A Systematic Review of Clinical Diagnostic Criteria of Early Childhood Caries

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Abstract

Objective: *This paper reviews case definitions and clinical diagnostic criteria of early childhood caries (ECC) and severe ECC (S-ECC) in children aged 1 to 5 years old. The acronym S-ECC as used in this paper refers to nursing caries, baby bottle tooth decay, rampant caries, labial caries, maxillary anterior caries, and other terms used to refer to severe dental caries in preschool children.* ***Methods:*** *A search was carried out for articles published in peer-reviewed journals and indexed in MEDLINE using the following terms: nursing caries, baby bottle tooth decay, early childhood caries, rampant caries in preschool children, labial caries, maxillary anterior caries, and nursing bottle caries. MEDLINE's MeSH terms "dental caries" and "deciduous teeth" were used to search for other relevant studies. Reports were selected if they included children 1 to 5 years of age and described diagnostic criteria or case definitions of S-ECC. Three previous reviews were searched for other relevant reports. One unpublished report was included in this review and data from NHANES III were analyzed to provide information on caries patterns in preschool children in the United States. The first author read all the abstracts from the MEDLINE search and tagged relevant reports for photocopying. He also abstracted all the information from the reports. The first author calibrated the second author, who independently read all included and excluded reports. Disagreements were resolved by consensus.* ***Results:*** *Out of 126 studies, 32 were excluded and 94 (93 published and 1 unpublished) were included in this review. Eighty-one of the 94 published studies were cross-sectional surveys or clinical studies, 7 were case-control clinical studies, 2 studies were controlled clinical trials, and 4 were cohort or field trials. About two-thirds of the included studies did not report on calibration of examiners. Information on reliability of examiners was reported by 19 of the 94 studies. The included studies varied widely in the name used to identify S-ECC, case definitions, and diagnostic criteria. "Cavitation" was the most common criterion used to define dental caries. Several studies measured early or noncavitated carious lesions. Twenty-seven studies used the presence of 1 dmf maxillary incisor to classify a child with S-ECC. Another 23 and 9 studies defined S-ECC by the presence of 2+ or 3+ dmf maxillary incisors, respectively. Dental caries in preschool children clusters in pits and fissures and on smooth tooth surfaces of primary molars and maxillary incisors.* ***Conclusions:*** *This review found a wide variation in the case definitions and diagnostic criteria used to diagnose ECC or define S-ECC. Dental caries in the maxillary incisors is one of several patterns of dental caries that may occur in primary teeth of preschool children. A consensus is needed on case definitions and diagnostic criteria that can assist researchers to test preventive interventions and study the etiology and epidemiology of ECC. [J Public Health Dent 1999;59(3):171-91]*

Key Words: Infant, child, preschool, dental caries, diagnosis, epidemiology, statistics, deciduous teeth.

Progress in understanding the etiology, epidemiology, and management of any disease depends on the continuous development of valid and reliable tools that can accurately diagnose the severity of a disease or condition. This important concept has not been followed in the science of cariology, where measurement of dental caries has not kept up with the evolving understanding of the disease process (1,2). This paper reviews the diagnostic criteria and case definition of dental caries in children between the ages of 1 and 5 years. In this review paper, dental caries in preschool children is referred to as early childhood caries (ECC). The paper also reviews the case definition of a severe pattern of ECC that initially attacks the maxillary primary incisors (3). Over the last 40 years, this pattern has been referred to as labial caries (LC) (3), caries of the incisors (4), rampant caries (RC) (5), nursing bottle caries (NBS) (6), nursing caries (NC) (7), baby bottle tooth decay (BBTD) (8), maxillary anterior caries (MAC) (9), early childhood caries (ECC) (10), and "rampant infant and early childhood dental decay" (11).

Some of these terms are uniquely specific about the behaviors that may lead to the development of severe ECC. The use of milk or sweetened drinks in baby bottles and nursing frequently during sleep have been associated with this severe carious attack in young children (12-14). While there is evidence that children with severe ECC have frequent exposures to sweetened drinks and milk, evidence also indicates that the likelihood of development of severe ECC is not uniform in all infants and toddlers who frequently are exposed to cariogenic fluids or milk (15,16). Moreover, there is no support for the claim that the use of names such as "baby bottle tooth decay" or "nursing caries" has aided in promoting healthy bottle feeding or nursing practices among at-risk population groups. Hence, for the purpose of this review paper, the term "severe early childhood caries" (S-ECC) will

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be used to refer to conditions known as nursing caries, baby bottle tooth decay, nursing bottle caries, maxillary anterior caries, labial caries, or rampant caries.

The current epidemiologic evidence indicates that dental caries remains a public health problem especially in low-income children in the United States (17). Severe early childhood caries may be a major reason for hospitalization of infants and toddlers (18). This condition is also costly to treat (19,20). Unfortunately, filling decayed teeth is ineffective in promoting the oral health of young children, and at best has provided only a temporary solution to the problem of severe early childhood caries (21).

A major problem that may have hindered efforts to combat this condition is the lack of agreement on case definitions and diagnostic criteria for ECC and S-ECC (22). Hence, this paper was written to provide information for a workshop convened by the National Institute of Dental and Craniofacial Research (NIDCR) to develop diagnostic criteria for ECC and case definitions for S-ECC.

This review answers the following questions using published and unpublished reports: first, what clinical diagnostic criteria were used to identify the presence of dental caries in primary teeth of preschool children; and second, what case definitions were used to identify children with S-ECC?

Methods

The review followed an explicit method to identify, select, and critically appraise relevant studies. To locate published reports, several MEDLINE searches were carried out to identify relevant studies published between January 1966 and December 1998. The search was restricted to articles written in English and that included human subjects. The first search used the following terms: "nursing caries" or "baby bottle tooth decay" or "early childhood caries." This search found 117 reports. The second search located 52 reports that included the term "rampant caries" and was limited to children aged 1 to 5 years. The third search located 7 reports that included the term "labial caries." The fourth search located 38 reports that included the term "nursing bottle caries." The fifth search located 6 reports that included the term "maxillary anterior caries." The sixth search located reports that included the medical subject heading (MeSH): "tooth, deciduous" (explode: tooth, deciduous) and dental caries (explode: dental caries). This search found 1,183 reports of which 383 included data on children between the ages of 1 and 5 years. No abstracts of unpublished reports were included in this review.

The first author read the abstracts of relevant reports identified in the MEDLINE search. Reports that in the opinion of the first author included information that may help to answer the review questions were tagged for photocopying. Additionally, the first author reviewed the reference lists of three previous reviews of the literature on ECC conducted by Ripa (12), Milnes (23), and Reisine and Douglass (24). This search identified several relevant reports included in this review. In addition, one unpublished report was provided to the authors for inclusion in the review (25). The authors also had access to data on the distribution of dental caries in preschool children in the United States. These data were collected during the third National Health and Nutrition Examination Survey (NHANES III), 1988–1994. The authors analyzed the NHANES III data using SUDAAN to map out ECC patterns in the primary teeth of preschool children in the United States.

The first author classified each report for inclusion or exclusion in this review based upon answers to the following questions: (1) does the report present data on dental caries in children between the ages of 1 and 5 years? **and** (2) does the report explicitly describe either diagnostic criteria for ECC **or** a case definition for S-ECC? Reports that did not meet one of these criteria were excluded. Additionally, the first author excluded "duplicate" reports that presented the same data, criteria, or case definitions used in other included reports by the same author or authors.

The first author abstracted relevant information from the included reports and prepared evidence tables (Tables 1–3). The first evidence table summarizes each study by year of publication, author(s), study design, terms used to define S-ECC, sources of patients or populations, teeth and tooth surfaces included in the definition of ECC or S-ECC, number of teeth used to define a child with ECC or S-ECC, prevalence of ECC or S-ECC, calibration and reliability of examiners, and age of sampled children. The second and third evidence tables summarize the diagnostic criteria of ECC (Table 2) and case definitions (Table 3). When data abstraction from the included reports was completed, the second author was provided with full copies of the included and excluded reports and the evidence tables (Tables 1–3). The first and second authors conducted a calibration exercise using five excluded and five included reports. The second author independently read the reports and rendered his own decisions regarding inclusion/exclusion and the accuracy of the data presented in Tables 1–3. In total the two authors differed on the inclusion/exclusion of eight out of 126 reports. All the eight reports were included. When differences were identified in the information presented in evidence tables, both authors reviewed the specific report(s) and reached a consensus on appropriate corrections.

The reviewers were not blinded to the identity of the authors of the included or excluded reports or the source of publication because there is no evidence that blinding of reviewers of descriptive studies has any effect on outcomes of a review. Moreover, while blind assessments of the quality of randomized controlled trials was found to result in lower and less variable scores compared with open assessments (26), blinding of reviewers currently is not required by the Agency for Health Care Policy and Research (AHCPR) and United States or Canadian experts in the field of systematic reviews (27). Blinding requires scanning all reports and concealing the identity of the authors, journal names, references, and other identifiers so that the reviewers cannot identify the authors or journal where a report was published. This approach is not always feasible because of the number of studies included in some systematic reviews.

By the end of the review process, the authors included 93 published reports and one unpublished report, and excluded 32 reports. This systematic review was not designed to locate all reports ever published on ECC or S-ECC. Such a goal was beyond the resources available to us because it would require conducting manual

TABLE 1
Characteristics of Studies Included in Early Childhood Caries Review [continued next page]

Year	Authors (Ref)	Study Type	Cond.†	Pop.	Teeth‡	Tooth Surfaces¶	No. Teeth	Percent Prevalence	Calibration/ Reliability	Age
1998	Dini (61)	III*	Caries	Preschool children from 2 districts of Araraquara City & 1 district of Gaviao City, Brazil	All	All	1+	32.4 in fluoridated area; 2nd molars=20.6; 1st molars=17.9; canines=2.5; max. incisors=14.1; mand. incisors=0.7	Intra- & interexaminer reliability, kappa=0.87–0.98	3–4 y
1998	Lopez (68)	III	ECC	Parent & child care centers of Health Start in NE region of Puerto Rico	Incisors	All	1+	53.9	—	3 y
1998	Weerheijm (14)	III	NC	Children whose mothers attended La Leche, the Netherlands	Incisors	—	2+	9.3	—	1–3.5 y
1997	Al-Shalan (69)	III	ECC	Pediatric dental clinic, School of Dentistry, Univ. of MN	Incisors	—	1+	50.4	—	2.8–2.9 y
1997	Berkowitz (21)	III	NC	Medicaid children from Strong Mem. Hosp., Rochester, NY	Incisors	—	2+	NA	—	1.8–5.6 y
1997	Febres (70)	III	BBTD	Patients from ped. clin., Houston Med. Ctr., TX	Anterior	—	2+	19	—	1–3.5 y
1997	Harrison (71)	III	NC	Vietnamese families from Child Health Clinic, Vancouver	Anterior	—	2+	63	—	3–74 mos
1997	Harrison (72)	III	NC, BBTD	First Nations, BC, Canada	Incisors	—	2+	59	—	18–38 mos
1997	Peretz (50)	II-3	BBTD	50 children w/BBTD and 50 w/o BBTD seen at Hadassah Faculty of Dent. Med., Israel	Incisors	F	3+	NA	—	3–4 y
1997	Tang (73)	III	Caries	Head Start & WIC clinics in AZ	All	All	1+	At age 3 y: Native Am.=54.0; African-Am.=27.0, Hispanic=42.0, white=24.0	Yes/ kappa=0.97	5 mos–4 y

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1996	Ayhan (19)	II-3	NC	Children scheduled for restorative treatment at Gazi Univ. dental clinic, Turkey	Incisors	Ring-like, gumline	1+	54.2	—	2–5 y
1996	Bruerd (39)	11-1b	BBTD	Am. Indians/Alaskan Natives from 12 Head Start programs in 10 states, US	Anterior	—	2+	43	—	3–5 y
1996	Douglass (74)	III	NC	Apache children from AZ Head Start program	Anterior	—	2+	64	—	4 y
1996	Kaste (75)	III	ECC	NHANES III: national probability sample of US households	Anterior	F, M, D	1+	0.8	Yes/ kappa=0.96	12–23 mos
1996	Li (76)	III	Caries	2 rural Chinese communities	All	All	1+	78.6–85.5	Yes/ kappa=0.86–0.88	3–5 y
1996	Mattos-Graner (41)	III	Initial & manifest caries	Day care nurseries randomly selected from 28 in Piracicaba, Sao Paolo, Brazil	All	All	1+	19–24 mos-old children: initial caries=10.6; manifest caries=13.6	Yes/ % agreement= 99.5	6–36 mos
1996	O'Sullivan (53)	II-2a	MAC	Head Start children in CT	Max. incisors, pits & fissures	All	2+	pit & fissure caries=28; max. anterior caries=10	Interexaminer agreement, kappa=0.91	3–5 y
1996	Ramos-Gomez (77)	III	Infant caries	Pediatric dent. clin., UCSF	Incisors	F, L	1+ 2+ 3+	27 32 27	—	<2–≥6 y
1996	Seow (63)	III	Maxillary anterior labial decay	Australian Aboriginal children	Anterior	F	1+	23	Yes/—	mean age= 4.4 y
1996	Shantinath (78)	III	NC	Patients from primary health care clinic in Seattle, WA	Anterior	—	1+	NA	—	2–4.5 y
1995	Al-Dashti (79)	III	NC	2 clinics in Kuwait that provide care to 85% of the population	Incisors	—	2+	19	—	18–48 mos
1995	Hallonsten (42)	III	Caries	Child welfare centers, 3 areas in Sweden	All	All	1+	2.1	—	18 mos

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1995	Jones (80)	III	Caries	Children regist. w/ Registrar of Cumbria Family Health Authority, UK	All	All	1+	18.5	Yes/—	3 y
1995	Douglass (54)	III	MAC	Nursery schools, Beijing, China	Incisors, & canines	Max. incisors & mesial surfaces of max. canines	2+	43 in 3-year-old children	—	3–6 y
1995	Marino (81)	III	Caries	Children living in fluoridated & nonfluor. areas, Chile	All	All	1+	41.5 in fluoridated; 62.3 in nonfluor. areas	Yes/ kappa>0.90	3 y
1995	Mayanagi (62)	III	Caries	13 nursery schools, Sendai City, Japan	All	All	1+	—	Yes/—	2–4 y
1995	Stecksen-Blicks (44)	III	Caries	Stratified sample selected from 1,386 children born in 1988 in Umea, Sweden	All	All	1+	43 of all children; initial caries=18; manifest caries=70	Yes/ r=0.99	4 y
1995	Thibodeau (82)	III	Caries	Low socioeconomic status preschool chuilkdren in CT	All	All	1+	Yes/ kappa=0.91	—	mean = 3.8 y
1995	Tsubouchi (83)	III	BBTD	WIC program, Marysville, WA	Not defined	—	—	Decalcified & deczyed=46.8	—	1–3 y
1995	Wyne (84)	III	NC	College of Dentistry, Saudia, Arabia	Incisors	F	1+	14.7	—	≤6 y
1994	Alaluusua (85)	III	Caries	Children from Orimattila, southern Finland	Incisors molars (at age 36 mos)	Labial or palatal or occlusal	1+	at 19 mos=8 at 36 mos=14	—	19–36 mos
1994	Benitez (86)	III	NBS	Pediatric dental clinic, Univ. of CT, Hartford	Incisors	—	1+	—	—	20–36 mos
1994	Cook (87)	III	NC	Head Start program, Choctow Indians, MS	Incisors	F, L	3+	50.2	Yes/–	3–5 y
1994	Domoto (40)	III	BBTD	WIC, Yakima Valley region, WA, Mexican-Am. children	Incisors	—	1+	1 carious ax. incisor=7; at least 1 incisor w/white spot lesion=30.4	—	0–3 y

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1994	Douglass (65)	III	MAC	CT's Head Start and Beijing nursery schools	Incisors	Incisors+ mesial canine	2+	Refer to Table 4	Yes/—	3–4 y
1994	Matee (88)	III	RC	Maternal & child health clinics in 9 of 25 regions in Tanzania	Incisors	—	2+	6.8	—	1–4 y
1994	O'Sullivan (52)	III	MAC	Navaho preschool children, US	Max. incisors & mesial/ max. canines; pits & fissures of molars; post. MD surfaces	All	1+	In 3-year-old children: MAC=68; pits & fissures= 50; post. prox.=45	Yes/—	1–4 y
1994	Roberts (89)	III	NC	Random sample of children from well child clinics in South Africa	Incisors	F, L	2+	NA	—	1–4 y
1994	Twetman (90)	II-2a	Caries	Preschool children in Halmstad, Sweden	All	All	1+	Prevalence= 30; incidence= 30–61	—	4 y
1993	Juambeltz (91)	II-3	NC	African-Am. pediatric patients seen at U. of MD School of Dentistry	Incisors	—	3+	NA	—	1.5–4.5 y
1993	Milnes (20)	III	NC	First Nations, Canada	Incisors	All	1+	—	—	<6 y
1993	O'Sullivan (9)	III	MAC	2 Head Start programs, CT	Incisors	All	—	16.0	Yes/ r=99.5%	3–4 y
1993	Paunio (92)	III	—	Random samples of children seen at maternity health clinics in Turku & Pori, Finland	Incisors	—	1+	69.0% of children w/ dentinal caries (8.3% of examinees)	Yes/ kappa=0.64	3 y
1993	Grindefjord (31)	III	Caries	Children from 8 suburbs of Stockholm, Sweden	All	All	1+	initial caries=5.3; manifest caries= 6.4	—	2.5 y
1993	Raadal (93)	III	Caries	Kindergarten schools in Khartoum, Sudan	All	All	1+	42	Yes/–	4–5 y

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1993	Serwint (57)	III	NC	Sample of healthy children seen in hospital-based pediatric clinic in southern California	Incisors or prim. molars excl. mand. incisors	All	1+	with NC=20	Yes/ Sen=100%; Sp=87%	18–36 mos
1992	Barnes (94)	III	BBTD	Children from Head Start programs in 5 southwestern states, US	Incisors	—	2+ 3+	23.8 15.2	Yes/interrater agree.=87%	3–5 y
1992	Jones (95)	III	BBTD	Head Start program in Alaska	Incisors	—	3+	Native children=25; nonnative=4	Yes/ kappa=0.88	3–5 y
1992	Kaste (96)	III	NC	Head Start children from 1 reservation in Arizona	Incisors	F, L Any Any	1+ 2+ 3+	45 76 61	Yes/ kappa=0.95	3–5 y
1992	Katz (55)	III	NC	US Virgin Islands (Head Start)	Incisors	Ringlike or to gum line	1+	Nursing caries=12.2; max. anterior caries=40.5	Yes/ kappa= 0.44–0.54	3–5 y
1992	Matee (15)	II-3	RC	Rural area in Tanzania	Incisors	—	2+	NA	—	1–2.5 y
1992	Silver (97)	III	LC	Bishop's Stortford, UK	Incisors	Labial or palatal	2+	in 1973=8; in 1981=1; in 1989=4	—	3 y
1992	Sönju Clasen (98)	III	Caries	Kindergarten children from Salzgitter, Austria, and Oslo, Norway	All	All	1+	In 4-year-old children: Salzburg=44; Oslo=8	Yes/–	4–5 y
1992	Vignarajah (99)	III	NBC	Nursery schools, Antigua, West Indies	Incisors	Labial or palatal	2+	4.6	—	3–4 y
1992	Weinstein (100)	III	BBTD	WIC Mexican-Am. children in Yakima Valley, WA	Anterior	—	2+	29.6	—	8–47 mos
1991	Kamp (101)	III	NC	Preschool children partici- pating in well-baby screening clinic at Misawa Airbase, US	Incisors	—	1+	5.3	—	0.5–4.5 y
1991	Mangskau (102)	III	BBTD	North Dakota Head Start centers	Incisors	—	2+	9.6	—	3–5 y

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1991	Wendt (43)	III	Caries	4 of 13 child welfare centers in Jonkoping, Sweden	Incisors	All	1+	0.5 4.7	—	1 y 2 y
1990	Greenwell (32)	II-2b	BBTD	3 dental practices in northeast Ohio	All teeth or incisors	F, L or M, D, & mesial of max. canine	1+	NA	—	1.5–15.5 y
1990	Louie (103)	III	BBTD	Region IX Head Start programs in US	Incisors	—	3+	Fluoridated community=13; nonfluoridated areas in CA =18, Hawaii=29, Micronesia= 36	Yes/–	3.5–5.5 y
1990	Onozawa (104)	III	Caries	Nerima Health Center, Tokyo	A-type: max. incisors or max. molars; B-type: max. incisors & max. molars; C-type: like B-type w/ caries in other teeth	All	1+	A-type=23.2 B-type=14.1 C-type=1.5	—	1.5–3 y
1990	Yagot (51)	III	Prolonged nursing habit caries	39 nursery schools in Baghdad, Iraq	Incisors	F, L, M, D	1+	15.6	Yes/r=0.97	12–53 mos
1989	Babeely (13)	III	NBS	Pediatric dental practice in Kuwait	Incisors	F, L	1+	28.9	—	17–52 mos
1989	Broderick (48)	III	BBTD	Navajo & Cherokee Head Start centers, US	Anterior	—	2+	Navajo children=72; Cherokee children=55	—	4–5 y
1989	Bruerd (8)	II-1b	BBTD	Native Am. Communities, OK, AK, SD, & AZ	Anterior	—	2+	43	—	0–5 y
1989	Holbrook (105)	III	Caries	Main Reykjavik health center, Iceland	All	All	1+	44.2	—	4 y
1988	Albert (106)	III	NC	Keewatin District of Northwest Territories, Canada	Incisors	—	—	50	—	25–30 mos

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TABLE 1 [continued from previous page]

Year	Authors (Ref)	Study Type	Cond.†	Pop.	Teeth‡	Tooth Surfaces¶	No. Teeth	Percent Prevalence	Calibration/ Reliability	Age
1988	Grytten (33)	III	Caries	Birth cohort of 1979–80 in medium-sized Norwegian town	All	All	1+	20	—	3 y
1988	Holt (107)	III	RC	Maternal & child welfare clinics in Camden, UK	Incisors	F, L	2+	12–23 mos=0 36–47 mos=10	Yes/ kappa= 0.74—0.89	12–59 mos
1987	Johnsen (59)	III	NC	Pediatric charts of pediatric dental clinic in Cleveland hospital & 1 private practice	Any tooth	Pits & fissures F, L M, D F, L, & M, D	1+	3.5 13.2 8.9 25.7	Yes/ r>99% in reading charts & radiographs	0–5 y
1987	Kelly (108)	III	BBTD	Am. Indian & Alaskan Native children in AK & OK	Incisors	—	3+	53	Yes/—	3–5 y
1986	Johnsen (60)	II-2a	NC	University pediatric dental clinic, Cleveland, OH	Incisors	—	3+	NA	—	~3.3 y
1985	Persson (109)	III	Caries	3 different parts of Sweden	All	All	1+	16	Yes	3 y
1985	Salako (38)	III	Caries	Nigerian children seen at dental school, Lagos	All	All	1+	—	—	3–7 y
1985	Williams (49)	III	RC	Nursery school children in Germiston, South Africa	Max. incisors All	Palatal or labial All	2+ dmft ≥5	At 5 years=7.0 26.4	Yes/>90%	2–5 y
1984	Johnsen (110)	III	NC	Children from dental practices in OH, LA, & WV	Incisors	F, L	3+	NA	—	3.5–5 y
1984	Johnsen (60)	III	NC	Pediatric dental clinics, US	Incisors	—	3+	NA	—	≤3.5 y
1982	Derkson (6)	III	NBS	Public health clinics, Vancouver, Canada	Incisors	F, L	1+	3.2	—	≤6 y
1982	Holt (111)	III	RC	Maternal & child welfare clinics in Camden & Islington, UK	Incisors	F, L	2+	2–4	Yes/ r=0.83	12–59 mos

—=No data were reported.

*I=randomized controlled trials, II-1a=controlled trials with pseudo/randomization, II-1b=controlled trials with no randomization, II-2a=cohort (prospective) studies with concurrent controls, II-2b=cohort (retrospective) studies with concurrent controls, II-3=case-control (retrospective) studies, III=large differences from comparisons between times and/or places with and without interventions (cross-sectional studies).

†BBTD=baby bottle tooth decay, ECC=early childhood caries, LC=labial caries, MAC=maxillary anterior caries, NBS=nursing bottle syndrome, NC=nursing caries, RC=rampant caries.

‡Anterior=maxillary anterior teeth (most likely refer to centrals and laterals); incisors=maxillary central and lateral incisors.

¶Tooth surfaces: F=facial or labial, L=lingual or palatal, M=mesial, D=distal.

TABLE 1 [continued from previous page]

Year	Authors (Ref)	Study Type	Cond.†	Pop.	Teeth‡	Tooth Surfaces¶	No. Teeth	Percent Prevalence	Calibration/ Reliability	Age
1982	Johnsen (7)	II-3	NC	Pediatric dental clinic in medical center in Morgantown, WV	Incisors	—	3+	NA	—	~3.5 y
1982	McInnes (112)	III	LC	Children from Kenhardt, North Western Cape, S. Africa	Max. & mand. incisors	F	1+	high fluoride area (3.2 ppm F)=2; low fluoride area=27	—	1–5 y
1981	Richardson (34)	III	LC	Black & white children, South Africa	Canines or incisors	F	1+	rural blacks= 11.7; urban blacks= 40; white children=12	—	1–6 y
1979	McInnes (113)	III	LC	Kuo Ting Chinese school, Johannesburg, South Africa	Max./ mand. incisors	F	1+	33	—	3–5 y
1978	Cleaton-Jones (35)	III	RC	White children, South Africa	Incisors or canines	F	1+ 2+	11.4 8.6	Yes/—	1–5 y
1978	Cleaton-Jones (36)	III	LC	Black children, South Africa	Anterior	F	1+	13.7	Yes/—	1–5 y
1977	Currier (56)	III	Anterior caries & baby bottle syndrome	Patients at Jefferson Maternal & Child Health Clinic, Richmond, VA	Anterior	Not defined	1+ 3–4	11 5	Yes/—	0–4 y
1976	Infante (114)	III	Caries	Guatemalan children from 4 villages	All	All	1+	45.8% of all carious teeth were observed in anterior teeth	—	6 mos–7 y
1976	Powell (58)	III	NBS	Dental practices in Los Angeles, CA	Anterior	F, L	1+	1	—	1.5–5 y
1974	Silver (37)	III	RC	Welfare clinic, Stortford, UK	Incisors	All	1+	81	—	3 y
1972	Kleemola-Kujala (115)	III	Caries	Child Welfare Center, Helsinki, Finland	All	All	1+	51.6	—	0–89 mos
1971	Winter (116)	III	RC	Child welfare centers, Camden & London, UK	Incisors	F, L	2+	1–<2 y=0.6 2–<4 y= 10 4–6 y=15	Yes/—	1–4 y

—=No data were reported.

*I=randomized controlled trials, II-1a=controlled trials with pseudo/randomization, II-1b=controlled trials with no randomization, II-2a=cohort (prospective) studies with concurrent controls, II-2b=cohort (retrospective) studies with concurrent controls, II-3=case-control (retrospective) studies, III=large differences from comparisons between times and/or places with and without interventions (cross-sectional studies).

†BBTD=baby bottle tooth decay, ECC=early childhood caries, LC=labial caries, MAC=maxillary anterior caries, NBS=nursing bottle syndrome, NC=nursing caries, RC=rampant caries.

‡Anterior=maxillary anterior teeth (most likely refer to centrals and laterals); incisors=maxillary central and lateral incisors.

¶Tooth surfaces: F=facial or labial, L=lingual or palatal, M=mesial, D=distal.

TABLE 1 [continued from previous page]

Year	Authors (Ref)	Study Type	Cond.†	Pop.	Teeth‡	Tooth Surfaces¶	No. Teeth	Percent Prevalence	Calibration/ Reliability	Age
1967	Goose (4)	III	Caries of incisors	Dental hospitals in Cheshire, & Leicester Boroughs, Liverpool, UK	Incisors & feeding habits	—	—	6.8	Yes/—	1–2 y
1966	Winter (5)	II-3	RC	Dental hospital, Child Welfare Center, London	Incisors	F, L	2+	NA	—	1–3 y
Unpublished Studies										
1999	Milgrom (25)	III	ECC	Randomly selected sample of children from Saipan, Northern Mariana Islands, US	All	All	1+	white spot lesions=45.3 ; enamel cavitation=36.3	10% reexamination; no data reported. "Discrepancies were few."	9–39 mos
1999	NHANES III*	III	Caries	National probability sample of US population	All	All	1+	Mand. incisors=0.2; mand. canines= 0.7; max. canines=2.1; MD molars= 2.9; BL molars=4.4; Occ. molars= 12.4; max. incisors=9.6	Kappa= 0.85–1.0	3 y
								Mand. incisors=0.5; mand. canines= 2.8; max. canines=2.7; MD molars= 11.0; BL molars=13.6; Occ. molars= 23.9; max. incisors=13.1		4 y

—=No data were reported.
*I=randomized controlled trials, II-1a=controlled trials with pseudo/randomization, II-1b=controlled trials with no randomization, II-2a=cohort (prospective) studies with concurrent controls, II-2b=cohort (retrospective) studies with concurrent controls, II-3=case-control (retrospective) studies, III=large differences from comparisons between times and/or places with and without interventions (cross-sectional studies).
†BBTD=baby bottle tooth decay, ECC=early childhood caries, LC=labial caries, MAC=maxillary anterior caries, NBS=nursing bottle syndrome, NC=nursing caries, RC=rampant caries.
‡Anterior=maxillary anterior teeth (most likely refer to centrals and laterals); incisors=maxillary central and lateral incisors.
¶Tooth surfaces: F=facial or labial, L=lingual or palatal, M=mesial, D=distal.

searches of all relevant dental and nondental journals and translation of reports written in other languages. Hence, a limitation of this review is its reliance on MEDLINE as a source for evidence. Even this extensive data base may not include all the reports published on a specific topic. Moreover, even if a report is included in the data base, it may not be indexed appropriately. For this reason, the authors have conducted multiple independent searches of the MEDLINE using multiple search strategies.

Results

Types of Studies. Table 1 describes the 93 published reports, one unpublished report, and the findings from the analysis of NHANES III. Eighty-one of the reports (86.2%) were cross-sectional surveys, seven were case-

TABLE 2
Diagnostic Criteria of Early Childhood Caries [continued next page]

Year	Authors (Ref)	Criteria
1998	Dini (61)	WHO criteria (cavitation)
1998	Lopez (68)	Decalcified lesions, decay, and fillings
1998	Weerheijm (14)	Dentinal caries
1997	Al-Shalan (69)	Not reported
1997	Berkowitz (21)	Visible extension of lesion into dentin
1997	Febres (70)	Carious lesions progressing beyond white spot stage
1997	Harrison (71)	Visible evidence of cavity that was thought by examiner to involve dentin
1997	Harrison (72)	Not reported
1997	Peretz (50)	Cavitation
1997	Tang (73)	Visual breakdown in enamel
1996	Ayhan (19)	Scheduled for restorative treatment. No criteria for examination.
1996	Bruerd (39)	Cavitation (None of the children had "questionable caries" on maxillary anterior teeth.)
1996	Douglass (74)	Radike criteria (cavitation)
1996	Kaste (75)	NIDR criteria (cavitation)
1996	Li (76)	WHO criteria (cavitation)
1996	Mattos-Graner (41)	Initial caries defined as loss of translucency and manifest caries as presence of cavitation
1996	O'Sullivan (53)	WHO criteria (cavitation)
1996	Ramos-Gomez (77)	Not reported
1996	Seow (78)	WHO criteria (cavitation)
1996	Shantinath (78)	No criteria for examination
1995	Al-Dashti (79)	WHO criteria (cavitation)
1995	Hallonsten (42)	Presence of initial and cavitated caries. Initial caries defined as a demineralized surface with chalky appearance but without macroscopic loss of tooth structure.
1995	Jones (80)	Caries at cavitation level involving dentin
1995	Douglass (54)	Radike criteria (cavitation)
1995	Marino (81)	WHO criteria (cavitation)
1995	Mayanagi (62)	Cavitation
1995	Stecksen-Blicks (44)	Initial caries: chalky white spot without break in enamel surface. Manifest caries is cavitation verified with exporing.
1995	Thibodeau (82)	Radike criteria (cavitation)
1995	Tsubouchi (83)	Decalcified tooth, decayed, filled, or missing teeth caused by caries. No criteria provided.
1995	Wyne (84)	Not reported
1994	Alaluusua (85)	WHO criteria (cavitation)
1994	Benitz (86)	White/brown spots on enamel and/or small caviation in dentin on 1 or more teeth
1994	Cook (87)	"Extensive caries"
1994	Domoto (40)	"White spots" and cavitated teeth
1994	Douglass (65)	Radike criteria (cavitation)
1994	Matee (88)	WHO criteria (cavitation)
1994	O'Sullivan (52)	Radike criteria (cavitation)
1994	Roberts (89)	WHO criteria (cavitation)
1994	Twetman (90)	WHO criteria (cavitation)
1993	Grindefjord (31)	Initial caries defined as demineralized surface with loss of translucency. Manifest caries defined as minimal that could be verified as cavity; detectable by probing, and for fissures, a catch of probe under slight pressure.
1993	Juambeltz (91)	Not reported
1993	Milnes (20)	Review of dental treatment records
1993	O'Sullivan (9)	Radike criteria (cavitation)
1993	Paunio (92)	Dentinal caries. Not reported.
1993	Raadal (93)	Cavitation
1993	Serwint (57)	Not reported
1992	Barnes (94)	Cavitation. Not reported.
1992	Jones (95)	NIDR criteria (cavitation)
1992	Kaste (96)	NIDR criteria (cavitation)
1992	Katz (55)	Visual evidence of advanced demineralization or cavitation
1992	Matee (15)	WHO criteria (cavitation)
1992	Silver (97)	Cavitation "thought to involve dentine"

TABLE 2
[continued from previous page]

Year	Authors (Ref)	Criteria
1992	Sönju Clasen (98)	WHO criteria (cavitation)
1992	Vignarajah (99)	Caries at cavitation level involving dentin
1992	Weinstein (100)	No criteria
1991	Kamp (101)	Not reported
1991	Mangskau (102)	Not reported
1991	Wendt (43)	Initial caries defined as demineralized surface with chalky appearance. Initial caries recorded on buccal, lingual, mesial, and distal surfaces of incisors. Manifest caries recorded when there was minimal cavitation that could be verified by exploring in fissures and when probe got "stuck at a slight pressure."
1990	Greenwell (32)	For pits and fissures, decay was present when there was resistance to withdrawal of #23 explorers. No criteria were provided for smooth tooth surfaces.
1990	Louie (103)	NIDR criteria (cavitation)
1990	Onozawa (104)	Not reported
1990	Yagot (51)	WHO criteria (cavitation)
1989	Babeely (13)	Not reported
1989	Broderick (48)	Frankly carious and soft surfaces
1989	Bruerd (8)	Cavitated lesions
1989	Holbrook (105)	1) Cavitation of enamel on smooth surfaces or probe catching in pits or fissures with or without discoloration and no dentin involvement. 2) Dentin caries. 3) Deep caries of dentin with probable pulpal lesion.
1988	Albert (106)	Not reported
1988	Holt (107)	Visible cavitation
1988	Grytten (33)	When tooth surface felt sticky to probing
1987	Johnsen (59)	Not reported
1987	Kelly (108)	Cavitation
1986	Johnsen (60)	Not reported
1985	Persson (109)	Cavitated lesions. Initial lesions were not measured because it was difficult to get the child to cooperate.
1985	Salako (38)	A tooth surface was considered carious if the Ash #6 probe stuck with gentle pressure ... and required definite pull for removal or if there was obvious cavitation.
1985	Williams (49)	WHO criteria (cavitation)
1984	Johnsen (110)	Cavitated lesions
1984	Johnsen (60)	Not reported
1982	Derkson (6)	Not reported
1982	Holt (111)	A visible cavity in which it was considered that dentin was involved
1982	Johnsen (7)	Not reported
1982	McInnes (112)	WHO criteria (cavitation)
1981	Richardson (34)	Probe caught in suspicious fissure or pit
1979	McInnes (113)	Any area in which probe got "stuck"
1978	Cleaton-Jones (35)	Probe caught in suspicious areas
1978	Cleaton-Jones (36)	Probe caught in suspicious areas
1977	Currier (56)	Not reported
1976	Infante (114)	"Obvious lesions with soft dentin"
1976	Powell (58)	Not reported
1974	Silver (37)	When softening of floor of cavity was detectable on probing, or when probe got stuck under gentle pressure and required definite pull to raise it.
1972	Kleemola-Kujala (115)	A caries lesion was recorded only when probe got stuck in surface. White spots, deep fissures, and point-shaped pits were not recorded as lesions. I—caries involving enamel; II=caries involving dentin; III=caries involving pulp.
1971	Winter (116)	Visual examination (cavitation)
1971	Goose (4)	Mild and advanced stages of caries (cavitated only)
1966	Winter (5)	Visual examination (cavitation)
Unpublished Studies:		
1999	Milgrom (25)	"White spot lesions" in gingival third of crowns, caries in which enamel was cavitated
1999	NHANES III	NIDR criteria (cavitation)

TABLE 3
Case Definitions of Severe Early Childhood Caries [continued next page]

Year	Authors (Ref)	Case Definition
1998	Lopez (68)	One or more lesions in maxillary incisors
1998	Weerheijm (14)	Two or more maxillary teeth following pattern of nursing caries with regard to time of eruption
1997	Al-Shalan (69)	One or more decayed primary incisors
1997	Berkowitz (21)	Smooth surface decay affecting 2 or more maxillary incisors
1997	Febres (70)	Two or more anterior teeth and mandibular anterior teeth were sound
1997	Harrison (71)	Two ore more decayed maxillary anterior teeth
1997	Harrison (72)	Two ore more decayed maxillary primary teeth
1997	Peretz (50)	Three decayed maxillary incisors on buccal surfaces and confirmed by children's eating and feeding habits
1997	Ayhan (19)	1) One or more maxillary incisors showed ringlike pattern of decay. 2) One or more maxillary incisors were decayed to gum line. 3) Mandibular molars were sound.
1996	Bruerd (39)	Decay of 2 primary maxillary anterior teeth
1996	Douglass (74)	Two or more carious teeth in maxillary anterior teeth, consistent with clinical definition frequently used in studies of the subject
1996	Kaste (75)	At least 1 maxillary incisor showed visual evidence of caries or restoration on a labial or approximal surface
1996	Mattos-Graner (41)	At least 1 maxillary anterior tooth (incisors and canines)
1996	O'Sullivan (53)	At least 2 maxillary centrals and laterals and mesial of canine
1996	Ramos (77)	1) One or ore decayed lesions on labio-lingual surfaces of maxillary incisors. 2) At least 2 decayed maxillary incisors.
1996	Seow (63)	One decayed anterior tooth
1996	Shantinath (78)	One or more maxillary anterior teeth
1995	Al-Dashti (79)	Two or more maxillary incisors and history of breastfeeding
1995	Douglass (54)	At least 2 maxillary anterior teeth and mesial surfaces of maxillary canines
1995	Tsubouchi (83)	No case definition was provided even though the study is about baby bottle tooth decay
1995	Wyne (84)	Labial surfaces of at least 2 maxillary primary incisors
1994	Alaluusua (85)	Labial or palatal surfaces of maxillary incisors (at least 1)
1994	Benitz (86)	White/brown spots on enamel and/or small cavitations in dentin on 1 or more teeth
1994	Cook (87)	Three or more maxillary incisors
1994	Domoto (40)	At least 1 maxillary incisor
1994	Douglass (65)	At least 2 maxillary anterior teeth and mesial surfaces of maxillary canines
1994	Matee (88)	At least 2 maxillary incisors
1994	O'Sullivan (52)	At least 2 maxillary centrals and laterals and mesial of canine
1994	Roberts (89)	Two or more carious labial or palatal surfaces of "upper deciduous" incisors
1993	Juambeltz (91)	Decay on at least 2 maxillary incisors
1993	Milnes (20)	One or more maxillary incisors
1993	O'Sullivan (9)	At least maxillary incisor caries (centrals and laterals)
1993	Paunio (92)	At least 1 decayed maxillary incisor
1993	Serwint (57)	Nursing caries was defined as caries involving 1 or more teeth including the maxillary central or lateral incisors or primary molars but sparing mandibular incisors
1992	Barnes (94)	Two or more maxillary anterior tooth surfaces with caries
1992	Jones (95)	Three or more maxillary incisors "have a history of caries experience"
1992	Kaste (96)	Three definitions: 1) either buccal or lingual caries on at least 1 primary maxillary incisor, 2) 2 or more, and 3) 3 or more decayed primary maxillary incisor
1992	Katz (55)	1) 1 or more maxillary incisors with ringlike pattern of decay, 2) or 1 or more maxillary incisors were decayed to gum line, and 3) and the mandibular incisors were sound
1992	Matee (15)	Two or more maxillary incisors
1992	Silver (97)	Caries involvement of labial or palatal surfaces of 2 or more maxillary incisors
1992	Vignarajah (99)	Two or more labial or palatal surfaces of a maxillary or maxillary incisor
1995	Douglass (54)	At least 2 maxillary anterior teeth and mesial surfaces of maxillary canines
1992	Weinstein (100)	Two or more anterior teeth
1991	Kamp (101)	One carious maxillary incisor
1991	Mangskau (102)	Two or more primary "upper front teeth"
1991	Wendt (43)	One or more maxillary incisors
1991	Greenwell (32)	One or more carious lesions on facial or lingual smooth surface of any tooth, or on approximal surface of incisor or mesial surface of canine

TABLE 3
[continued from previous page]

Year	Authors (Ref)	Case Definition
1990	Louie (103)	Three or four maxillary incisors
1991990	Onozawa (104)	At least 1 decayed primary incisor or primary molar
1990	Yagot (51)	0=caries-free teeth; 1-white spot lesion on gingival third of maxillary primary incisors; 2=yellow or black discoloration on gingival third without cavitation; 3=cavity formation on gingival third of labial surface; 4=cavity formation on gingival third of labial surface and approximal surface with or without involvement of lingual surface; 5=extensive destruction of crown by caries or retained root or missing tooth
1989	Babeely (13)	Mild=caries on labial and/or palatal surface of 1 or more of maxillary incisors. Caries may also be present on buccal, palatal, or occlusal surfaces of 1 or both of the maxillary first molars (optional). Moderate=caries on labial and/or palatal surface of 1 or more of maxillary incisors. Caries present on buccal, palatal, or occlusal surfaces of 1 or both of the maxillary first molars. Caries present on buccal or occlusal surface of 1 or both of the mandibular first molars. Severe=same clinical picture as moderate, except that 1 or more of designated teeth have three or more surfaces with contiguous decay.
1989	Broderick (48)	Minimal=2 maxillary anterior tooth surfaces with caries; no carious lesions in posterior teeth. Mild=more than 2 maxillary anterior tooth surfaces with caries; no carious involvement of posterior teeth. Moderate=2 or more maxillary anterior tooth surfaces with caries; 1 or more posterior teeth with caries. Severe=2 or more maxillary anterior tooth surfaces with caries; 1 or more pulpal involvement and/or mandibular anterior decay.
1989	Bruerd (8)	Two or more maxiillary anterior tooth surfaces with caries
1988	Albert (106)	Of 42 30-month-old children with anterior caries, only 2 had a single tooth affected; 12 had 2 teeth and 28 had 3 or more teeth affected.
1988	Holt (107)	Two or more labial or palatal surfaces of maxillary incisors
1987	Johnsen (59)	Facial/lingual lesions (1 or more) on any tooth or an approximal surface of an incisor (excluded are the facial surface of the mandibular second primary molar and the lingual surface of maxillary second primary molar).
1987	Kelly (108)	Three of 4 maxillary incisors
1986	Johnsen (60)	Three incisors with cavitated carious lesions
1985	Williams (49)	1) Labial or palatal surfaces of 2 or more maxillary incisors; 2) dmft≥5
1984	Johnsen (110)	One or more lesions on facial or lingual surface of incisor tooth
1984	Johnsen (60)	Three maxillary incisors
1982	Derkson (6)	One or more lesion on labial and lingual surfaces of maxillary incisors
1982	Holt (111)	Caries involving labial or palatal surfaces of 2 or more maxillary incisor teeth
1982	Johnsen (7)	Three incisors exhibited cavities
1982	McInnes (112)	Labial surface of maxillary or mandibular tooth
1981	Richardson (34)	One or more decayed labial surfaces of canines and incisors
1979	McInnes (113)	Labial surface of maxillary or mandibular incisor
1978	Cleaton-Jones (35)	Caries on labial surface of 1 or more incisors or canines
1978	Cleaton-Jones (36)	Caries on labial surface of 1 or more incisors or canines
1977	Currier (56)	Three to 4 of maxillary primary incisors had obvious tooth destruction with associated extensive posterior caries in 7 of 9 patients
1976	Powell (58)	Labial-lingual surfaces of maxillary anterior teeth
1974	Silver (37)	Rampant caries of incisor teeth (number not defined)
1971	Winter (116)	Two maxillary incisors with carious lesions involving labial and palatal surfaces
1971	Goose (4)	Labial surfaces of incisors (number not defined)
1971	Winter (5)	Two maxillary incisors with carious lesions involving labial and palatal surfaces

control studies, two were controlled clinical trials, and four were cohort or field trials.

Names Used to Refer to S-ECC. The most frequently used name to refer to S-ECC was "nursing caries" (23 studies) followed by "baby bottle tooth decay" (14 studies). "Rampant caries" was used by nine included studies published between 1966 and 1994. Other names such as "labial caries," "early childhood caries," and "maxillary anterior caries" were used less frequently.

Sampled Populations. Three-quarters (n=71) of the published reports collected data from population-based samples and the other one-third (n=23) collected data from children seen in health or dental clinics. The studies reported a wide range of prevalence of children with ECC or S-ECC. Recent clinical studies published during the last two years found that between 19 percent and 63 percent of the examined children had S-ECC. Population-based studies reported a prevalence ranging from 0.8 percent, in 1–2-year-old children in the United States (Table 1) to 64 percent in 4-year-old Apache children in Arizona (Table 1). The studies also covered a wide age range, with about 55 percent of them (*n*=53) reporting data on children with an age range of 2 or more years.

Diagnostic Criteria of ECC or S-ECC. Table 2 lists the criteria that were reported to diagnose the presence of dental caries. "Cavitation" was the most commonly used sign of dental caries (*n*=44). No diagnostic criteria were reported by 22 studies. The World Health Organization (WHO) criteria (28) were reportedly used by 15 studies. Ten studies reported using the Radike or NIDR criteria (29,30). Eight studies explicitly stated that dental caries was diagnosed when an explorer "got stuck" in a carious lesion (31-38). Other studies used terms such as "dentinal caries" (14) and "scheduled for restorative treatment" (19) to identify children with dental caries.

One research team claimed that "none of the [3–5-year-old] children had questionable caries on the maxillary anterior teeth" and that S-ECC appeared to be an "all-or-nothing" dental disease (39). Another research team reported that 30.4 percent of the infants and toddlers examined had at least one incisor with incipient carious lesions ("white spot lesions") (40). None of the studies that had diagnosed "initial" caries reported data on reliability of the examiners in identifying these lesions. The criteria used for diagnosing the so-called "initial" or "enamel" lesions were vague. Early carious lesions were diagnosed when the examiners noticed "loss of translucency" (31,41) or "chalky appearance without macroscopic loss of tooth structure" (42-44). Four studies (31,42-44) used Koch's diagnostic criteria for initial lesions without reporting that the developer of the criteria decided after testing not to record "initial caries" to "minimize the subjective diagnostic error of the examiner" (45).

Evidence from an in vitro study suggests that dental caries advances during a short time period of about 3.4 weeks, on average, from enamel to dentin. (46). Epidemiologic evidence also indicates that noncavitated caries is more prevalent than cavitation during the first 18 months of life (25,41). Most of the included studies collected data from children older than 2 years of age. Hence, investigators might not have been able to detect early lesions, especially in high S-ECC populations, because most children were examined at an age when caries had already advanced into dentin.

In children with high exposure to a sugary diet during the first year of life, finding noncavitated lesions, however, might contribute to early interventions and the prevention and arrestment of progression. A recent study found that children with at least 10^6 colony-forming units of *Streptococcus mutans* in plaque were between four and five times more likely to have at least one "white spot lesion" in the gingival third of a crown or enamel cavitation, compared with children who have lower infection levels (25). Another recent study found that discolored pits and fissures in permanent teeth of children is a good indicator of colonization with mutans streptococci (*Streptococcus mutans* and *Streptococcus sobrinus*) (47).

Case Definitions of S-ECC. Table 3 presents the case definitions of S-ECC. The different research teams, even in reports published during the last two years, used different case definitions of S-ECC. The number of maxillary incisors included in the case definitions ranged between 1 and 3 teeth. Twenty-seven studies used the presence of a decayed, missing, or filled (dmf) incisor to define a child with S-ECC. Another 23 studies classified a child with S-ECC if he or she had two or more dmf teeth. Nine studies identified a S-ECC child if three or more maxillary incisors were affected. In three studies, no case definition was provided while others tested multiple definitions (1+, 2+, 3+ teeth) (Table 3). This review identified four studies that reported conditional case definitions using the number of maxillary incisors affected by caries and the carious status of posterior teeth (13,48) or presence of five or more dmf teeth (49), or inappropriate feeding habits (50). One study used an index that classified a child with S-ECC by the severity and location of dental caries (white, yellow, or black discoloration; cavity formation on the gingival third of the labial and then lingual surfaces) (51).

A few of the studies included the mesial surfaces of maxillary canines (52-54) in the case definition of S-ECC and one study differentiated between maxillary anterior caries and "nursing caries" (55). Only a few studies explicitly stated the carious status of the mandibular incisors or of other posterior teeth (9,13,48,51,55,56).

With a few exceptions, the included studies defined S-ECC by the presence of "decay." This approach may imply that the researchers have only looked for current signs of decay, such as softness or cavitation, or have considered in addition previous experiences with dental caries (fillings and extractions due to decay). The severity, location, or shape of a carious lesion were described only in a few reports (e.g., incipient lesions, ringlike, at gum line) (51,55).

Dental examinations in one of the included studies were conducted by a pediatrician who, after a four-hour training session with a pediatric dentist, examined children seen at a medical clinic for presence of signs of S-ECC ("nursing caries"). The case definition in that study included the presence of "one or more teeth including the maxillary central or lateral incisors or the primary molars, but sparing the mandibular incisors" (57). After the pediatrician and pediatric dentist screened the first 50 patients recruited into the study, the pediatrician had a sensitivity of 100 percent and a specificity of 87 percent in screening for signs of S-ECC.

Only 19 of the 94 included studies (Table 1) reported reliability coefficients for the diagnosis of ECC and S-ECC. Two-thirds (*n*= 59) of the studies did not report any information on calibration of examiners. The construct validity of the presence of dental caries in maxillary primary central or lateral incisors seems to be supported by findings that children with S-ECC have a high overall prevalence and incidence of dental caries in primary molars (13,32,48,58,59). The likelihood ratio of having dental caries in the primary molars—for example, in children with S-ECC—was about 3.5 (60). One study reported a kappa coefficient of 0.93 between the severity of dental caries (in incisors and molars) and frequent exposures, during the day and at bedtime, to sugary drinks and foods (13).

Caries Patterns of ECC in the Primary Dentition. Dental caries in young children develops on all teeth and tooth surfaces. Population-based studies have described a hierarchy of caries attack on different teeth and tooth surfaces (61-63) (Table 1). Dini et al. (61), for example, found that 3–4-year-old children with lifetime exposure to fluoridated water had the following ECC pattern (from most to least prevalent): second and first pri-

TABLE 4
Percentage Distribution of Children with Nursing Caries According to Affected Primary Teeth and Racial or Ethnic Group (Ref 65)

	% Children by Caries Pattern			
Caries Pattern	White (*n*=58)	Black (*n*=126)	Hispanic (*n*=69)	Chinese (*n*=95)
Pits and fissures*	22.4	38.9	52.2	62.1
Maxillary anterior†	13.8	17.5	13.0	43.2
Posterior proximal‡	5.2	3.2	7.2	14.7
Posterior facial-lingual¶	3.4	3.2	2,9	8.4

*Includes occlusal surfaces of molars as well as buccal pits of mandibular 2nd molars and lingual grooves of maxillary 2nd molars.
†Includes facial, lingual, and approximal surfaces of maxillary primary incisors and mesial surfaces of maxillary primary canines.
‡Includes distal surfaces of canines and all contacting posterior smooth surfaces.
¶Posterior buccal/lingual smooth pattern includes all buccal and lingual surfaces of molars excluding pits and fissures.
Tooth surfaces excluded from the classification system system were the buccal and lingual surfaces of canines, the mesial surfaces of manidbular canines, and all tooth surfaces of the mandibular incisors. The categories are not mutually exclusive.

mary molars, maxillary incisors, canines, and mandibular incisors. The hierarchy of the ECC pattern in 3-4-year-old children from Sendai, Japan, was as follows: second mandibular molars, maxillary central incisors, first mandibular molars, maxillary lateral incisors, maxillary canines, mandibular lateral incisors, and canines (62). In Aboriginal Australian children (mean age=4.4 years) the ECC pattern was as follows: mandibular molars, maxillary molars, maxillary incisors, maxillary canines, mandibular incisors, and canines (63). Our analysis of data from a national survey conducted in the United States in 1988 to 1994 (NHANES III) found a hierarchy of caries prevalence in primary teeth. In 3-year-old children, the occlusal surfaces of primary molars were the most affected tooth surfaces, followed by maxillary incisors, buccal-lingual surfaces of primary molars, mesial-distal surfaces of primary molars, maxillary canines, and mandibular canines and incisors. (The caries examination form used in NHANES III did not separate smooth tooth surfaces from pits or fissures of buccal and lingual surfaces of second primary molars.) This review did not find data on the progression of dental caries from one tooth group to another as a child passes through the different physical, behavioral, and dental development periods during the first five years of life.

During the last 20 years, different research groups have attempted to develop classification systems for ECC. A system developed by Johnsen and colleagues (32,59,64) classified ECC into three main patterns. These are:

I. Lesions associated with developmental defects

A. Pit and fissure defects—one or more lesions in pits or fissures of primary molars (occlusal surface of any molar as well as lingual surfaces of maxillary second molars and facial surfaces of mandibular second molars).

B. Hypoplasia—altered enamel contour with a detectable rough surface and darkened enamel or dentin, including caries adjacent to an area of hypoplasia and caries on the medial aspect of the facial surface of the primary canine.

II. Smooth surface lesions

A. Facial-lingual lesions (only cavitated lesions were included; "white spot" lesions were excluded from this system)—one or more lesions on a facial or lingual surface of any tooth (except for the facial surface of mandibular second primary molar and the lingual surface of the maxillary second primary molar) or an approximal surface of an incisor tooth.

B. Approximal molar lesions—one or more lesions on an approximal surface of a primary molar or distal surface of a primary canine.

C. Facial-lingual plus approximal lesions.

III. Rampant caries—14 out of 20 primary teeth having carious lesions including at least one mandibular incisor.

This system was tested using dental charts and radiographs obtained from two dental clinics in Ohio (59). Each child's dentition was classified with preference given to smooth surface carious lesions over those in pits and fissures and approximal over facial-lingual carious lesions. The tooth surfaces with the highest prevalence of caries were the smooth surfaces of primary molars and incisors. Patients with the facial-lingual pattern (which included S-ECC) were at the highest risk of being diagnosed with dental caries in the mixed dentition compared with patients with other patterns (32).

Another classification system is the Caries Analysis System (CAS) (65). The CAS defines four patterns of caries in the primary teeth (Table 4). The "fissure pattern" includes the occlusal surfaces of molars, buccal pits of mandibular second molars, and lingual grooves of maxillary second molars. The "maxillary anterior" pattern includes the facial, lingual, and approximal surfaces of maxillary primary incisors and mesial surfaces of maxillary primary canines. The "posterior proximal" pattern includes distal surfaces of primary canines and all contacting posterior smooth surfaces. The "posterior buccal/lingual smooth" pattern includes all buccal and lingual surfaces of molars, without pits and fissures. Tooth surfaces that are excluded from the classification system include all buccal surfaces of canines, lingual surfaces of the maxillary canines, lingual and mesial surfaces of the mandibular canines, and all tooth surfaces of the mandibular incisors. In this system the presence of one or more patterns of caries is recorded (Table 4).

The CAS was validated by investigating its association with future caries development in Head Start children in Hartford, CT (53) (Table 4). As expected, children with the maxillary anterior pattern had 2.4 times higher two-year increments of pit and fissure caries compared with caries-free children. They also had eight times higher caries increments in the buccal/lingual and proximal areas than caries-free children. Children with the fissure pattern also were three to four times more likely to develop caries compared with disease-free children.

The system was tested in other populations. In 3-year-old Navajo children, the maxillary-anterior pattern was more prevalent than the fissure or the posterior-proximal pattern (52). In 4-year-old Navajo children, the fissure pattern was more prevalent than the maxillary anterior pattern. In 3-year-old children from Beijing, China, the fissure pattern was the most prevalent, followed by the maxillary anterior, posterior proximal, and posterior buccal/lingual smooth surfaces (65). In 4-year-old Chinese children, the posterior proximal pattern was the second most common one after the fissure pattern (65). These data may indicate that early in life dental caries in high-disease populations occurs in stages with the smooth surfaces of the maxillary incisors being attacked first followed by pit and fissure surfaces. No longitudinal data to support this observation are available.

Another classification system, proposed by Veerkamp and Weerheijm (66), claims to account for the stage of development of the dentition and severity of dental caries (initial and cavitated). This classification system assumes that dental caries occurs in successive stages starting late in the first year (10 months) and ending in the fourth year of life (48 months). The four stages were referred to as initial, damaged, deep lesions, and traumatic. At each stage, a different group of teeth are involved and dental caries can range from enamel demineralization (opaque white demineralization) to cavitation involving enamel and dentin. This system has not yet been validated.

Discussion

This review presents a synopsis of the evidence on the diagnosis and definitions of ECC and S-ECC. The evidence from the 94 included studies shows that there is inconsistency in the case definition of S-ECC and diagnostic criteria of ECC.

Scientific inquiries start with developing a hypothesis that may explain a phenomenon or propose a solution to a problem. The most crucial step in any scientific research project is the development of measurement criteria and tools that can validly and reliably estimate the parameters included in a hypothesis. Research on diagnosis of dental caries and other oral conditions has received little attention from the dental research community and funding agencies in the United States. We concur with Horowitz's conclusion, presented at the 1997 Early Childhood Caries Conference, that we need to conduct research "to ascertain what, in fact, constitutes ECC" (11).

The first goal for research in this field must be to diagnose ECC as early as possible to prevent its progression to advanced forms of dental caries (cavitation and tooth destruction). The second goal should be to collect information on risk predictors of ECC or S-ECC to intervene early and arrest progression of the disease. To achieve these goals, the scientific community should reach consensus on answers to the following questions:

1. Does the term early childhood caries (ECC) represent a single disease pattern (for example, caries on the facial-lingual surfaces of maxillary anterior teeth) or several patterns of caries occurring on primary teeth of children between the ages of 1 and 5 years?
2. Should diagnostic criteria measure and present data for tooth surfaces affected by dental caries for each single preschool year of life?
3. Should the definition of dental caries include early or noncavitated carious lesions?
4. In research projects, what other predictors or indicators of S-ECC should be measured?

This review concludes that most studies of S-ECC have focused on classifying children by the presence of decayed or filled maxillary incisors. The case definitions reported in the literature classified a child with S-ECC based on the presence of one or more, two or more, or three or more decayed or filled maxillary incisors. The majority of studies (n=59) did not report on whether calibration of examiners was carried out and some even did not report the diagnostic criteria used to diagnose dental caries. The diagnostic criteria of dental caries have relied mostly on the presence of cavitation or "stickiness." The content validity of these indicators of dental caries is weak (1,2).

Because of the problems associated with tertiary care of children with ECC and the disparities in oral health status between children from low- and high- or medium-income groups in the United States (17), early detection of dental caries should be paramount in public health programs and dental practice. Hence, it is perhaps pertinent in future studies to consider several dimensions of dental caries in the case definition of ECC. The classification of ECC should be expanded to include age and other predictors of dental caries. Data should be reported separately for single ages to evaluate the progression of ECC in relation to the dietary changes and behavioral development of a child.

Dental caries in young children does not occur in one group of teeth or tooth surfaces. In some Canadian provinces where children are covered by a dental insurance plan, the most costly tooth surfaces to treat are the contacting surfaces of posterior teeth (67). In Nova Scotia, for example, where 80 percent of the 140,000 eligible children visit a dentist annually and all treatments provided in dental offices and hospitals are paid for by one insurance board, the approximal surfaces of primary teeth are the most costly tooth surfaces to treat. A 1993–94 analysis of the dental insurance program of the province found that 96 percent of all two-surface restorations were placed in primary posterior teeth. The cost of restoring, crowning, and extracting primary molars is about $3 million (Canadian) annually out of a budget of $10 million (Canadian) for all dental programs.

This review concludes that dental caries in children occurs on molars, maxillary incisors, and even canines and mandibular incisors. Research is needed to develop diagnostic tools to study the etiology and epidemiology of early childhood caries. The goal of any research in this area should be to promote oral health of young children. Achieving this goal is hindered by the inconsistencies in diagnostic criteria of early childhood caries and case definitions of severe early childhood caries. Definitions of ECC and S-ECC must be tested for their predictive validity, feasibility, and their impact on assessing the outcomes of prevention and treatment of ECC and S-ECC. Research programs that aim to reduce disparities in oral health of children should support developing valid and feasible methods of diagnosis and classification of severity of dental caries in preschool children.

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