An overview of caries risk assessment in 0-18 year-olds over the last ten years (1997-2007)

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Abstract

This study aimed to review the dental literature about caries risk assessment over the last 10 years in order to show which variables have been considered risk predictors and risk factors of dental caries in infants, preschool-, schoolchildren and adolescents. A Medline search of the published English language literature from 1997 to 2007 was made for papers of longitudinal studies that reported on caries risk assessment. A total of 39 papers were included in this review. Most studies were conducted in schoolchildren (n = 19), followed by preschool children (n = 9), adolescents (n = 7) and infants (n = 4). Variables such as caries experience, gingival status, microbiological counts, oral hygiene, plaque mineral concentration, fluoride history, socioeconomic and educational level, demographic, anthropometrical, oral, dietary and toothbrushing habits were studied. Past caries experience has been the predominant predictor for future caries in 0-18-year-old subjects. Other variables, such as dietary habits, including sugar intake, and toothbrushing habits may also help identifying high-risk individuals. In conclusion, the variables related to caries experience continue to be the main predictor of caries increment.

Key words: dental caries; risk; assessment; prediction

Introduction

One of the main goals of Dentistry has been to prevent dental caries, which has been, according to Aoba and Fejerskov[1], the predominant cause of tooth loss in all populations worldwide.

In general, two preventive strategies can be used to prevent and/or control caries disease: the "high-risk strategy", which is directed towards individuals particularly susceptible to developing dental caries[2], and the "population strategy", which endeavors to protect all the people, including high and low caries risk individuals. Burt[3] has referred to the "geographically targeted strategy", in which the preventive measures are targeted to a sub-group or a specific area of the city/country, such as schools in deprived areas of the city or an area of immigrant population. However, all strategies have the same goal: to prevent and/or to control the development of new carious lesions or to arrest the progression of preexisting lesions. In spite of increase in the adoption of preventive measures, it seems that for a minority of children these procedures have been insufficient for preventing and controlling the disease, as the majority of carious lesions are concentrating in this group. Therefore, oral health care providers have been adopted the "high risk strategy" for these individuals.

If individuals with a risk for developing dental caries are correctly identified, planning specific measures for caries control and prevention may become a biological and socioeconomic measure, increasing the efficiency of preventive programs, as emphasized by Giannoni et al.[4]. Moreover, identifying caries risk factors/predictors allows selecting the individuals or population groups that will really benefit from preventive measures. This makes it possible to use specific and appropriate preventive measures in target people and may work as an alert for conducting a more detailed dental examination. In addition to the aforementioned advantages, knowing caries risk factors is decisive in detecting those with initial carious lesions, who may benefit from novel and emergent preventive

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technologies[5]. Fontana and Zero[6] discussing caries risk assessment in private practice have recommended that factors such as caries experience, dietary habits, fluoride exposure, presence of cariogenic bacteria, salivary status, general medical history and sociodemographic characteristics should be evaluated when assessing the patient's caries risk.

Assessing caries risk consists of determining which individuals are more or less likely to prevent or to control dental caries in the future by means of knowing the variables associated with the disease[5]. Caries risk assessment studies can be performed using cross-sectional data, in which the subjects' data, usually about a disease prevalence or severity, are collected once or longitudinal data, in which the individuals are examined repeatedly over time. In addition to clinical variables, several others such as, socioeconomics, demographics, and behavioral characteristics can be used to assess their effects on caries levels (cross-sectional studies) or in caries incidence and/or increment (longitudinal studies). Although longitudinal studies are expensive, difficult to conduct and depend on the participants´ willingness, their results are stronger than those obtained in cross-sectional studies[7]. Moreover, when assessing caries risk, the use of multiple regression analysis is preferable[8-9] since the etiology of dental caries is multifactorial.

The aim of this work was to review the dental literature about caries risk assessment over the last 10 years (1997-2007), in order to show which variables have been considered caries risk factors/predictors in longitudinal studies conducted in infants, preschool-, schoolchildren and adolescents.

Concepts and Terminology

As one of the study's aims is to review the dental literature about risk factors and risk predictors in longitudinal studies of dental caries, it is important to consider the following terms.

Risk factor has been defined by Beck[8] as "an environmental, behavioral or biologic factor confirmed by temporal sequence, usually in longitudinal studies, which if present directly increases the probability of a disease occurring, and if absent or removed reduces the probability. Risk factors are part of the causal chain, or expose the host to the causal chain. Once disease occurs, removal of a risk factor may not result in a cure".

Risk predictor is also named by Beck[8] as a risk marker, and is defined as a characteristic associated with a high risk for the disease. The risk predictor predicts well but it is not thought to be part of the causal chain. As a good example, past caries experience has been strongly associated with a high risk for caries increment in the future. However, this variable is not part of the causal chain and is therefore considered a risk predictor. Moreover, it has been reported that in case of preventive measures being introduced in the studied caries risk group to reduce the disease activity, past caries experience becomes a risk predictor with reduced worth.

In this study, the expressions "risk factor" (RF) and "risk predictor" (RP) will be used for classifying those variables statistically associated with caries increment in multivariate regression analyses, if they were either part (RF) or not (RP) of the causal chain of dental caries.

Material and Methods

A search of the English Language literature published from 1997 to 2007 was made in the Medline database for articles that reported on caries risk assessment using the following descriptors: longitudinal caries risk. Furthermore, MeSH Database PubMed Service was used with some of the cited terms: "Longitudinal Studies"[MeSH] AND "Dental Caries"[MeSH] AND "Risk"[MeSH]. The limits for the search included: "Publication Date from 1997 to 2007"; Language: English; Ages: "All Child: 0-18 years". Studies were selected if they met the following criteria: longitudinal study conducted with children aged 0-18 years, providing information on sample size, age at initial examination (baseline), variables collected at baseline, study lasting, statistical tests used and a measure of caries increment/ incidence as an outcome variable. In accordance with the search criteria, 189 papers were retrieved. A total of 59 were selected by reading the title and among them 30 were selected by reading the abstract and/or the full text. Twenty-nine papers were excluded because they did not report the outcome variable as caries incidence/increment (n = 9), were review articles (n = 2), validation study (n = 1) evaluation/comparative studies (n = 11) or used cross-sectional data (n = 6). Moreover, hand searching was performed from the citations of the identified reports (n = 3) and other key papers (n = 6). Therefore, a total of 39 papers were included in this review.

A variable that is part or expose the host to the causal chain of dental caries and remained statistically significant in multivariate regression models was considered risk factor. Risk predictor was considered the variable that is not part of the causal chain of dental caries and remained statistically significant in multivariate regression models.

Results and Discussion

Researches on caries risk assessment have been conducted since the 1980's, focused on developing an easy tool for identifying high-caries-risk individuals[10]. Published studies in general have studied clinical, microbiological, salivary, socioeconomic and demographic data, medical history, dietary habits, fluoride history, use of dental services and dental health behaviors, separately and in combination to identify high-caries-risk individuals.

According to the dental literature, the use of caries increment during a period of time is the primary outcome measure[11] and statistical analysis based on logistic regression with multiple factors are preferable because of the complex and multifactorial etiology of the caries process[8].

Tables 1 to 4 present a detailed review of the papers published over the last 10 years (1997-2007) about caries risks assessment in infants (<2 years), preschool children (2-5 years), schoolchildren (6-12 years) and adolescents (13-18 years) is presented. The age groups were established based on those of Medline. The studies on caries risk assessment during the last 10 years were conducted mainly in schoolchildren (n=19), followed by preschool children (n=9), adolescents (n=7), and infants (n=4). The majority of them were related to data collected in Finland (n=7), followed by Brazil (n=4), Sweden (n=3), China (n=3), Norway (n=3), USA (n=3), the Netherlands (n=3), Belgium (n=2), Greece (n=2), Japan (n=2), Australia (n=1), Denmark (n=1), Germany (n=1), Israel (n=1), Italy (n=1), Mexico (n=1) and New Zealand (n=1). As one can see, European countries have contributed a great deal to the dental literature on caries risk assessment over the last decade. For classifying a variable as a risk factor (RF) or risk predictor (RP), the study had to use multivariate regression analyses including several variables in the regression models.

There are few studies targeting infants at baseline examination, and these collected mainly dental variables (Table 1). Only one study[12] used logistic regression models with multiple variables for identifying risk predictors/factors (RP/RF) for caries development, which are the preferable model for this type of study, as dental caries presents a multifactorial and complex etiology[8]. In the Pienihäkkinen's et al.[12] study the mutans streptococcus counts, the presence of incipient caries lesions, and the use of candies were predictors for caries increment after a 3-year-follow-up. Another study[13] used survival analysis and identified the consumption of candies and the lack of daily toothbrushing as the variables that impacted on caries onset. As one can see, sugar consumption is an important variable that may identify children at risk of caries in this age group. It is an important finding since according to Zero[14], the relationship between sugar consumption and dental caries is less strong in comparison to that from the prefluoride era. Therefore dietary counseling is highly recommended to mothers and should be part of oral health preventive programs in public health services. Considering the small number of studies in this age group during the last 10 years, further studies should be conducted and make use of more appropriate statistical analysis.

As regards studies concerning preschool children (Table 2), 9 papers published over the last 10 years were selected. Variables such as dental, socioeconomic, behavioral, dietary, microbiological, medical and demographic data have been collected in study periods ranging from 0.5 to 10 years. Most studies (n=7) used regression models as statistical analyses and showed that the main risk predictor was caries experience and the risk factors were sugar consumption and the presence of plaque/toothbrushing related habits. Caries experience detected at baseline has

Table 1 - Review of literature on caries risk assessment in infants (0-2 years old) over the last 10 years (1997-2007)

Author, year and local	Sampl e*	Ag e†	Variables collected at baseline (VB) Examination (EX)	Tim e‡	Data Analysis ¶	Outcome Variable	Main results RP/RF§
Yonezu and Machida[18], 1998 (Tokyo), Japan	374	1.5	**VB**: Caries (cavitation): decayed or filled primary teeth (dft) **EX:** Mirror, explorer, optimal light after drying (cotton/air)	1.5	CS, St	Differences in dft scores	Developing caries before the age of 2 indicated that a child is at risk for dental caries
Mattos-Graner et al.[19], 2000 (Piracicaba), Brazil	142/101	1-2.5	**VB**: Caries (initial + manifest lesions), plaque on the labial surf aces of upper incisors, mutans streptococci virulence factors (MS acidogenesis, water-insoluble glucan synthesis - WIG, adherence analysis) **EX**: Dental surfaces brushed and dried with gauze	1	MW, CS, CA	Caries incidence (high risk: ≥3 manifest caries)	Mean new lesions: 1.7 (9% developed ≥3 manifest caries) Caries incidence associated with high MS levels and positively correlated with WIG synthesis
Pienihäkkinen et al.[12], 2004 (Saarijärvi), Finland	226•	2	**VB**: Caries – dmfs (incipient caries lesions in enamel + dentinal lesions), sealan ts (surface level), presence of visible plaque (VP), gingival bleeding (GB) on buccal tooth surfaces, Mutans streptococci (MS) from proximal surface of a central maxillary incisor and of the most distal mandibular right molar, questionnaire (consumption of fluorides and candies) **EX:** Dental unit with good light and compressed air, mirror with 1.6 -fold magnification, blunt periodontal probe and fiber-optic transillumination	3	MLR, ROC	Increment of cavitated carious lesions and or fillings >0	RP: incipient caries lesions; RF: MS strip, use of candies None of the studied variable reached an accuracy of 80%
Ollila and Larmas[13], 2007 (Oulu), Finland	183	2	**VB**: Caries (initial: restricted to the enamel + manifest caries: i n dentin needing restorative dental care), questionnaire (consumption of candies, use of fluo ride tablets, toothbrushing, pacifier sucking, use of a nursing bottle at night, prolonged beastfeeding) **EX**: Local health center dentists (normal routines)	7	SA	Timing of caries onset on primary and permanent molars	RF: lack of daily toothbrushing, consumption of candies

Table 2 - Review of literature on caries risk assessment in preschool children (2-5 years old) over the last 10 years (1997-2007)

Author, year and local	Sample*	Age†	Variables collected at baseline (VB) Examination (EX)	Time‡	Data Analysis ¶	Outcome Variable	Main results RP/RF§
Mattila et al.[20], 1998 (Turku), Finland	1292/1003	3	**VB**: Caries (enamel lesions + dmf index), dental cleanliness (no disclosing solution), questionnaire (basic educational level, occupational education,occupation, toothbrushing behaviors, use of xylitol chewing gum, snacking on sweets and frequency of snacking, drinking something other than pure water) **EX**: Public dental centers	2	CS, MW, KW, W, MLR	Changes in dmf index	RP: Mothers' education (up to nine years of basic education), presence of caries; RF: presence of plaque
Ollila et al.[21], 1998 (Oulu), Finland	166/152	2.5 (mean)	**VB**: Caries (initial + manifest caries), salivary lactobacilli andcandida, questionnaire (pacifier- and thumb-sucking, breastfeeding, bottle-feeding at night, social class of the family) EX: At dental health centers	2	CS, MLR	Occurrence of caries (yes/no)	RP: pacifier-sucking ≥ 2 years; RF: use of nursing bottle at night
Thibodeau and O'Sullivan[22], 1999 (Hartford), USA	85/83	3.8 (mean)	**VB**: Caries (Radike method), mutans streptococci counts in saliva **EX**: Portable dental chair, mirror, #23 explorer focusable flashlights	6	KW, MW	Differences in caries scores	High caries risk children at baseline (> 50 colony forming units): significantly greater caries scores at final examination
Rodrigues and Sheiham[23], 2000 (Recife), Brazil	650/510	3	**VB**: Caries (WHO criteria), enamel hypoplasia (DDE index– Developmental Defects of Enamel), nutritional status, sugar intake during 3 non-consecutive days, daily frequency of sugar intake, 24-h period dietary recall at home, questionnaire (socioeconomic, medical, demographic, dietary history and dental-related information) **EX**: Classroom, head lamp, mouth mirror, probes	1	MLR	Caries increment	RP: previous caries experience (most important factor), fluoride usage; RF: not attending nurseries with guidelines for sugar intake, frequency and amount of sugar intake, toothbrushing related habits
Li and Wang[24], 2002 (Beijing), China	504/362	3- 5	**VB**: Caries (dmf/DMF- WHO criteria) on entire dentition and on subsets of teeth: maxillary incisors, maxillary anterior teeth, maxillary first and second molars, mandibular first and second molars, all primary molars **EX**: Classroom setting, natural light, mouth mirrors, explorers	8	MLR, CA, PV	Developing caries in permanent dentition	RP: caries in primary teeth (caries on primary molars: highest predictive value - 85.4%)
Peretz et al.[25], 2003, (Jerusalem and Petah Tikva), Israel	150	3-5	**VB**: Caries: 3 groups with 50 children each being caries free children (CF), children with early childhood caries (ECC), and children with posterior cariesonly (PC) **EX**: Files of two private pediatric dental clinics, radiographic examinations	7-10	ANOVA, Sch	New affected surfaces per year	Children with ECC had the highest number of new affected surfaces per year, followed by the children with posterior caries and the caries-free children. ECC groups differed statistically from caries-free group and posterior caries group
Seki et al.[26], 2003 (Tokyo), Japan	147/129	1.5-5	**VB**: Caries (WHO criteria), dental plaque (visually on the labial surface of the maxillary incisors without disclosing solution), oral microbiology (unstimulated saliva and plaque in four proximal surfaces: 54-d, 55-m, 74-d, 75-m) **EX**: Visual inspection	0.5	Sn, Sp, PV, CS, MLR	≥1 new carious surface	Mean dmfs: 4.43 at baseline and 6.78 at follow-up. Groups with high Mutans Streptococci (MS) and/or high plaque MS scores: significantly higher caries incidence RP: caries experience at baseline; RF: high plaque MS score
Skeie et al.[27], 2004 (Bergen), Norway	217/186	5	**VB**: Caries (enamel + dentine lesions) **EX**: Teeth polished and dried, probes, plain, mirrors, favorable light conditions, bitewing radiographs	5	St, MLR	Taking part of a risk group (caries increment in primary teeth)	Mean increment (enamel + dentin lesions): 3.05 RP: ≥1 lesions on proximal surfaces of the primary molars
Skeie et al.[28], 2006 (Bergen), Norway	217/186	5	**VB**: Caries (enamel + dentin caries; visual inspection) **EX**: Teeth polished with prophylactic paste, air-dried/cotton rolls, operating lights, bitewing radiographs	5	CS, St, CA, MLR, Sn, Sp, PV, ROC	Taking part of a risk group (based on caries increment in permanent teeth)	Significant correlation between caries in the primary dentition and in permanent teeth RP: ≥1 carious lesion on primary second molars Highest sum of Sn and Sp (148%): predictor "more than two lesions in primary second molars"

**Sample size at initial/final examination; †Age at baseline (years); ‡Study lasting (years); ¶Statistical tests: ANOVA = Analysis of Variance; CA = Correlation analysis; CS = Chi-square; KW = Kruskall Wallis; MLR = Multiple logistic regression; MN = McNemar; MW = Mann-Whitney; PV = Predictive values; ROC = Receiver operator characteristic curves; Sch = Scheffe; Sn = Sensitivity; Sp = Specificity; St = Student's t-test; W = Wilcoxon; §RP/RF: Risk predictors/Risk factors obtained in Regression Analyses*

Table 3 - Review of literature on caries risk assessment in schoolchildren (6-12 years old) over the last 10 years (1997-2007)

Author , year and local	Sample*	Age†	Variables collected at baseline (VB) Examination (EX)	Time ‡	Data Analysis ¶	Outcome Variable	Main results RP/RF§
Kirstil ä et al.[29], 1998 (Turku), Finland	69/63	12	VB: Caries (DMF/ dmf - WHO criteria, white spots lesions), periodontal status (bleeding and calculus), usage of fluoridated dentifrices, saliva samples (buffer capacity, hypothiocyanite assay, total streptococci and mutans streptococci, lactoferrin and lysozyme analysis, agglutination assay, total salivary peroxidase activity, total and specific IgA and IgG antibodies) EX: Visual -tactile method + FOTI	2	St, CA	DMF increment >0	Mean caries increment: 0.95 DMFS Caries increment: negative correlations with baseline lactoferrin , total IgG and total anaerobes; positive correlation with specific anti -S. mutans , IgG antibody levels, mutans streptococci, lactobacilli and specific anti -S. mutans IgG. Children with significantly higher baseline concentrations of hypothiocyanite , total IgG antibodies and total anaerobes: no new caries lesions
Splieth and Bernhardt[30], 1999, Germany	230/169	6-7	VB: Caries (DMFS/ dmfs – WHO criteria, initial lesions), sealants for all molar fissures , occlusal plaque samples from teeth 16 and 36 (mutans streptococci tests), plaque index (Quigley -Hein) EX: Explorer without pressure, light source	2	CA, KW, MW, Sn , Sp	Caries development	Mean caries incidence: 0.69 DMFS Significant correlation between initial MS scores and caries development
Petti and Hausen[15], 2000 (Rome), Italy	314/304 (Caries - free)	6-7	VB: Caries (WHO criteria), plaque index (Silness and Löe), microbiological analysis of mutans streptococci - MS, (non -stimulated saliva samples), questionnaire (sucrose intake, fluoride exposure) EX: Clinical examination, visual inspection, bitewing radiographs	2	CS, Sn, Sp, PV, MLR, CA	DMFT increment ≥1	Mean caries increment: 0.68 teeth The more often the MS test positive, the higher the proportion of children who developed caries lesion RP: fluoride; RF: MS
Vanderas et al.[31], 2000, Greece	314/270	6-8	VB: Caries (DMF/ dmf), dental plaque, catecholamine content in urine sample, body weight, parental age, education and profession, medical history and medications EX: Bitewing radiographs	1	St, LiRA , MLR	Caries increment	RP: Epinephrine levels
Wandera et al.[32], 2000 (Michigan), USA	140	0.9 -11	VB: Charts of patients containing: medical, dental and fluoride history, diet, oral hygiene, retentive pits and fissures, existing restorations, newly erupted teeth, caries /decalcifications, pulpits/abscess, gingivitis, crowding, behavior, age, gender EX: Variables collected at patient 's charts (retrospective longitudinal study)	2.5	CS, MLR, ANOVA	Cumulative future caries lesions (high risk: ≥ 5 new surface lesions)	RP: presence of decayed teeth and decalcifications (most significant); RF: dietary factors, poor oral hygiene
Mattila et al.[33], 2001 (Turku), Finland	1074	7	VB: Caries (DMFT/ dmft), questionnaire (socioeconomic, demographic, family factors, diet, dental hygiene, parents' own earlier dental health habits, parents ´ previous dental health, children 's diseases and physical symptoms) EX: Mirror, probe, fiber -optic light	3	CS, MLR	Caries increment	Mean caries increment: 0.45 dmft/DMFT RP: mother 's previous caries (deciduous teeth); RF: toothbrushing only occasionally, child frequent use of sweets and child 's bedtime after 9 p. m. (permanent teeth), eat sweets frequently at 3 years of age (both dentitions)
Vanobbergen et al.[34], 2001 (Flanders), Belgium	3303/3002	7	VB: Caries (BASCD criteria – cavitation level), oral hygiene (Silness and Löe's plaque index and plaque index on occlusal surfaces – Carvalho 's index), eruption stage, questionnaire (oral hygiene, dietary habits, fluoride exposure, access to oral health care services, medical history, socioeconomic level) EX: Mobile dental clinic, WHO/CPITN probe	3	MLR, Sn, Sp, ROC, CS	DMFS increment ≥2 on permanent 1st molars	RP: dmfs, educational system; RF: frequency of brushing, daily use of sugar -containing drinks
van Palenstein Helderman et al.[35], 2001 (Tiel , Culemborg) The Netherlands	318/287	7.5	VB: Caries (non cavitated and cavitated caries, filling) and sealants EX: Visual examination, dental probe, dental lamp and small mouth -light, bitewing radiographs	8	CA, MLR, ROC	High caries increment (ΔD3 surfaces >0; >2; >4, >7)	RP: number of cavitated and non -cavitated fissures of the newly erupted permanent first molar
van Palenstein Helderman et al.[36], 2001 (Culemborg), The Netherlands	69/62	7.5	VB: Caries (incipient + cavitated lesions + fillings), mutans streptococci - MS and lactobacilli (LB) counts (stimulated saliva) EX: Visual observation, dried surfaces, dental lamp, small mouth -light, radiographs	4	CA, MLR	Caries increment	No statistically significant predictor (p>0.05)
Pearce et al. [37], 2002 (Beijing), China	175/164	12	VB: Caries (cavitation level), plaque score (Quigley and Hein index), fluorosis score (TF index), inorganic compounds in dental plaque (supragingival plaque collection from buccal and lingual surfaces after 3 days with no oral hygiene), toothbrushing frequency, snacks use, parents ' occupation EX: Child seated in an upright chair, adequate illumination, sharp probe	2	MW, W, MLR	DMFS increment ≥3	Mean DMFS increment: 1.14 RP: plaque Ca concentration, baseline DMFS score (useful predictor); RF: toothbrushing frequency

Table 3 – cont.

Author , year and local	Sample *	Age†	Variables collected at baseline (VB) Examination (EX)	Time ‡	Data Analysis ¶	Outcome V ariable	Main results RP/RF§
Källestål and Wall [38], 2002, Sweden	3373/3107	12	VB: Caries (DMF + enamel caries), sealants, questionnaire (ethnicity, residential area, socioeconomic level) EX: Clinical setting: mirror, good operating light, compressed air, cotton rolls, two bitewings radiographs	2	PR	Caries increment	Mean DMFS increment: 1.0 (including enamel lesion=1.88) RP: previous experience of caries, socioeconomic level
Kopycka-Kedzierawski and Billings [16], 2004 (New York), USA	464*/160 *caries-free	6-7	VB: Caries (visual-tactile criteria of Radike), microbiological (MS counts in whole stimulated saliva: if ≥106 CFU/ml high levels of MS) EX: Fiber-optic lights, plane mirrors, #23 explorers (cleaning of surfaces and detecting of sealants)	6	SA, W	Time to caries onset	RF: High MS levels Low MS levels: significant effect on the longer survival times
Vanderas et al. [39], 2004, Greece	314/196	6-8	VB: Caries (presence of caries on the primary second molars' distal surfaces - PSMDS), age, gender EX: Bitewing radiographs	4	MLR, Sn, Sp, PV	Caries incidence on mesial surfaces of permanent 1° molars (MSPFM)	RP: Presence of caries on PSMDS Sn= 45% to 97%; Sp= 80% to 89%
Leroy et al. [40], 2005 (Flanders), Belgium	4468	6	VB: Caries (BASCD criteria), presence of plaque on the occlusal surfaces of permanent first molars (PFM), timing of tooth emergence, gender, questionnaire (oral hygiene and dietary habits) EX: Visual inspection	6	SA	Survival time of a PFM	RP: gender (girls - for lower molars), cavity experience in the deciduous dentition; RF: occlusal plaque accumulation, reported brushing frequency
David et al. [41], 2006 (Bergen), Norway	159/112	12	VB: Caries (enamel + dentin lesions), questionnaire (gender, mother's education) EX: Teeth polished and dried, plane mouth mirror, probe, bitewing radiographs in equipped dental clinics	6	St, Sn, Sp	Caries (dentin level) increment on proximal surfaces (DFS > 0, 1, 2, 3 and 4)	Mean caries increment: 4.2 (enamel + dentinal lesions) Highest predictive power: proximal lesions in premolars and second molars
Jeppesen and Foldspang [42], 2006 (Aarhus), Denmark	3705	7-12	VB: Caries (dmfs, DMFS, number of surfaces with initial caries, n° of surfaces with primary and secondary caries, number of filled surfaces, number of surfaces missing due to caries), gender, year of birth, number of children in household, number of adults in household, citizenship EX: Danish routine dental and socioeconomic registers	1	CS, MLR, Sn, Sp, PV, ROC	Caries incidence	DMFS increase: positively associated with dmfs increase and with initial caries RP: past caries experience Area under ROC curve: 76%
Tagliaferro et al.[43], 2006 (Piracicaba), Brazil	480/206	6-8	VB: Caries (DMF/ dmf -WHO criteria, initial caries lesions), plaque score (Simplified Oral Hygiene Index), dental fluorosis (Dean index), questionnaire (toothbrushing frequency, type of preventive topical method, father's and mother 's educational level, gender, race, number of working people living in the household, monthly family income, dental visits in the year prior to baseline, reason for dental visit, daily sugar consumption, number of sugar spoons in beverages, number of between-meal snacks oral hygiene habits) EX: Dental probe and mirror, under natural light in outdoor setting at schools	7	CS, MN, MLR, Sn, Sp, PV, ROC	DMFS≥1 increment	Mean DMFS increment: 2.63 RP: dmfs, DMFS, mother 's education dmfs>0: highest Sn (69%) DMFS>0: highest Sp (92%).
Vallejos-Sánchez et al.[44], 2006 (Campeche), México	580/452	6-9	VB: Caries (DMFT, dmft – WHO criteria, caries in any first permanent molar, caries in any permanent upper molars, caries in any permanent lower molars, caries severity), age, gender EX: Dental mirror, teeth dried with gauze, natural daylight, at schools	2	CS, MW, KW, CA, W, MRA	DMFT≥1 increment	Total DMFT increment: 0.52 RP: caries in permanent molars, DMFT, caries severity
Zhang et al. [45], 2007 (Wuhan), China	650/433	6-7	VB: Caries (enamel + dentin lesions), Mutans Streptococci (MS) counts in saliva EX: Teeth dried, fiber-optic light on a mouth mirror, dental probe (removal of plaque, detection of fissure sealants)	2	CA, MRA	Caries increment (dentin level)	Significant, but weak, correlation between MS counts and caries RP: past caries experience

**Sample size at initial/final examination; †Age at baseline (years); ‡Study lasting (years); ¶Statistical tests: ANOVA = Analysis of Variance; CA = Correlation analysis; CS = Chi-square; KW = Kruskall Wallis; LiRA = Linear regression analysis; MLR = Multiple logistic regression; MN = McNemar; MRA = Multiple regression analysis; MW = Mann-Whitney; PR = Poisson Regression; PV = Predictive values; ROC = Receiver operator characteristic curves; SA = Survival Analysis; Sn = Sensitivity; Sp = Specificity; St = Student's t-test; W = Wilcoxon; §RP/RF: Risk predictors/Risk factors obtained in Regression Analyses*

Table 4 - Review of literature on caries risk assessment in adolescents (13-18 years old) over the last 10 years (1997-2007)

Author, year and local	Sample*	Age†	Variables collected at baseline (VB) Examination (EX)	Time‡	Data Analysis ¶	Outcome Variable	Main results RP/RF§
Bjarnason and Köhler[46], 1997, Sweden	155/87	15-16	**VB**: Caries (cavitation and incipient lesions), mutans streptococci (MS) and lactobacillus (LB) counts in stimulated saliva **EX**: Clinical + radiographic examination	3	CA, MRA, Sn, Sp, PV	DFS increment ≥5 DFS increment ≥3	RP: Incipient caries experience; RF: salivary microorganisms Incipient + manifest lesions: combined values of Sn and Sp allowed to predict caries development in the majority of individuals
Lawrence and Sheiham[47], 1997 (Rio de Janeiro, Mangaratiba and Angra dos Reis), Brazil	420/290	12-16	**VB**: Caries (DMFS index – WHO criteria), dental plaque (Patient Hygiene Performance - PHP index), malocclusion (WHO criteria), enamel defects (Developmental Defects of Enamel-DDE index), at baseline and final examination, interview (age, gender, socioeconomic status, race, fluoride exposure, residence histories, preventive dental health behaviors, use of dental services, toothbrushing frequency, toothpaste brand used, professionally applied fluoride gel rinses, varnishes or sealants, home use of fluoride mouthrinses, use of fluoride supplements during early childhood, number of years of residence in the research area, sources of domestic drinking water) **EX:** Head lamp, plane mirror, caries explorer, CPITN probe, drying at dental surgeries or classrooms at schools, posterior bitewings	1	St, W, CS, MLR	Caries progression	RP: Fluoride level in the drinking water, caries prevalence, number of cavitated carious lesions; RF: toothbrushing frequency
Utriainen et al.[48], 1998 (Kokola, Pietarsaari, Vaasa, Seinäjoki) Finland	2422/1472	13	**VB**: Caries (DMF index, D component), gingivitis (CPITN index), questionnaire (information on smoking) **EX**: Annual dental examinations in health centers and at schools, radiographic examinations	2	MLR	Number of cavitated teeth during the period	Subjects with no cavities at baseline: 60% remained cavities-free Subjects with gingival health at baseline: 47% remained healthy at the final examination RP: DMFT>2, DT>0, great gingival infection, gender (males)
Meldrum et al.[49], 2001 (Otago), New Zealand	976/781	15	**VB**: Caries (WHO criteria), parental socioeconomic level, asthma status. (*Note: 206 individuals having no history of asthma were used as the comparison group)* **EX:** Fiber-optic light, plane dental mirror and sickle explorer	3	CS, MW	DFS increment	Mean DFS increment: 2.06 Asthmatic groups: no significantly higher caries increment than the non-asthmatic group
Stenlund et al.[50], 2002 (Stockholm), Sweden	536/534	11-13	**VB**: Proximal surfaces status: caries-free or in a caries status **EX**: Only radiographic examination	10	SA, PR	Incidence of the first new proximal caries lesion	Median time to the first new proximal caries lesion: 2 years Individuals with no proximal lesions at baseline: 0.031 surface/year Individuals with 3 proximal lesions at baseline: 0.077 surface/year
Campain et al.[51], 2003 (Melbourne), Australia	645/504	12-13	**VB**: Caries (WHO criteria), height and weight ("estimation of subjects ' basal metabolic rate"), four-day diet records, questionnaire (household income, education level, occupation and ethnicity) **EX**: Fiber-optic light source, plane mouth mirror, sickle probe, at schools	2	MLR	Total DMFS increment; pit and fissure DMF increment; smooth surface DMF increment ≥1	Mean DFS and DMFS increment: 0.98 and 1.10, respectively RF: low sugar-high starch foods for caries increment on all surfaces and pit and fissures surfaces
Poorterman et al.[52], 2003, The Netherlands	202	14, 17, 20	**VB**: Caries, questionnaire (dental knowledge, oral health behavior, oral health care attitudes) **EX**: Clinical and radiographic examination	3	St, MLR	Differences between scores from baseline and final examination	RP: oral health concern; RF: oral health behavior (for only those aged 17 years at baseline)

**Sample size at initial/final examination; †Age at baseline (years); ‡Study lasting (years); ¶Statistical tests: ANOVA = Analysis of Variance; CA = Correlation analysis; CS = Chi-square; MLR = Multiple logistic regression; MRA = Multiple regression analysis; MW = Mann-Whitney; PR = Poisson Regression; PV = Predictive values; RR = Relative risk; Sn = Sensitivity; Sp = Specificity; St = Student's t-test; W = Wilcoxon; §RP/RF: Risk predictors/Risk factors obtained in Regression Analyses*

been a strong variable in identifying children at risk because it shows that the oral environment was prone to develop caries. Sugar consumption has played an important role in caries risk assessment in young children, as previously described for infants. Others variables related to oral hygiene also showed their significance in identifying children at risk. The presence of plaque on teeth, due to the lack and/or deficiency in toothbrushing, offers substrates to cariogenic bacteria favoring caries development.

Schoolchildren have been the most studied group in caries risk assessment (Table 3). From 1997 to 2007, 19 papers were selected and reviewed. Study duration ranged from 1 to 8 years and, as usual, dental variables were collected at baseline in all the papers. Other variables that also were collected in a considerable number of studies were: socioeconomic, microbiological and behavioral characteristics. Among the studies that used regression techniques (n = 16) in statistical analysis the predominant RP was past caries experience followed by others related to socioeconomic level. The main RFs were the variables related to oral hygiene. As previously reported, past caries experience detected at baseline is the variable that best indicates those at risk for developing new lesions and poor oral hygiene increases the probability of caries increment. Seven studies involving caries risk assessment in adolescents (Table 4) were found from 1997 to 2007. The researchers followed-up the participants from 1 to 10 years, and collected data on dental, behavioral, demographic, socioeconomic, anthropometric, medical and microbiological variables and dietary habits. Caries experience at baseline was the main RP obtained in regression techniques.

In general, review of the papers demonstrated that past dental caries was the risk predictor of the future disease for all age groups. Others important RP include socioeconomic level and fluoride usage. The risk factors obtained in regression analyses were variables related to oral hygiene, sugar consumption and microbiological counts.

Collecting data on dental caries is very easy and may help in caries risk assessment. However, the disease has to be present. Others risk factors such as sugar consumption and oral hygiene related characteristics are also not difficult to gather information on them from a community point of view and help dental professionals in selecting those caries-free individuals at risk. In fact, it has been suggested that in caries risk assessment, variables such as caries experience and severity, plaque index, fluoride use, socioeconomic level status should be collected before the application of the test for e.g. mutans streptococcus[15]. As reported by Kopycka-Kedzierawski and Billings[16], "a caries risk assessment protocol must involve the use of measures that are easily obtained, widely accepted, simple to use, reproducible and cost-effective".

It is important to take into consideration that this study presents some limitations such as the absence of quality criteria for selecting the papers (no score for papers), and the selection of studies mainly from Medline database. In spite of its limitations, by reviewing the published papers over the last 10 years, this study could clearly demonstrate that past caries experience has been the predominant predictor for future caries in subjects from 0 to 18 years of age. Therefore, those with previous contact with the disease should receive good oral health education, preventive measures and should be made aware that they are subjects at risk for developing caries. Continuous monitored is necessary to prevent the onset of new lesions.

On the other hand, as discussed by Tinanoff[17], it would be unwise to wait for the presence of caries to know which subject will be more susceptible to develop lesions in the future. Further studies involving a large number of caries-free individuals should be conducted on caries risk assessment. Nevertheless, the use of other variables such as dietary habits, including sugar consumption, and toothbrushing habits or presence of dental plaque may help identifying those caries-free subjects who might be more prone to have new carious lesions in the future.

In conclusion, the variables related to caries experience collected at the initial examination continue to be the main risk predictor of caries increment. Moreover, those related to sugar consumption and oral hygiene could identify subjects at caries risk.

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