children.[31] Children of parents who are unaware that a bottle of milk at bedtime is bad for their child's teeth are at increased risk for decay.[31] Another study reported that parents who consider it necessary to treat caries involving primary teeth are more likely to have a child at risk for future caries.[23] Due to this limited evidence, assessments of parental knowledge and attitudes towards early childhood oral health should not be included in a CRA tool.

Behavioural Factors:

Oral hygiene behaviours:

Several studies examined toothbrushing behaviours and its association with caries risk. Three of nine studies reported that toothbrushing frequency was associated with developing caries with odds ratios ranging from 2.0 – 4.6.[28, 30, 36] One study reported that initiating brushing in the first year of life was protective (OR 0.2) and reduced the risk of caries.[35] Four of six studies reported on the association between parental supervision or assistance with child toothbrushing with an OR ranging from 0.1 - 1.8 and a RRI 18.[21, 23, 26, 35] One of these studies suggested that parents helping the child brush their teeth daily (OR 0.9) was associated with increased caries risk.[23] However, the other three concluded that regular parent-supervised toothbrushing was protective against caries (OR 0.1)[35] while no or infrequent parental involvement was associated with future caries development (OR 0.9 - 1.8).[21, 23] This suggests that a question about the frequency of toothbrushing and/or the involvement of parents in supervising daily toothbrushing may be helpful if included in a CRA tool.

Exposure to fluoride was also reported in some of the studies. One study reported that use of fluoridated toothpaste was protective (OR 0.6).[33] Another study indicated that average daily fluoride intake was associated with caries (OR 1.9).[28] Access to fluoridated tap water is also a predictor of caries risk as fluoride levels in drinking water (OR 2.4)[28] and fluoridated water (OR 0.7)[31] can influence caries development. One of these studies also reported that fluoride use, other than toothpaste, is also associated with caries risk (OR 0.4).[31] However, this study did note

that this could be a result of high caries burden at baseline.[31] Based on this evidence, an assessment of exposure to sources of fluoride should be included in a CRA tool.

Infant Feeding Behaviours:

Several studies reported on the association between infant feeding behaviours and caries risk, namely breastfeeding, feeding duration, and bottle feeding. Five of ten studies provided evidence on breastfeeding and duration of breastfeeding.[21, 27, 28, 31, 33] Two studies revealed that breastfeeding was associated with an increased risk of caries.[21, 27] Three other studies on breastfeeding duration concluded that the number of months of breastfeeding (OR 1.0)[31, 33] and breastfeeding for fewer than six months (OR 2.2)[28] was associated with increased caries risk. Another study did not differentiate between feeding method, but reported that the duration of breast and bottle feeding for greater than one year increased the risk for caries (OR 6.2).[35] Only one study revealed that bottle use at 18 months of age was associated with caries (RRI 18).[26] Another indicated that bedtime feeding was associated with caries risk (OR 1.5)[31] and the use of a feeding cup was also reported to increase childhood risk for caries.[27]

Based on this evidence it would be prudent for a newly developed CRA tool to inquire about infant feeding practices and durations, but to separately ask about breastfeeding and bottle feeding.

As only one study reported that the use of a comforter or soother was associated with increased caries risk[27], this variable should not be included in a CRA tool.

Dietary Habits and Behaviours:

Snacking habits and behaviours were identified in eight of 11 studies. One study indicated that irregular meals and snacks increased the risk for caries (RRI 16 at 18 months).[26] Another revealed that eating snacks while playing increased risk (OR 2.3).[21] A third reported that the frequency of between-meal sweets was associated with greater risk for future caries development (OR 1.3).[31]

Two studies looked at the frequency of intake of sweets and reported associations with increased risk for decay; one indicated that the frequency of candy consumption was a risk factor (OR 3.6)[19] while the other revealed that the frequency of sweets increased risk (OR 1.4).[33] Three studies also mentioned that consuming food and drink at night increased children's risk for

caries.[18, 27, 31] Eating and drinking food at night (OR 3.0)[18, 27] and sweets at bedtime (OR 1.3)[31] were all reported to increase caries risk.

The consumption of cow's milk was found to be protective against caries at 18 months (RRI -12) and at 3 years (RRI -5). [26]Additionally, drinking anything except water between meals was associated with caries risk (OR 7.1)[18]. Sugar-sweetened beverage consumption (OR 3.0)[25], use of powdered beverages[30], and exposure and frequency of 100% juice (OR 0.4)[30, 36] were associated with future decay.

Based on this evidence, dietary practices and habits should be integrated into a CRA tool. This includes the frequency of snack foods and sugary drinks between meals.

Only two studies revealed data on the use of vitamins. One study reported that the use of vitamins was associated with an increased risk for caries[27] while the other indicated that the absence of vitamin D supplementation (OR 1.9) increased a child's risk for decay[29].

Dental Home and Dental Attendance Behaviours:

Dental home and dental attendance behaviours were identified in six of ten of the studies. Three studies reported that regular dental care is protective against caries.[29, 35, 38] One study indicated that follow-up visits to the dentists were protective (HR 0.1), another indicated regular dental care was protective (OR 0.5), while the other revealed that two or more visits per year was protective against caries (OR 0.1).[29, 35, 38] An additional study reported that not seeking annual dental check-ups for the child because their teeth did not bother the child was protective against caries[31]. Meanwhile, another study reported that children with previous visits to the dentist were at greater risk for caries (OR 4.6).[36] The author noted that this association might be due to parent-identified need to see a dentist and/or referrals to dentists by the study team[36]. Hong et al (2009) reported that the child's age at the time of their dental exam was predictive of caries (OR 7.6).[28]

Based on this evidence, a history of dental visits and presence of a dental home should be considered in a CRA tool.

Clinical Factors:

Previous caries experience was the most commonly identified factor from the included studies with nine of 25 reporting its association with increased caries risk. [19, 23, 30, 31, 33, 37-40] Another reported that the number of teeth with active non-cavitated caries lesions was also

associated with future caries development (HR 9.5).[38] Therefore, there is ample evidence to include previous caries experience in a CRA tool for preschool children.

The next most common clinical variable was presence of dental plaque or plaque index with an OR of 6.5, 8.9, 5.2 respectively.[29, 31, 33] Any newly developed instrument should include an assessment of visible dental plaque. Only two of the studies reported that enamel hypoplasia was a significant risk factor for future caries (OR 8.9 & 5.2).[22, 28] However, enamel hypoplasia has often been overlooked in past caries studies. Fortunately, there is growing recognition that enamel hypoplasia increases the risk for caries. Therefore, enamel defects, including enamel hypoplasia, could be considered for inclusion in a newly developed CRA tool.

Salivary & Bacterial Factors:

Two of four studies were found to report significant associations between saliva and oral pH and caries risk. One reported that an average oral pH (stimulated saliva flow) was protective against caries development (OR 0.2)[31] and the other revealed that reduced salivary flow increased the risk for caries (Multivariate mean 3.6, 95% CI 2.5-4.7) [39]. Based on this limited information there is little value in adding saliva flow and oral pH as variables in a newly developed CRA tool for preschool children, especially for use by non-dental professionals.

Five of nine studies reported that levels of mutans streptococci were significantly associated with future caries development with OR ranging from 2.1- 4.4, suggesting that consideration of this variable is warranted in CRA instruments.[18, 19, 25, 31, 33] Meanwhile, only two of five studies revealed an association between lactobacilli levels and future caries risk.

Environmental Scan of Caries Risk Assessment (CRA) Tools for Children < 6 Years of Age

An environmental scan of existing CRA tools for children < 6 years of age was also conducted. A total of 22 CRA tools were identified (see Table 5). While the majority are paper-based, some are electronic. These tools vary in formatting, phrasing of questions, and how responses are used to assign a level of risk. Overall, based on this environmental scan it would be prudent to consider including the following variables when developing a new CRA tool for use with preschool children:

Sociodemographic: Child's age, caries experience of the child's caregiver or siblings, family SES, special health care needs of the child

Behavioural: Dietary habits and practices, infant feeding histories and behaviours, oral hygiene and toothbrushing habits and behaviours, exposure to fluorides, dental attendance, and dental visit history

Clinical: Past caries experience of the child, active caries (cavitated or non-cavitated), incipient lesions, presence of plaque, and enamel defects, including enamel hypoplasia.

Discussion:

This systematic review identified risk factors for caries in preschool-aged children that informed the development of a Canadian pediatric CRA tool. Based on this systematic review, several sociodemographic, behavioural, and clinical variables could be incorporated into a new CRA tool for use with preschool children. Sociodemographic factors to consider include child's age and SES of the family (i.e., low SES and household income, parental education level). It is well recognized that the risk for caries increases as children get older as they have more teeth and these teeth have been subjected to longer periods of demineralization as compared to younger children. While SES should be included in CRA tools, it is important to recognize that collecting household income information is a sensitive matter, and not all parents and caregivers may feel comfortable providing such information.

Behavioural factors to consider include toothbrushing habits with fluoridated toothpaste (i.e., frequency, involvement of parents in supervising daily toothbrushing), exposure or lack of exposure to fluorides (i.e., fluoridated toothpaste, community water fluoridation), breastfeeding (i.e., frequency, duration > 12 months), bottle feeding (i.e., frequency, duration > 12 months, use at bedtime), dietary habits and behaviours (i.e., snacking and drinking between meals, intake of sugary beverages, intake of sweets), the existence of a dental home and dental attendance history (i.e., child has dental home, regular dental visits). Breast milk provides all the energy and nutrients that the infant needs according to the Dietary Reference Intakes from Health Canada and the World Health Organization recommend exclusive breastfeeding for the first six months after which infants should then be offered nutrient dense and safe complementary foods, along with continued breast feeding.[42, 43] Due to these recommendations, it may be best not to include questions about feeding history in a CRA tool intended for use by non-dental providers so that misconceptions about breastfeeding and caries are not perpetuated.

Additionally, clinical factors such as the caries experience of the child (i.e., past and current caries experience, past treatment of caries), and presence of visible plaque are important to assess. While developmental defects of enamel (e.g., enamel hypoplasia) are an important risk factor, they are not easily identified and thus not practical or realistic to include in a CRA instrument intended for use by non-dental providers. A recent study reported that many dentists' are unable to accurately recognize developmental defects of enamel revealing a need for further training and calibration.[44] Therefore, before we expect non-dental providers to screen for such defects, the dental profession needs to ensure its members are appropriately trained. As assessments of saliva flow and bacterial levels are essentially limited to clinical settings and are predictive of future caries risk, CRA tools that are designed for screening purposes and for use by non-dental professionals in non-clinical settings should not include assessments of these variables.[31, 33] Further, assessing cariogenic bacteria levels is not feasible or possible for a CRA tool developed for screening purposes and for use by non-dental professionals.

Since this systematic review was completed in the fall of 2017, we recognize that there have been additional publications that would have met our inclusion criteria. Some of these publications have confirmed our original findings while others have made some new discoveries. Not surprising, one Chinese study reported that high plaque mutans streptococci levels and past caries experience were associated with new caries development.[45] A 2018 study reported that caesarian delivery, parental smoking, siblings with caries, and drinking juice were associated with increased caries risk.[46] Similarly, a US study reported that prenatal and partner smoking were associated with increased caries experience in preschool children.[47] A fourth publication reported that preterm birth and small for gestational age at birth were associated with a higher risk for caries at 5 years of age.[48] Another revealed that brushing less than twice daily at two years of age and difficulties in performing brushing at two and three years of age were associated with greater caries risk.[49] Given the emerging discoveries, our team intends to update our systematic review in 2022 by reviewing all of this new evidence."

This systematic review was undertaken at the request of the OCDO of Canada at the Public Health Agency of Canada (PHAC). The OCDO convened important interprofessional stakeholder meetings to discuss the findings from this systematic review with participants from the OCDO, the Canadian Paediatric Society (CPS), Canadian Academy of Pediatric Dentistry, and the Canadian Association of Public Health Dentistry. Representatives from the Canadian

Dental Association, Canadian Dental Hygienists Association, Canadian Dental Assistants Association, Saskatchewan Dental Therapists Association, and the College of Family Physicians of Canada attended as observers. Participants discussed questions that should be included in a future Canadian CRA tool for preschool children.

Our team was subsequently contracted by the OCDO at PHAC to develop this Canadian CRA tool for children < 6 years for use by non-dental primary care providers and dental providers in non-dental clinical settings.[50, 51] This six-item tool is based on evidence from a systematic review of the literature and of existing pediatric CRA tools. We undertook focus group testing with 62 non-dental primary care providers (e.g., nurses/nurse practitioners (15), physicians (27), dieticians (6) to refine the tool. The OCDO, CPS, Canadian Academy of Pediatric Dentistry, and Canadian Association of Public Health Dentistry have all endorsed this tool (http://umanitoba.ca/CRA_Tool_ENG_Version.pdf). It has also been added into the online Rourke Baby Record©. A pilot validation of this CRA tool is underway and funded by the Network for Canadian Oral Health Research. Funding from the Canadian Institutes of Health Research now enables us to implement the CRA tool in Indigenous communities by training non-dental primary care providers to perform CRA. Our team is also hoping to report on the feedback obtained from focus group participants (Table 2), which shaped the tool's development and layout.

As previously mentioned, CRA tools are not without limitations. Only a handful are validated[52-54], some of the combined factor questions are not evidence-based, and many are developed by expert panels rather than based on systematic reviews of the literature. Fortunately, there is growing recognition that CRA tools must be evaluated and validated. This is why our team first conducted the systematic review of the literature, undertook the environmental scan of existing CRA tools, focus group tested our drafted tool with end users in order to refine it and are now undertaking a pilot validation study of this newly developed Canadian CRA tool for children < 6 years of age.

Involving non-dental primary care providers in CRA can improve access to dental care for many children via referrals and is a sustainable option in communities having paucity of dental professionals. A recent systematic review revealed that non-dental providers can successfully perform CRA to control ECC.[55] Another recent systematic review indicated that CRA tools for preschoolers have good accuracy and strongly endorsed and recommended the

practice of CRA despite there being a limited number of prospective trials to validate CRA tools.[56]

Few Canadian children benefit from early dental visits, which increases the risk for ECC, particularly in low socioeconomic areas.[57, 58] Those dwelling in rural and remote regions are less likely to receive early first initial exams.[59-61] Promising ways to improve early childhood oral health include CRA, promoting first visits by the first birthday, and establishing dental homes.[62, 63] Early adoption of preventive oral health routines sets the foundation for a lifetime of optimal dental health and earlier visits contribute to better dental outcomes, less restorative and emergency care, more prevention, and lower treatment costs.[57, 64-66] Engaging primary care providers in early childhood oral health promotion and CRA is needed to address ECC in Indigenous communities.

While CRA and preventive oral health care delivered by non-dental primary care providers is new in Canada[67-69], there are good lessons on integration from the United States.[70-81] Several studies show that primary care providers are willing and can successfully provide preventive oral health services (CRA, counselling, fluoride varnish, silver diamine fluoride) to children facing access to care challenges and that this can reduce the need for treatment under general anesthesia and resulting dental costs.[55, 72, 73, 79-87] A recent Canadian study revealed that primary care providers in Indigenous communities are willing to incorporate preventive oral care into their clinics[68], aligning with American Academy of Pediatrics and CPS recommendations to work interprofessionally to address ECC.[88, 89]

Conclusion:

This review identified factors significantly associated with caries onset in preschool children over time, which informed the development of a CRA tool for young children in Canada for use by primary care professionals, including non-dental providers. While it is important to have such a tool for screening purposes, there is considerable utility in developing a complementary tool for use by dental professionals. This tool has the potential to improve access to oral health assessments and interprofessional collaboration in the area of young children's oral health.

Why this paper is important to paediatric dentists?

- This review identified several key factors to be considered including in caries risk assessment tools for preschool children.
- Many children face access to primary oral health care challenges, highlighting the need for innovative and interprofessional approaches to improve early childhood oral health.
- This new Canadian CRA tool has the potential to improve access to oral health assessments and interprofessional collaboration in the area of young children's oral health.

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Table 1 – Inclusion Criteria for Reviewing Articles from Caries Risk Assessment Literature Search (modified from Mejàre et al[19] and Zero et al[29])

Study Design: ▪ Prospective/longitudinal cohort studies OR randomized controlled trial ▪ Studies using the same sample, but a different prediction model for caries risk are acceptable ▪ Studies using ≥ 1 risk factors/etiological factors/causative factors as a predictor of caries risk are acceptable (e.g. past caries experience; microbiological factors; host factors – enamel defects/hypoplasia, saliva flow rate; diet, socioeconomic; fluoride exposure; oral hygiene; etc.) ▪ Studies only looking at previous caries experience as a predictor of caries risk are acceptable.
Study Sample: ▪ Inclusion criteria for study defined, selection of study sample declared ▪ Population defined and representativeness of sample understandable (no appearance of selection bias) ▪ Demographic characteristics of participants described ▪ Clinical characteristics of participants described ▪ All participants initially involved should be included.

Methods: ▪ Caries diagnostic criteria described ▪ Predictor factors/variables are defined ▪ Validation variables are defined ▪ Studies involving only 1 dental examiner allowed if the same person completed both baseline and follow-up exams.
Follow-up Time: ▪ ≥ 1 year follow-up for primary teeth ▪ ≥ 2 year follow-up for permanent teeth.
Outcomes and Analysis: ▪ Caries incidence or caries increment (dentin and/or enamel) reported at the tooth and tooth surface level ▪ Predictive validity: sensitivity and specificity are reported, relative risk, odds ratio, hazard ratio, caries rate ratio (incidence density ratio) or area under ROC curve. For this systematic review we will only include articles that reported sensitivities and specificities derived from multivariate analysis, which allows us to compare predictors across included articles. ▪ Studies on post-eruptive age as a risk factor for caries will be included if caries rate (incidence density) or some other survival analysis is performed or possible to calculate from reported data in study.

Table 2 – Project Timeline

Date	**Activity**
June 2017	University of Manitoba based team contracted by the Office of the Chief Dental Officer (OCDO) of Canada, Public Health Agency of Canada, to undertake CRA project. This included a systematic review and drafting a CRA tool for children < 6 years of age primarily for use by non-dental primary health care providers.
June – October	Systematic review conducted by team.

November 2017	Completed systematic review report submitted to the OCDO. The report title: A Systematic Review of Evidence on Caries Risk Assessment for Preschool Children and Recommendations for the Development of a Canadian Caries Risk Assessment Tool for Screening Purposes.
March 2018	OCDO convenes an expert working group panel with key stakeholder groups to review the report and provide feedback. Expert working group discusses which factors are best suited and should be included in the CRA tool for use in non-dental clinical settings for use by non-dental primary health care providers and dental providers. Recommendation made to undertake focus group pilot testing of CRA tool.
May 2018	OCDO contracts the University of Manitoba team to undertake a critical appraisal of the evidence on caries risk in preschool children, focus group pilot testing of the CRA tool for use by primary health care professionals, and to refine the CRA tool based on feedback from stakeholders.
June – September 2018	Trial use of drafted CRA tool at preschool health and wellness fairs and multiple focus group sessions with predominantly non-dental primary health care providers. Multiple focus group sessions with 62 predominantly non-dental primary care providers (e.g., nurses/nurse practitioners (15), physicians (27), and dieticians (6)) were held in order to obtain feedback to refine the CRA tool.
October 2018	Revised report and feedback from focus group testing to refine CRA tool submitted to OCDO.
November 2018	OCDO convenes a meeting of the expert working group panel to review the revised report and review data obtained from the focus group pilot testing of the CRA tool. Revised CRA tool reviewed.
January 2019	Final report submitted to OCDO including final feedback from the expert working group.

April 2019	French translation completed by the Public Health Agency of Canada.
2019	OCDO of Canada disseminates report to members of the Federal Provincial Territorial Dental Directors Working Group and various provincial and territorial dental and dental hygiene regulators in Canada.
April – December 2019	Endorsement of CRA tool by Canadian Academy of Paediatric Dentistry, Canadian Association of Public Health Dentistry, and Canadian Paediatric Society.
January – February 2020	Launch of online version of Canadian CRA tool < 6 years of age. https://umanitoba.ca/CRA_Tool_ENG_Version.pdf Inclusion of CRA tool into online version of Rourke Baby Record.

Table 3 – Summary of Included Articles in Systematic Review (modified from Mejàre et al[19])

Reference	Age at Start (years)	Possible Predictors of Risk Assessed	Outcome in Final Model	Quality of Evidence
Leverett et al 1997[34]	Birth cohort	Prenatal fluoride supplementation Sex	Poisson regression: No significant association of prenatal fluoride supplementation with caries at age 3 to 5 years	⊕⊕⊕⊕ **High**
Pienihakkinen et al 2004[19]	2 years at baseline	Mutans streptococcus from plaque	Mutans streptococcus from plaque (OR 3.9)	⊕⊕○○**Low**

		Previous caries experience d1-3mfs Visible plaque Gingival Bleeding Fluoride use Frequency of candy consumption	Previous caries experience d1-3mfs (OR 7.3) Frequency of candy consumption (OR 3.6)	
Skeie et al 2004[40]	5 year olds	Previous caries experience	≥ 1 one caries lesion (d1-5mfs) on proximal surface or molars at 5 years of age (OR 4.4) Total d1-5mfs > one standard deviation above mean at 5 years of age (OR 3.8)	⊕⊕◯◯**Low**
Ji et al 2006[21]	1.5 years at baseline	Cariostat completed for each child Breastfeeding Eat snacks while playing Frequency of snacks Brushing assistance by mother Set time for snacks	Risk factors at 18 months to predict caries at 42 months: Breastfeeding (OR 3.3) Eat snacks while playing (OR 2.3) Risk factors at 30 months to predict caries at 42 months: Eat snacks while playing (OR 1.6) No brushing assistance	⊕⊕◯◯**Low**

			by mother (1.8)	
Alaki et al 2008[24]	Birth cohort	Acute otitis media (medical claims) Respiratory tract infections (medical claims) Urinary tract infections (medical claims Race Sex	Acute otitis media and respiratory tract infection at 0-12 months (HR 1.3) Male (HR 1.1) Hispanic (HR 1.8) African American (HR 1.6)	⊕⊕◯◯**Low**
Hong et al 2009[28]	0.5-2 years at baseline (Iowa Fluoride Study birth cohort)	Enamel hypoplasia Sex Childhood illness Gestational age Birth weight Breast-feeding for ≥ 6 months Fluoride concentration of home drinking water Average daily fluoride intake Average daily soda pop intake Daily toothbrushing frequency Previous caries experience	Logistic GEE model for caries at age 5 years: Enamel hypoplasia (OR 7.6) Dental exam age (OR 7.6) Breastfeeding < 6 months (OR 2.2) Average home tap water fluoride concentration 1.0 ppm (OR 2.4) Logistic GEE model for caries at age 9 years: Enamel hypoplasia (OR 5.2) Average daily toothbrushing frequency during 5-9 years old (OR	⊕⊕◯◯**Low**

			2.2) Logistic GEE model for caries incidence age 5-9: Previous caries experience (OR 5.1) Average daily fluoride intake during 5-9 years of age (OR 1.9) Average daily toothbrushing frequency during 5-9 years of age (OR 2.0)	
Warren et al 2009[25]	0.5-2 years at baseline (Iowa Fluoride Study birth cohort)	Age Presence of plaque Presence of *Mutans Streptococcus* Sugar-sweetened beverage consumption Night time bottle feeding	Age (OR 1.1) Presence of *Mutans Streptococcus* (OR 4.4) Sugar-sweetened beverage consumption (OR 3.0)	⊕⊕◯◯**Low**
Gao et al 2010[31]	3-6 years	Age Sex Race Country of birth Parents' education level Housing condition Feeding histories Diet habits Oral hygiene Fluoride applications	Prediction Screening Model: Age (OR 1.0) Malay race (OR 1.8) Father's education level (OR 0.6) Months of breastfeeding (OR 1.0) Frequency of between-meal sweets (OR 1.4)	⊕⊕◯◯**Low**

		Dental attendance Systemic disease Parental knowledge and attitudes on oral health Plaque pH *Mutans Streptococcus* levels Lactobacillus levels Past caries experience	No health problems (OR 2.9) Past caries experience (baseline) (OR 7.3) Plaque index (5.1) Full Prediction Model: Age (OR 1.1) Father's education level (OR 0.6) Months of breastfeeding (OR 1.1) Using fluorides (other than toothpaste) (OR 0.4) No annual dental check-up because teeth didn't bother child (OR 0.5) No health problems (OR 2.7) Past caries experience (baseline) (OR 3.9) Plaque index (8.9) *Mutans Streptococcus* levels (OR 2.7) Lactobacillus levels (OR 2.3) Average pH (OR 0.01) Risk Screening Model: Age (OR 1.1)	

			Months of breastfeeding (OR 1.0) Bedtime feeding (OR 1.5) Frequency of between-meal sweets (OR 1.3) Bedtime sweets (OR 1.3) Never lived in non-fluoridated community (OR 0.7) Plaque index (9.1) Full Risk Model: Age (OR 1.1) Months of breastfeeding (OR 1.0) Plaque index (7.4) *Mutans Streptococcus* levels (OR 2.6) Lactobacillus levels (OR 2.1) Average pH (OR 0.02) Community Screening Model: Age (OR 1.0) Malay race (OR 2.1) Using fluorides (other than toothpaste) (OR 2.6) Parent's belief that "tooth worm" as reason	

			for caries (OR 0.1) Parents do not know that bedtime milk bottle is bad for teeth (OR 2.0) Child`s number of decayed teeth estimated by parent (OR 12.8)	
Chankanka et al 2011[30]	≤ 0.5 years (Iowa Fluoride Study birth cohort)	Powdered beverages Soda pop Juice drinks 100% juice Milk Water only Daily toothbrushing frequency Water fluoride level Proportion of new non-cavitated lesions to surfaces at risk (10% change) Proportion of new cavitated lesions to surfaces at risk (10% change) Socioeconomic status Sex Dentition	General linear mixed models (GLMM) regression for non-cavitated caries: 100% juice exposure General linear mixed models (GLMM) regression for cavitated caries: Powdered beverage exposure 100% juice exposure Multivariate General linear mixed models (GLMM) regression for non-cavitated caries: 100% juice exposure – middle and high frequency (↓37-50%) Tooth brushing	⊕⊕◯◯**Low**

			frequency (↓33%) Proportion of new cavitated caries lesions to surfaces at risk (↑110%) High socieoeconomic status (↓42%) Multivariate General linear mixed models (GLMM) regression for cavitated caries: 100% juice exposure – high frequency (↓48%) Proportion of new non-cavitated caries lesions to surfaces at risk (↑253%)	
MacRitchie et al 2012[27]	1 year olds	Caries experience *Mutans Streptococcus* Lactobacillus Yeasts Height Weight Head circumference Immunization status Ethnic origin Illnesses	Model 1 – d1mft > 0 at age 4 years ("any caries risk" model): Health visitor opinion of caries risk Deprivation Category score	⊕⊕◯◯**Low**

		Medication Weaning Use of comforter (i.e. soother) Vitamin supplementation Feeding problems Family history Parental employment Parental health Parental smoking Housing status Health Visitor assessment if child at risk for caries Deprivation Category score Breast/bottle feeding Meals Drinks Snacks Toothbrushing Fluoride supplementation Sociodemographics	Parental smoking Breastfeeding Use of comforter (i.e. soother) Model 2 – d3mft >0 at age 4 years ("any caries risk" model): Health visitor opinion of caries risk Parental smoking Food and drink at night Model 3 – d1mft ≥ 3 at age 4 years ("high caries-risk" model): Type of housing Use of a feeder cup Model 4 – d3mft ≥ 3 at age 4 years ("high caries-risk" model): Type of housing	

			Health visitor opinion of caries risk Use of vitamins	
Gao et al 2013[12]	3 years old	NUS-CRA, Cariogram, AAPD CAT, CAMBRA Age Ethnicity Family socioeconomic status Infant feeding history Diet Fluoride Dental attendance Oral hygiene Past caries White spot lesions Enamel defects Dental appliance Systemic health Medication Salivary flow rate Salivary buffering capacity *Mutans Streptococcus* levels Lactobacillus levels	CAT (screening) ≥ high (RR 2.0, 95% CI 1.1-2.5) CAT (screening) excluding ≥ high (RR 1.8, 95% CI 0.99-2.4) CAT (comprehensive) excluding socioeconomic factors (RR 2.2 95% CI 0.95-2.6) CAMBRA (screening) ≥ moderate (RR 2.3 95% CI 1.8-2.5) CAMBRA (screening) ≥ high (RR 2.4 95% CI 2.1-2.5) CAMBRA (comprehensive) ≥ moderate (RR 2.2 95% CI 1.9-2.4) CAMBRA	⊕⊕◯◯**Low**

			(comprehensive) ≥ high (RR 2.3 95% CI 2.1-2.4) Cariogram (screening) ≥ 38.5% chance of caries (RR 2.2 95% CI 1.9-2.3) Cariogram (comprehensive) ≥ 37.6% chance of caries (RR 2.2 95% CI 2.0-2.4) NUS-CRA (screening) ≥ 32.8% chance of caries (RR 2.5 95% CI 2.3-2.5) NUS-CRA (comprehensive) ≥ 35.2% chance of caries (RR 2.5 95% CI 2.4-2.6)	
Hallett and O'Rourke 2013[39]	5-10 year olds (assessment included both primary and permanent teeth though)	CariScreen reading (to measure visible light release from dental plaque) *Mutans Streptococcus* reading (CariCult) Visible plaque Visible cavitations present Fillings within previous 3 years	Visible cavitations (Multivariate mean 3.9 95% CI 3.0-4.9) Reduced saliva flow (Multivariate mean 3.6 95% CI 2.5-4.7) Orthodontic appliances (Multivariate mean 4.2 95% CI 2.5-5.9)	⊕⊕◯◯**Low**

		Reduced saliva flow Exposed dentin Deep enamel pits and fissures Radiographic proximal lesions White spot enamel lesions (incipient caries) Orthodontic appliances		
Schroth et al 2014[22]	Birth cohort. Assessed factors prenatally and in infancy	Low annual income Child's health status Infant's teeth being cleaned or brushed Enamel hypoplasia Household employment Government assistance (i.e. social assistance) Infant age at time of dental exam Bottle feeding Breastfeeding Season Prenatal vitamin D level	Enamel hypoplasia (OR 8.9) Infant age (≥ 14 months) (OR 5.0) Prenatal vitamin D level (OR 2.0)	⊕⊕◯◯**Low**
Abanto et al 2014[38]	1-12 year olds (assessment included both primary and permanent teeth	Caries risk Gingival bleeding index Dental plaque index Caries experience Lesion activity assessment Number of teeth with active non-cavitated	Survival analysis for new initial caries lesions (adjusted model): Past caries experience (dmft index) (HR 1.9 95% CI 1.4-2.7) Follow-up dental visits	⊕⊕◯◯**Low**

	though)	lesions Sex Age Caregiver of child Use of dental floss Follow-up dental visits	(HR 0.2 95% CI 0.1-0.6) Number of teeth with active non-cavitated lesions (HR 9.5 95% CI 5.6-16.2) Survival analysis of active initial lesions (adjusted model): Number of teeth with active non-cavitated lesions (HR 1.3 95% CI 1.1-1.5) Male (HR 0.8 95% CI 0.6-0.9) Follow-up dental visits (HR 0.1 95% CI 0.05-0.1)	
Peltzer et al 2014[41]	Birth cohort. Assessed factors prenatally and in infancy. First dental exam at 2 years	Drinking water in household Birthweight Height at 6 months Smoking during pregnancy Secondary smoke (at 1 year) Mother had dental cavitation(s) at baseline Mother's age at birth	Drinking water in household (rain, well or other) (OR 2.0) Mother completed high school (OR 2.5) Mother completed post-high school (OR 3.2) Household income	⊕⊕◯◯**Low**

		Mother's education at birth Household income Religious affiliation Single parent Family size Sex of child Frist child in family Psychological distress of mother Psychological distress of father Parenting style Family distress Family support index Spousal relationship (mother) index Spousal relationship (father) index Infant feeding (at 6 months) Nocturnal feeding at 12 months Introduction of soft drinks (at 12 months) Sleeping with bottle (at 30 months) Brushing teeth in past 2 weeks (at 12 months) Sweet candy in days in a week (at 30 months)	$100,000-$199,999 (OR 0.4) Household income ≥ $200,000 (OR 0.3)	

		Brush with toothpaste (at 12 months) Brushing teeth (at 26 months) Previous dental visit (at 30 months)		
Gao et al 2014[33]	3-5 year olds	Parent's education level Type of housing Age Sex Ethnicity Feeding history Diet habits Oral hygiene Fluoride exposures Dental attendance Parental knowledge, attitudes and self-efficacy in protecting children's teeth *Mutans Streptococcus* levels Lactobacillus levels Past caries experience	*Mutans Streptococcus* levels: Dentocult score 1 (RR 2.0) Dentocult score 2 (RR 3.4) Dentocult score 3 (RR 4.6) Lactobacillus levels: Dentocult score 1 (RR1.9) Dentocult score 2 (RR 2.7) Dentocult score 3 (RR 2.7) Past caries experience (RR 1.6) Model with *Mutans Streptococcus*: Age (months) (OR 1.1) Malay race (OR 1.8) Father's education (OR 0.7)	⊕⊕○○**Low**

			Months of breastfeeding (OR 1.0) Fluoridated toothpaste (OR 0.6) No health problems (OR 2.4) Past caries experience (OR 4.3) Plaque index (OR 5.2) *Mutans Streptococcus* (OR 2.2) Model with Lactobacillus: Age (months) (OR 1.0) Father's education (OR 0.6) Months of breastfeeding (OR 1.0) Frequency of sweet (OR 1.4) Fluoridated toothpaste (OR 0.6) No health problems (OR 2.4) Past caries experience (OR 4.8) Plaque index (OR 5.2) Lactobacillus (OR 1.9) Model with *Mutans Streptococcus* and	

			Lactobacillus: Age (months) (OR 1.1) Father's education (OR 0.6) Months of breastfeeding (OR 1.1) Fluoridated toothpaste (OR 0.6) No health problems (OR 2.2) Past caries experience (OR 3.0) Plaque index (OR 5.2) *Mutans Streptococcus* (OR 2.1) Lactobacillus (OR 1.9)	
Yokomichi et al 2015[26]	< 1 year of age	Sex Birth weight Age of mother Gestational age Birth order Number of teeth (at 18 months) Parental employment Bottle use (at 18 months) Dental fluoridation experience (at 3 years) Parental smoking (at 3 years) Sibling < 6 years (at 3 years)	Boys (RRI 3) Birth weight ≥ 4,000 g (RRI 19) Birth weight < 2,500 g (RRI -5) Age of mother < 25 (RRI 17) Age of mother ≥ 35 (RRI 2) Not first born child (RRI 26) 14-20 teeth at 18 months (RRI 13) Both parents unemployed (at 3 years)	⊕⊕◯◯**Low**

		Someone who supports child rearing (at 3 years) Parental brushing child's teeth (at 18 months) Parental brushing child's teeth (at 3 years) Drinking cow milk (at 18 months) Drinking cow milk (at 3 years) Irregular meals and snacks (at 18 months) Irregular meals and snacks (at 3 years) Watching TV or video daily (at 3 years)	(RRI 11) Bottle use (at 18 months) (RRI 4) Parental smoking (at 3 years) (RRI 15) No one supports child rearing (at 3 years) (RRI 17) Parents sometimes or never brushing child's teeth (at 18 months) (RRI 18) Parents sometimes or never brushing child's teeth (at 3 years) (RRI 22) Drinking cow milk (at 18 months) (RRI -12) Drinking cow milk (at 3 years) (RRI-5) Irregular meals and snacks (at 18 months) (RRI 16) Irregular meals and snacks (at 3 years) RRI 16	
Ghazal et al 2015[36]	< 2 years old	Age Sex Delivery type (standard, C-section, forceps, other) Premature delivery Birthweight Allergies	Model A – 3 year incidence: Premature delivery (< 37 weeks) (OR 0.2) 100% juice consumption ≥ 1 time per day (OR 0.4)	⊕⊕◯◯**Low**

		Chronic systemic medical condition Acute illness in previous 6 months Breast fed Bedtime bottle Bottle use Beverages consumed (type, frequency, timing) Methods of drinking liquids other than water Amount of beverages consumed Toothbrushing Toothpaste Dental history Sources of drinking water Use of vitamin drops or tablets with fluoride History of dental problem Reason for last dental visit Presence of regular dentist	Model B – Incidence from age 2 to 3 years: Greater daily frequency of toothbrushing at baseline (OR 0.3) Previous visit to dentist (OR 4.6)	
Wagner and Heinrich-Weltzien 2016[29]	Birth cohort (< 12 months of age)	Caries experience Sex Migration background Socioeconomic status Single parent	Model of associations between caries experience of children and low socioeconomic status, family early	⊕⊕○○**Low**

		Mother/primary caregiver has active caries Family early childhood caries burden Preterm birth General disease/special health care needs Medication Systemic antibiotic medication No use of vitamin D supplements Child has > 3 between-meal sugar-containing snacks/beverages per day Child is put to bed with a bottle containing natural or added sugar Child's teeth were brushed daily with fluoridated toothpaste Child receives topical fluoride from health professional Child has dental home/regular dental care Enamel defects Plaque on teeth	childhood caries burden, systemic antibiotic medication, no use of vitamin D supplements, receives topical fluoride from health professional, child has regular dental care and child has plaque on teeth: Family early childhood caries burden (OR 2.2) No use of vitamin D supplements (OR 1.9) Child has regular dental care (OR 0.5) Plaque on teeth (OR 6.5)	

Hultquist & Bagesund 2016[18]	1 year olds	Siblings Siblings have dental caries Child eats or drinks anything except water at night Child still breastfed Child has illness/disease Child regularly takes medication Child drinks anything except water between meals Parent brushes child's teeth Number of teeth visible in mouth *Mutans Streptococcus* counts	Siblings have dental caries (OR 4.8) Child eats or drinks at night (OR 3.0) Child drinks anything except water between meals (OR 7.1) High level of *Mutans Streptococcus* (score 2-3) (OR 3.4)	⊕⊕○○**Low**
Lin & Lin 2016[20]	Mean age 4 years at baseline who underwent pediatric dental surgery for ECC	Gender Age Father's education level Mother's education level Diet frequency per day Snacks/drinks between meals Bedtime sweet without brushing Brushing by child or parent Frequency of tooth	Score of caries risk assessment using Cariogram (OR 1.1)	⊕⊕○○**Low**

		brushing Buffer capacity of saliva *Mutans Streptococcus* count Lactobacillus count Plaque index (oral hygiene status) Score of caries risk assessment		
Wang et al 2016[23]	3-5 year olds	Caries status (dmft) Sex Age Parental education Parental occupation Income Eating habits Oral hygiene behaviours	Caries experience (OR 5.0) Parent helps child brush teeth daily (OR 0.9) Parents consider caries in primary teeth need to be treated (OR 1.3)	⊕⊕◯◯**Low**
Correa-Faria et al 2016[37]	4-7 year olds	Sex Caries Oral hygiene Place of residence Mother's education level Household income Age	Previous caries experience (RR 1.5)	
Wagner and Heinrich-Weltzien 2017[35]	Birth cohort (< 12 months of age)	Sex Age Migration background Socioeconomic status Age at start of tooth brushing	Model of association between caries experience in children and low socioeconomic status, start of tooth brushing,	⊕⊕◯◯**Low**

		Frequency of tooth brushing Supervision of tooth brushing/regular second brushing by parent Use of fluoride salt and/or fluoride toothpaste Age at first dental visit Number of dental visits/year Application of fluoride varnish Frequency of in-between meals Consumption of sugar-containing snacks/beverages per day Duration of breastfeeding Duration of bottle feeding Previous caries experience	supervision/regular second brush by parent, frequency of tooth brushing, first dental visit, frequency of dental visits, application of fluoride varnish, frequency of in-between meals, sugar-containing snacks/beverages per day, duration of breastfeeding > 1 year, duration of bottle feeding > 1 year: Low socioeconomic status (OR 10.4) Started brushing in first year of life (OR 0.2) Supervision/regular second tooth brushing by parent (OR 0.1) ≥ 2 dental visits per year (OR 0.1) Duration of breast-/bottle-feeding > 1 year (OR 6.2)	

Bernabe et al 2017[32]	1 year	Sex Birth order Birth weight Maternal age at birth Maternal education Breastfeeding duration Marital status Maternal smoking Parental employment Area deprivation Child's toothbrushing frequency	Age (coefficient 0.16, 95% CI 0.12-0.21) Final Linear Mixed Effects model: Birth weight (p=0.039) Parental employment (p<0.001) Maternal smoking (p=0.006) Maternal education (p<0.001)	⊕⊕○○**Low**

Note: Odds Ratio (OR), Relative risk (RR), Hazard Ratio (HR)

Factor/Variable	# of Studies that include that factor	# of Studies which show significant association	Range of effect sizes	Expert opinion on inclusion of this factor (Yes/No)

Table 4 – Level of association between risk factor and caries

Sociodemographic & family factors				
Age[22, 25, 31-33]	11	5	OR 1.1 – 5.0	Yes
Sex[24, 26, 38]	16	3	HR 1.1 – 3.0	No
Ethnicity[24, 31, 33]	5	3	HR 1.1, 1.8 OR 1.8, 2.1	No
Household socioeconomic factors[26, 27, 30, 32, 35, 41]	11	6	2.38X OR 0.3 - 10.4 RRI 11 p<0.001	Yes
Housing type[27]	3	1	Data not available	No
Household water[41]	2	1	OR 2.0	No
Parental education level [31-33, 41]	4	7	OR 0.6 - 3.2 P < 0.001	No
Maternal age [26]	3	1	RRI 2 , RRI 17	No
Parental smoking[26, 27, 32]	4	3	RRI 15 , p = 0.006	No
Acute Otitis media [24]	1	1	HR 1.3	No
No health problems [31, 33]	2	2	OR 2.2 – 2.9	No
Prenatal Vitamin D[22]	1	1	OR 2.0	No
Premature Delivery (< 37 weeks)[36]	2	1	OR 0.2	No
Birth weight[26, 32]	5	2	RRI -5, RRI 19 p= 0.039	No
Parent Attitude [23, 31]	3	2	OR 0.1 - 2.0	No
Not first born child[26]	1	1	RRI 26	No

Lack support with child rearing[26]	1	1	RRI 17	No
Family ECC burden[29]	1	1	OR 2.2	No
Siblings have dental caries[18]	1	1	OR 4.8	No
Behavioural Factors				
Frequency of Toothbrushing [28, 30, 36]	9	3	OR 2.0 – 4.6	Yes
Initiating brushing in the first year of life[35]	1	1	OR 2.0	No
Parental supervision or assistance with toothbrushing [21, 23, 26, 35]	6	4	OR 0.1 – 1.8, RRI 18	Yes
Exposure to Fluorides[28, 31, 33]	11	3	OR 0.4 – 2.6	Yes
Evidence of Breastfeeding and duration of breastfeeding (BF)[21, 27, 28, 31, 33]	10	5	OR 1.0 – 6.2	Yes
Comforter or Soother [27]	1	1	Data not available	No
Snacking habits and behaviours [19-21, 26, 27, 30, 31, 33]	11	8	OR 1.4 – 7.1 RRI -5, RRI -12, RRI 16	Yes

Dental home and dental attendance behaviours [28, 29, 31, 35, 36, 38]	10	6	OR 0.1 – 7.6 HR 0.1	Yes
Clinical factors				
Previous caries experience [19, 23, 30, 31, 33, 37-40]	25	9	OR 3.9, OR 4.3, OR 4.4, OR 5.0, OR 5.1, OR 7.3, OR 7.6, HR 1.9, RR 1.5, RR 1.6	Yes
Active non-cavitated caries lesions[38]	1	1	HR 9.5	Yes
Dental plaque or plaque index [20,22.36]	7	3	OR 5.2, 6.5, 8.9	Yes
Enamel hypoplasia [28, 90]	5	2	OR 8.9, OR 5.2	Yes
Having 14-20 teeth by 18 months[91]	1	1	RRI 4	No
Orthodontic appliance[92]	1	1	Multivariate mean 4.2, 95% CI 2.5-5.9	No
Salivary & Bacterial Factors				
Saliva and oral pH[31, 39]	4	2	OR 0.01, 0.02 multivariate mean 3.6	No
Mutans Streptococcus[18, 19, 25, 31, 33]	9	5	OR 2.1 - 4.4	Yes

Table 5 – Inventory of identified caries risk assessment tools for children < 6 years of age

Factors	ADA	AAPD (age 0-3)	AAPD (age 0-5)	AAP	Bankel	CAB	CAMBRA	CF	CMS
Socio-demographic									
Age	✓			✓			✓		✓
Ethnicity									
Family SES	✓	✓	✓	✓					
Recent immigrant		✓	✓						
Special health needs	✓	✓	✓	✓			✓	✓	
Caries experience of caregiver/siblings	✓	✓	✓	✓			✓	✓	
Educational level of caregivers/Health literacy							✓		
Behavioural									
Infant feeding history		✓	✓	✓	✓		✓	✓	
Diet	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fluoride	✓	✓	✓	✓		✓	✓		✓
Dental attendance	✓	✓	✓	✓				✓	
Parental attitudes/beliefs								✓	
Tooth brushing habits		✓	✓	✓			✓		✓
Clinical									
Oral hygiene/ Plaque	✓	✓	✓	✓		✓	✓	✓	✓
Past caries		✓	✓	✓	✓	✓	✓	✓	✓
White spot lesions or Active caries (cavitated/Non-cavitated)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Enamel defects		✓	✓				✓		
Dental appliance	✓							✓	
Systemic health						✓	✓	✓	
Medication							✓	✓	
Other oral concerns (e.g. Gingivitis)				✓					
Protective factors (e.g. sealants)									
Salivary & Bacterial									
Saliva flow	✓					✓	✓	✓	
Saliva buffering capacity									
Mutans Streptococci			✓		✓		✓		

Lactobacilli							✓		
Reduced pH									

Factors	CG	DCRAM	EBHnow (McGill)	FDI	Maine	MSB	NUS	PRAT
Socio-demographic								
Age			✓	✓	✓		✓	✓
Ethnicity		✓					✓	
Family SES		✓		✓			✓	
Recent immigrant		✓					✓	
Special health needs			✓					
Caries experience of caregiver/siblings		✓	✓	✓	✓	✓		
Education level of caregivers/Health literacy				✓			✓	
Behavioural								
Infant feeding history		✓	✓			✓	✓	✓
Diet	✓	✓	✓	✓		✓	✓	✓
Fluoride	✓	✓	✓	✓		✓	✓	
Dental attendance			✓		✓	✓	✓	
Parent attitudes/beliefs		✓				✓	✓	
Tooth brushing habits		✓			✓	✓		✓
Clinical								
Oral hygiene/ Plaque	✓	✓	✓	✓	✓		✓	✓
Past caries	✓		✓	✓	✓	✓	✓	✓
White spot lesions or active caries (Cavitated/Non-cavitated)	✓	✓	✓	✓	✓		✓	
Enamel defects			✓					
Dental appliance			✓					
Systemic health	✓	✓	✓				✓	
Medication	✓	✓		✓				
Other oral concerns (e.g. Gingivitis)	✓		✓		✓			
Protective factors (e.g. sealants)				✓				

Salivary & Bacterial								
Saliva flow	✓			✓				
Saliva buffering capacity	✓			✓				
Mutans Streptococci	✓	✓	✓				✓	
Lactobacilli	✓	✓	✓				✓	
Reduced pH				✓			✓	

Factors	**SSC**	**Texas (6 -35 months)**	**Texas (3-5 years)**	**UCC (Ireland)**	**WesternU CDM**	**Total**
Socio-demographic						
Age	✓	✓	✓	✓		13
Ethnicity						2
Family SES						7
Recent immigrant						4
Special health needs		✓	✓		✓	10
Caries experience of caregiver/siblings		✓	✓		✓	14
Education level of caregivers/Health literacy						3
Behavioural						
Infant feeding history		✓	✓		✓	14
Diet	✓	✓	✓	✓	✓	21
Fluoride		✓	✓	✓	✓	17
Dental attendance		✓	✓		✓	12
Parent attitudes/beliefs						4
Tooth brushing habits				✓		10
Clinical						
Oral hygiene/ Plaque	✓	✓	✓		✓	19
Past caries	✓	✓	✓	✓	✓	20
White spot lesions or active caries (cavitated/Non-cavitated)	✓	✓	✓	✓	✓	20
Enamel defects		✓	✓	✓		7
Dental appliance					✓	4
Systemic health				✓	✓	9
Medication						5
Other oral concerns (e.g.		✓	✓	✓		7

Gingivitis)						
Protective factors (e.g. sealants)				✓		2
Salivary & Bacterial						
Saliva flow	✓	✓	✓		✓	10
Saliva buffering capacity	✓					3
Mutans Streptococci	✓					8
Lactobacilli	✓					6
Reduced pH						2

ADA – American Dental Association

AAPD- American Academy of Pediatric Dentistry (AAPD)

AAP- American Academy of Pediatrics

Bankel – Bankel et al.

CAB- Cabral, Hilgert, Faber, & Leal et al. (University of Brasilia)

CAMBRA- Caries Management by Risk Assessment

CF- CariFree

CMS – Caries Management System

CG- Cariogram (Electronic Program)

DCRAM- Dundee Caries Risk Assessment Model

EBHnow- (McGill University) Online Search Engine for CRA

FDI- World Dental Federation

Maine- Maine Oral Health Risk Assessment and Referral Tool

MSB- My Smile Buddy (Electronic iPad based program)

NUS- National University of Singapore Caries Risk Assessment

PRAT- Pediatric Risk Assessment tool (Shenkin et al.) Academy of General Dentistry

SSC- Sugar Snack Caries Risk Test

Texas - Texas Department of State Health Services

UCC- University College Cork (Ireland)

WesternU (CDM) – AxiUm Electronically Modified-Caries Risk Assessment Form 0-5 Years of Age