

Literature Review



Association of Mutans Streptococci Between Caregivers and Their Children

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Abstract: The purposes of this literature review were to: (1) review the sources of mutans streptococci (MS) colonization in children and the effect of MS levels of primary caregivers on children's MS colonization; and (2) evaluate studies examining interventions to reduce transmission of MS from caregivers to their children. Forty-six studies were reviewed. Strong evidence demonstrated that mothers are a primary source of MS colonization of their children. A few investigations showed other potential sources of children's MS colonization, notably fathers. The role of other factors influencing transmission, such as socioeconomic status (SES) and specific cultural or behavioral practices, are unclear. There were at least 12 reports of microbiological interventions to reduce transmission of MS from caregivers to their children. Even though most studies found a reduction of MS in the children and 2 showed significant caries reduction, these studies generally lack consistent findings regarding caries reduction, have a small sample size and inadequate control groups, and lack blindness of investigators and subjects. The efficacy of microbiological approaches on the caregivers to reduce caries risk in children still needs to be established through more rigorously designed clinical trials. (*Pediatr Dent* 2008;30:375-87) Received July 16, 2007 | Last Revision October 28, 2007 | Revision Accepted October 29, 2007

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The incidence of dental caries has decreased steadily in most industrialized countries in the past 30 years, although there is evidence that this decline may not be continuing. Furthermore, caries remains highly prevalent in children of low socioeconomic families and children from underdeveloped countries.¹ The dental caries development mechanism depends on interrelationships between the tooth surface, dietary carbohydrates, and specific oral bacteria. A group of phenotypically similar micro-organisms, the so called mutans streptococci (MS), is associated with dental caries' initial development.² The MS that are most frequently associated with human dental caries are *Streptococcus mutans* and *Streptococcus sobrinus*. This group of bacteria has the ability to adhere to enamel, produce abundant acid from dietary carbohydrates, and survive at a low pH. It is believed that MS colonization in children must precede enamel demineralization and subsequent tooth enamel surface cavitation.³ Once the enamel surface is breached, other oral bacteria, such as lactobacilli, may colonize the tooth, produce acid, and foster further tooth demineralization.

Understanding the factors that affect initial MS colonization is essential to understanding caries development in preschool children. Preschool children with high MS colonization levels have been shown to have greater levels of caries, as well as greater risk for new lesions, than children with low levels.⁴⁻⁶ Additionally, studies have demonstrated that MS colonization at a young age is an important factor for early caries initiation.^{5,7,8} MS colonization of the oral cavity in children is believed to be caused by transmission of these micro-organisms from the child's primary caregiver.⁹ The transmission has been associated with high MS levels, open lesions, poor oral hygiene in the caretakers, low economic status, and frequent snacking by the child. The exact transmission mechanism is not clear, however, but it has been suggested that intimate contact, sharing of food or utensils, or immunological issues are contributing factors.¹⁰

Ascertaining the factors associated with MS transmission and timing of initial colonization are important to understand caries risk factors for the child and implement caries preventive measures. Several clinical trials have evaluated whether decreasing colonization levels in the primary caretakers affects MS transmission and subsequent dental caries in children.¹⁰⁻¹²

The purposes of this literature review were to: (1) review the sources of mutans streptococci (MS) colonization in children and the effect of MS levels of primary caregivers on children's MS colonization; and (2) evaluate studies examining interventions to reduce transmission of MS from caregivers to their children.

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Table 1. EVIDENCE FOR MOTHERS AS THE MUTANS STREPTOCOCCI SOURCE IN CHILDREN YOUNGER THAN 6-YEARS-OLD

Paper	Country	Mother-child pairs (N)	Technique	Children with ≥ 1 phenotype/genotype identical to their mother % (N)
Berkowitz et al (1975) ¹³	USA	4	Bacteriocin typing	100 (4)
Berkowitz et al (1985) ¹⁴	USA	20	Bacteriocin typing	100 (20)
Caufield et al (1989) ¹⁵	USA	3	Genotyping	100 (3)
Li et al (1995) ¹⁶	USA	34	Genotyping	71 (24)
Alaluusua et al (1996) ¹⁷	Finland	12	Serotyping and ribotyping	67 (8)
Emanuelsson et al (1998) ¹⁸	Sweden	11	Genotyping	55 (6)
Redmo Emanuelsson et al (1998) ¹⁹	China	11	Genotyping	55 (6)
De Soet et al (1998) ²⁰	Holland	21*	Genotyping	38 (8)
Kozai et al (1999) ²¹	Japan	19	Serotyping and genotyping	84 (16)
Li et al (2000) ²²	China	38	Genotyping	45 (17)
Tedjosasongko et al (2002) ²³	Japan	19	Genotyping	33 (6)
Kohler et al (2003) ²⁴	Sweden	16	Ribotyping	85 (14)
Ersin et al (2004) ²⁵	Turkey	8	Genotyping	100 (8)
Lindquist et al (2004) ²⁶	Sweden	10	Genotyping	70 (7)
Klein et al (2004) ²⁷	Brazil	16	Genotyping	81 (13)
Li et al (2004) ²⁸	USA	37	Genotyping	89 (33)
Hames-Kocabas et al (2006) ²⁹	Turkey	25	Genotyping	24 (6)

* Children had clefts.

Table 2. EVIDENCE FOR FATHERS AS THE MUTANS STREPTOCOCCI SOURCE IN CHILDREN YOUNGER THAN 6-YEARS-OLD*

Paper	Country	Father-child pairs (N)	Technique	Children with ≥ 1 phenotype/genotype identical to their father % (N)
Li et al (1995) ¹⁶	USA	7	Genotyping	0 (0)
Emanuelsson et al (1998) ¹⁸	Sweden	11	Genotyping	0 (0)
Redmo Emanuelsson et al (1998) ¹⁹	China	11	Genotyping	46 (3)
Kozai et al 1999 ²¹	Japan	19	Genotyping	58 (11)
Li et al (2000) ²²	China	38	Genotyping	0 (0)
Tedjosasongko et al (2002) ²³	Japan	19	Genotyping	8 (2)
Kohler et al (2003) ²⁴	Sweden	7	Ribotyping	86 (6)
Ersin et al (2004) ²⁵	Turkey	3	Genotyping	100 (3)
Hames-Kocabas et al (2006) ²⁹	Turkey	12	Genotyping	0 (0)

* All studies included maternal data found in Table 1.

Materials

Literature searches were made using PubMed, utilizing the terms “mutans streptococci” or “*Streptococcus mutans*” in conjunction with “maternal,” “mother,” “paternal,” “father,” “infant,” “children,” “transmission,” and “colonization.” Secondary searching was performed using the selected articles’ reference lists. Abstracts were screened, and articles covering the relevant topics were obtained. The inclusion and exclusion criteria were based on: 1) studies focusing on the relationship between MS in primary caregivers and their children younger than 6 years old; 2) the investigation of the effect of micro-

biological interventions in the caregivers on MS colonization or caries prevalence in their preschool-age children; and 3) their potential to provide information relevant to the research questions.

All articles selected in this critical review were included in Tables 1 to 5. When repeated reports of the same study were identified, the study was only listed once in Tables 1 to 5. No articles were excluded based on sample size or methodological quality.

Because of the varying microbiologic techniques found in these papers, it was often difficult to determine whether

the data represented the bacterial group, MS, or the individual species (eg, *S. mutans* and *S. sobrinus*). Therefore, the term MS has been used throughout this report. In papers that made clear distinctions between *S. mutans* and *S. sobrinus*, table data were calculated based on the total number of MS—in other words, the results for *S. mutans* and *S. sobrinus* were pooled.

When possible, data from publications were recategorized or recalculated so that the results of various studies could be presented in the same table with similar formats for comparison. Studies in each table are listed in chronologic order based on their publication date.

Regarding studies that investigated the effect of maternal interventions on children's MS levels and caries incidence, the degree of methodological rigor was variable. Therefore, a set of predetermined criteria on study limitations was used to assess the quality of these reports. The criteria were: (1) study design issues; (2) small sample size; (3) inadequate description of study population; (4) non-representative sample; (5) generalizability issues; (6) no/inadequate control group; (7) inadequate description of methods; (8) possible clinical examination bias; (9) data analysis issues; and (10) interpretation of results issues.

Results

After extensive searches of the databases and secondary investigations using reference lists from selected articles, 46 studies published between 1975 and 2006 were identified. Of these studies: 17 examined the evidence for mothers as the source of MS in their children (Table 1); 9 examined the evidence for fathers as the MS source (Table 2); 13 examined the evidence for the sharing of MS between spouses (Table 3); and 14 examined the relationship between MS levels in mothers and their children (Table 4). Regarding maternal interventions to decrease the transfer of MS to their children, 12 papers were identified (Table 5). Papers that addressed several areas of interest may have been included in more than one table.

One of the key issues regarding MS colonization in infants and preschool children is how they become colonized by MS. A pioneering study by Berkowitz and Jordan in 1975, using serotyping to demonstrate that mother-child pairs harbored similar MS strains, suggested the possibility of early MS transmission from primary caregivers to their children.⁶¹ Since that initial report, there have been at least 17 cross-sectional studies from as many as 8 different countries using various bacterial phenotyping or genotyping techniques to investigate MS transmission from mothers to their preschool children (Table 1). Although some of these studies have small sample sizes, generally in the range of 20 mother-child pairs, the data have consistently shown that children acquired at least 1 phenotype or genotype of MS isolate identical to their mothers. Remarkably, most of these reports showed that over half of the MS isolates found in children were identical to their mothers.

An inherent question that would follow this apparent mother-child relationship is whether the father also could be an MS source. Among the 9 studies identified in Table 2, 4 found that over 50% of the children had at least 1 genotype of MS that was identical to their mother's genotypes but not to their father's.⁶²⁻⁶⁴ Four other studies, however, reported that a similar percentage of children acquired MS that were identical to both their fathers and mothers.⁶⁵⁻⁶⁸

To gain further insights on the issue of parent-child MS transmission, an additional literature search was conducted to examine the evidence of sharing identical MS isolates between spouses; 13 studies from 9 different countries were identified (Table 3). Although the total number of spouses in each study was small, 9 of the 13 studies (75%) found that spouses shared at least 1 identical MS isolate.

Since data from Tables 1 and 2 present strong evidence that mothers are a primary source of MS transmission to their children, it is important to examine the issues that foster the

Table 3. EVIDENCE FOR SHARING OF IDENTICAL MUTANS STREPTOCOCCI STRAINS BETWEEN SPOUSES

Paper	Country	Spouse pairs (N)	Technique	Spouses sharing ≥ 1 phenotype/genotype % (N)
Rogers (1981) ³⁰	Australia	11	Bacteriocin typing	0 (0)
Davey et al (1984) ³¹	Australia	10	Bacteriocin typing	40 (4)
Kulkarni et al (1989) ³²	Canada	5	Genotyping	60 (3)
Saarela et al (1989) ³³	Finland	3	Ribotyping	66 (2)
Li et al (1995) ¹⁶	USA	7	Genotyping	0 (0)
Emanuelsson et al (1998) ¹⁸	Sweden	11	Genotyping	0 (0)
Redmo Emanuelsson et al (1998) ¹⁹	China	11	Genotyping	27 (3)
Kozai et al 1999 ²¹	Japan	20	Genotyping	15 (3)
Van Loveren et al (2000) ³⁴	Netherlands	8	Bacteriocin typing	50 (4)
Remo Emanuelsson et al (2001) ³⁵	Sweden	13	Genotyping	8 (1)
Kohler et al (2003) ²⁴	Sweden	7	Ribotyping	86 (6)
Ersin et al (2004) ²⁵	Turkey	3	Genotyping	100 (3)
Hames-Kocabas et al (2006) ²⁹	Turkey	12	Genotyping	0 (0)

Table 4. RELATIONSHIP BETWEEN MUTANS STREPTOCOCCI (MS) LEVELS IN MOTHERS AND THEIR CHILDREN YOUNGER THAN 6 YEARS OLD

Paper	Country	Mother-child pairs (N)	Child's age	Outcome*
Kohler et al (1978) ³⁶	Sweden	36	4-5 yrs	<ul style="list-style-type: none"> • 75% of children whose mothers had high MS were colonized[†]; • 25% of children whose mothers had low MS were colonized
Berkowitz et al (1981) ³⁷	USA	156	8-18 mos	<p>Mothers' and children's MS levels were significantly associated</p> <ul style="list-style-type: none"> • 58% of children whose mothers had high MS were colonized; • 12% of children whose mothers had low MS were colonized
Brown et al (1985) ³⁸	Australia	24	<6 yrs	<p>Mothers' and children's MS levels were significantly associated</p> <ul style="list-style-type: none"> • 91% of children whose mothers had high MS were colonized; • 15% of children whose mothers had low MS were colonized
Brown et al (1985) ³⁸	Australia	112	<2 yrs	<p>Mothers' and children's MS levels were significantly associated</p> <ul style="list-style-type: none"> • 79% of children whose mothers had high MS were colonized; • 52% of children whose mothers had low MS were colonized
Aaltonen et al (1988) ³⁹	Finland	50	4-6 yrs	Mothers' and children's MS levels were significantly correlated (r=0.48)
Caufield et al (1988) ⁴⁰	USA	87	2-5 yrs	<p>Mothers' and children's MS levels were significantly associated</p> <ul style="list-style-type: none"> • 68% of children whose mothers had MS above the median had colonization levels above the median; • 40% of children whose mothers had MS below the median had colonization levels above the median
Caufield et al (1993) ⁴¹	USA	46	0-5 yrs	Mothers' and children's MS levels were not significantly associated
Aaltonen et al (1994) ⁴²	Finland	55	6 yrs	Mothers' and children's MS levels were not significantly associated
Roeters et al (1995) ⁴³	Netherlands	252	2-5 yrs	Correlation between mother's and children's MS levels were low and did not exceed r=0.22
Tanner et al (2002) ⁴⁴	Saipan	156	6-36 mos	<p>Caregivers' and children's MS levels were significantly associated (81% of caregivers were mothers)</p> <ul style="list-style-type: none"> • 93% of children whose caregivers had MS were colonized; • 54% of children whose caregivers had no MS were colonized; • Children were 13 times more likely to be colonized if the caregiver had MS
Thorild et al (2002) ⁴⁵	Sweden	200	18 mos, 3 yrs	<p>Mothers' and children's MS levels were significantly associated[‡]</p> <p>18-month-olds:</p> <ul style="list-style-type: none"> • 40% of children whose mothers had high MS were colonized; • 13% of children whose mothers had low MS were colonized <p>3-year-olds:</p> <ul style="list-style-type: none"> • 52% of children whose mothers had high MS were colonized; • 15% of children whose mothers had low MS were colonized <p>All children:</p> <ul style="list-style-type: none"> • Children were more likely to be colonized if their mother had high MS (odds ratio=5.28)
Tedjosongko et al (2002) ²³	Japan	39	0-5 yrs	Mothers' and children's MS levels were not significantly associated
Wan et al (2003) ⁴⁶	Australia	111	0-2 yrs	<p>Mothers' and children's MS levels were significantly associated</p> <ul style="list-style-type: none"> • Children whose mothers had high MS had 2.1-8.5 odds ratio of being colonized.
Li et al (2005) ²⁸	USA	156	0-4 yrs	<p>Mothers' and children's MS levels were not significantly associated except for age of colonization</p> <ul style="list-style-type: none"> • 37% of children whose mothers had high MS were colonized; • 32% of children whose mothers had low MS were colonized

* High MS: MS counts ≥10⁵ colony forming units (CFU). Low MS: MS counts <10⁵ CFU, unless otherwise indicated.

† High MS: MS counts >10⁶ CFU; Low MS: MS counts <10⁵ CFU (note: moderate MS mothers were excluded).

‡ High MS: MS counts >150 CFU; Low MS: MS counts = 1-15 CFU (note: moderate MS mothers were excluded).

transmission from mothers to children. One factor examined was the effect of mothers' MS levels on the transmission of MS to the children. Fourteen studies were identified that examined the relationship of MS levels between mothers and

their children (Table 4). To simplify comparisons, the data were recalculated (where possible) to compare the percentage of children with high MS mothers who were colonized to the percentage of children with low MS mothers who were

colonized. There was a clear trend indicating that children were more likely to harbor MS when their mothers were highly colonized by MS. For example, in one study with 156 mother-child pairs where the children were 3 to 36 months old, it was found that among children with high MS mothers, 93% of children were colonized compared to only 54% with low MS mothers.⁴⁴ Even though most of the data show evidence of a significant positive association between MS levels in mothers and that in their children, 4 of the 14 studies listed in Table 4 did not show such an association.

Perhaps the most important clinical issue of the relationship between the MS levels in primary caregivers and the MS colonization in their children is whether an intervention aimed to decrease caretakers' MS levels will delay or reduce MS colonization, and consequently decrease caries incidence in their children. Twelve clinical trials were identified that used either a single agent or a combination of agents and behavioral interventions with the hope of decreasing MS levels of primary caregivers and, consequently, the development of caries in their children (Table 5). The pioneering reports in this arena were by Kohler et al in 1983 and 1994,^{47,48} in which mothers with high MS levels were treated with 1% chlorhexidine gel once a day for 2 weeks and were provided dietary counseling, prophylaxis, oral hygiene instructions, and restorative treatment. Three years after the treatment, reportedly fewer children with mothers in the treatment group were colonized by MS.⁴⁸ Seven years after the treatment, the children of treatment group mothers also reportedly had significantly lower caries.⁸ Similar studies utilizing 10% chlorhexidine varnish or 40% chlorhexidine gel reported MS reductions in the children, but there was either no change or no report of a reduction in caries increment (Table 5a).

Four studies reported the effect of using chlorhexidine rinses or gels combined with fluoride rinses or varnishes on the mothers' MS levels and MS colonization and caries in their children (Table 5b). All of these studies found a reduction, ranging from 10% to 50%, in MS colonization of the children.^{52-54,69} Three of these studies also reported a significant decrease in the number of children who had caries.^{53,54,69}

Three studies examined the effect of antimicrobial agents, other than chlorhexidine and fluoride, on MS (Table 5c). Two randomized, controlled trials that used iodine and NaF on the mothers found marginal effects on MS colonization and caries increment in their children at 30 to 36 months of follow-up.^{12,70} Additionally, 1 retrospective study examined caries prevalence in children in which experimental group mothers obtained restorative treatment combined with the use of a fluoride mouthrinse, a fluoride dentifrice with triclosan, and educational reinforcement.⁵⁶ Mothers in a retrospective comparison group did not receive any intervention. Children with experimental group mothers experienced significantly lower caries prevalence.

Two studies compared the effect of chewing xylitol gum vs chlorhexidine or fluoride varnishes or gums on MS levels

in mothers and MS colonization in children (Table 5d). Only the Isokangas and Soderling et al study^{11,71,72} observed that children of mothers chewing xylitol gum had significantly decreased MS levels and caries.

Discussion

MS are the group of micro-organisms most associated with the dental caries process. Preschool children with high MS levels have been shown to have greater caries experience and a much larger risk for new lesions than those children with low MS levels.⁷³⁻⁷⁵ Additionally, early MS colonization is also an important risk factor for the early development of dental caries.⁷⁶⁻⁸⁰ Thus, there has been great interest in the past several decades to determine how children become colonized with MS and whether this colonization can be postponed or reduced to decrease a child's caries risk. Since the first attempt to investigate the possibility of person-to-person transmission of MS, done by Jordan et al in 1972,⁸¹ numerous reports have been published about MS transmission. This literature review examined 46 studies published between 1975 and 2006 that evaluated the role of primary caregivers in the MS colonization of their preschool children and the effect of microbiological interventions on MS transmission from primary caregivers to their children.

Beginning in 1975, most of the early investigations were cross-sectional studies utilizing serologic⁸² or bacteriocin⁶¹ characteristics to distinguish MS isolates. The use of serologic typing to differentiate clinical MS isolates was developed in the early 1970s.⁸³⁻⁸⁵ By comparing recognizable antigen extracts obtained from heat-killed MS cells against known serotype-specific antisera, 5 serological groups of MS commonly associated with dental caries in humans were identified: serotypes c, e, and f for *S. mutans*; and serotypes d and g for *S. sobrinus*. Of the MS isolates in dental plaque and carious dentin, 95% have been identified as serotype c for *S. mutans*.⁸⁶ Similarly, at least 4 types of bacteriocins (mutacins) produced by MS have been purified and biochemically characterized,⁸⁷⁻⁹¹ mostly for *S. mutans*. In the late 1980s and early 1990s, molecular genetic techniques were developed that differentiate MS isolates based on genotypic characteristics of individual DNA samples. These techniques identified diverse genotypes of MS strains within the same MS serotypes⁹² or among MS isolates carrying similar types of bacteriocins.⁹³ Therefore, the use of bacteriocins or serologic typing to determine the fidelity of MS transmission from primary caregivers to their children could be challenged for sensitivity and lack of accuracy.

To overcome these difficulties, molecular typing methods have been developed and become important tools for studying MS transmission and colonization. To date, the most commonly used genetic methods include MS chromosomal DNA fingerprinting with specific endonuclease enzyme digestion^{63,64,67,68,94} and MS chromosomal DNA ribotyping.^{95,96} Recently, a single polymerase chain reaction (PCR) with randomly selected DNA primers has been sufficient to examine similarity of MS clinical

Table 5. THE EFFECT OF MATERNAL INTERVENTION TO DECREASE MUTANS STREPTOCOCCI (MS) COLONIZATION AND CARIES IN CHILDREN

Paper and country	No. of subjects	Study type and duration	Control group therapy	Treatment group therapy	Outcome
5a. Chlorhexidine interventions (single agent)					
Kohler et al (1983, 1994) ^{47,48} Sweden	249 mothers screened; 87 high MS mothers participated; 81 completed study. 48 evaluated at 36 mos; 58 evaluated at 7 yrs.	Randomized clinical trial. 3 yrs from when children were 3-5-mos to 3-yrs-old	None	Education Restoration Tx of large cavities Prophylaxis Fluoride Tx (unspecified) If subjects still had high MS, then 1% chlorhexidine (CHX) gel 1x/day for 2 wks. Preventive protocol repeated every 4 mos if maternal MS levels required it.	Significant reduction in maternal MS in Tx vs control group at 7 yrs: • 6.2 x10 ⁵ vs 1.3 x10 ⁶ CFU Significant reduction in children's MS colonization and caries scores in treatment vs control group: • 15 mos MS: 10% vs 24%; • 23 mos MS: 16% vs 45%; • 36 mos MS: 38% vs 63%; • 7 yrs MS: 46% vs 95%; • 7 yrs defs: 5.2 vs 8.6.
Limitations: <i>Analysis not rigorous; interpretation of results issues</i>					
Dasanyake et al (2002) ⁴⁹ USA	428 pregnant mothers were screened; 75 mothers with no "open" cavities participated; 66 completed study.	Randomized clinical trial. 3 yrs from pregnancy to when children were 4-yrs-old	Emergency restorative treatment Prophylaxis Placebo varnish.	Same as control, plus: 10% CHX varnish 1x/wk for 4 wks repeated every 6 mos until child was 36-mos-old.	Significant reduction in maternal MS in treatment vs control group at 18 mos: • 7 mos MS: 10 ² vs 10 ⁴ CFU; • 12 mos MS: 10 ³ vs 10 ⁵ CFU; • 18 mos MS: 10 ⁴ vs 10 ⁵ CFU. No significant difference in children's MS colonization or caries scores in Tx vs control group at 4 yrs: • MS: 36% vs 41%; • dft: 2.5 vs 2.4.
Limitations: <i>None</i>					
Gripp et al (2002) ⁵⁰ Germany	44 mothers with newborns. Three groups: 16 high MS Tx; 15 low MS controls; 13 high MS controls	Stratified clinical trial. 2 yrs from when children were 4-mos to 24-mos-old.	Education	Same as control, plus: Prophylaxis and 40% CHX varnish at 3-mo intervals for entire study.	Significant reduction in maternal MS in treatment group from baseline. Significant difference in children's MS colonization between Tx or low MS control vs high MS control at 24 mos: • 12 mos MS: 9% vs 0% vs 13%; • 18 mos MS: 20% vs 0% vs 33%; • 24 mos: MS 19% vs 7% vs 69%
Limitations: <i>Small sample size; No/Inadequate control group</i>					
5b. Chlorhexidine and fluoride interventions					
Tenovu et al (1992) ⁵¹ Finland	202 mothers with 1-y-old infants; Three groups: 70 high MS treatment 53 low MS control 79 high MS control	Stratified clinical trial. 3 yrs from when children were 1-yr to 4-yrs old.	Education	Same as control plus: 1% chlorhexidine/0.2%/NaF gel treatments 6x over 2-day period; CHX repeated every 6 mos.	No significant difference in children's MS colonization or caries scores in Tx vs low MS control vs high MS control groups: • 2 yrs MS: 20% vs 10% vs 18%; • 3 yrs MS: 36% vs 42% vs 48%; • 3 yrs dft: 0.1 vs 0.02 vs 0.46; • 4 yrs MS: 50% vs 53% vs 58%; • 4 yrs dft: 0.59 vs 0.18 vs 0.68.
Limitations: <i>Possible clinical examination bias; Interpretation of results issues</i>					
Brambilla et al (1998) ⁵² Italy	310 pregnant mothers screened; 65 high MS mothers participated; 60 completed study	Randomized clinical trial. 30 mos from pregnancy to when children were 2-yrs-old	Education Prophylaxis 1 mg fluoride tabs	Same as control, plus: Daily 0.05% fluoride rinse; Daily 0.12% CHX rinse (20 days on, 10 days off) during last trimester.	Significant reduction in maternal MS in treatment vs control group: • 30 mos MS: 0.17x10 ⁵ vs 6.2x10 ⁵ CFU Significant reduction in children's MS colonization in Tx vs control group: • 30 mos: 48% vs 83%.
Limitations: <i>Data analysis issues</i>					

Table 5. Continuation

Paper and country	No. of subjects	Study type and duration	Control group therapy	Treatment group therapy	Outcome
Gunay et al (1998) ⁵³ Germany	86 pregnant mothers; 47 completed study; Comparison group comprised 45 children recruited from kindergarten unrelated to original program site.	Prospective study. 4 yrs from pregnancy to when children were 4-yrs-old	None	Education Referral for restorative treatment Prophylaxis Fluoride varnish CHX rinse (latterly varnish).	Significant reduction in maternal MS in treatment group from baseline. Significant reduction in children's MS colonization and caries prevalence/dmfs in Tx vs comparison group: <ul style="list-style-type: none"> • 3 yrs MS: 0% vs 62%; • 3 yrs caries: 0% vs 18%; • 4 yrs MS: 57% vs 73%; • 4 yrs caries: 8% vs 42%; • 4 yrs dmfs 1.5 vs 7.0.
Limitations: <i>No control group; Study design issues; Possible clinical examination bias; Interpretation of results issues</i>					
Turksel Dulgergil et al (2004) ⁵⁴ Rural Turkey	53 mothers with infants with fewer than 6 teeth screened; 27 mothers participated.	Randomized clinical trial. 2 yrs from when children were 2-18 mos to 24-42 mos old.	Education Extraction of non-restorable teeth.	Same as control plus: Fluoride toothpaste with Triclosan ART and GI sealants; Fluoride varnish and 0.02% CHX rinse for 10-day period repeated every 6 mos.	Significant reduction in maternal MS in treatment vs control group. Significant reduction in children's MS colonization and caries prevalence in Tx vs control group at 2-yr follow-up: <ul style="list-style-type: none"> • MS: 66% vs 100%; • Caries: 13% vs 92%; • dft: 0.2 vs 2.0
Limitations: <i>Small sample size; Data analysis issues; Interpretation of results issues; Generalizability issues</i>					
5c. Interventions with antimicrobials (other than chlorhexidine) and fluoride					
Dasanayake et al (1993) ¹² USA	62 high MS pregnant mothers with <4 missing teeth; 48 completed study.	Randomized clinical trial. 3 yrs from birth to when children were 3 yrs old.	Restorative treatment Prophylaxis Placebo agent	Same as control plus: Sealants NaF/Iodine (1 g I ₂ , 1 g KI, 53 ml glycerin, 1.2 g NaF and water to make to 100 ml) applied 6x over 2 wks when children were 6-12 mos old.	Significant reduction in maternal MS in treatment group by 70% immediately post-treatment, but difference not sustained. No significant difference in children's MS colonization or caries scores in treatment vs control groups at 3 yrs: <ul style="list-style-type: none"> • Caries: 30% vs 16%
Limitations: <i>None</i>					
Zanata et al (2003) ⁵⁵ Brazil	81 pregnant mothers with active caries; 64 completed study.	Randomized clinical trial. 30 mos from pregnancy to when children were 2-yrs-old	Preventive education: Restorative treatment (IRM posterior teeth/composite anterior teeth)	Same as control plus: Restorative treatment (glass ionomer) Prophylaxis NaF/Iodine (1 g KI, 53 ml glycerin, 1.2 g NaF and water to make to 100 ml) applied 3x over 1 wk repeated at 6 and 12 mos.	No significant difference in maternal caries increments in treatment vs control groups at 30 mos. No significant different in children's caries prevalence in treatment vs control group at 2 yrs: <ul style="list-style-type: none"> • Caries: 15% vs 33%
Limitations: <i>Study design issues; Possible clinical examination bias</i>					
Gomez et al (2001) ⁵⁶ Chile	930 mothers participated in preventive program; 241 completed; 180 randomly selected for analysis; Comparison group comprised 180 mothers recruited from clinic unrelated to original site.	Retrospective study. 4 yrs retrospective comparison from pregnancy to when children were 3.5-yrs old.	None	Education every 6 mos Prophylaxis Restorative Tx Daily 0.02% NaF mouth-wash and Fluoride toothpaste with triclosan	Significant reduction in children's caries prevalence/dft in Tx vs comparison group at: <ul style="list-style-type: none"> • 2-3 yrs caries: 1% vs 24%; • 2-3-yrs dft: 0.01 vs 0.51; • 3-3.5 yrs caries: 4% vs 42%; • 3-3.5 yrs dft: 0.20 vs 1.40.
Limitations: <i>No/Inadequate control group; Study design issues; Not representative sample</i>					

Table 5. Continuation

Paper and country	No. of subjects	Study type and duration	Control group therapy	Treatment group therapy	Outcome
5d. Chewing gum interventions (xylitol, chlorhexidine and fluoride)					
Isokangas et al and Soderling et al (2000, 2001) ^{11,57,58} Finland	338 pregnant mothers screened; 195 high MS mothers participated; 143 completed study.	Randomized clinical trial but no control group. 6 ys from pregnancy to when children were 6-yr-old.	None	All received basic prevention and restorative treatment then divided into 3 Tx groups: 1) 65% xylitol gum 4x/day used when infants 3 to 24 mos; 2) 40% CHX varnish at 6, 12, and 18 mos; 3) Fluoride varnish at 6, 12, and 18 mos.	Significantly lower MS prevalence in children in xylitol group compared to CHX and Fluoride groups at: • 1 yr: 7% vs 4% vs 18%; • 2 yrs: 10% vs 29% vs 49%; • 3 yrs: 28% vs 37 vs 65%; • 6 yrs: 52% vs 86% vs 84%. Significantly lower caries prevalence in children in xylitol group than CHX and Fluoride groups at: • 2 yrs: 10% vs 29% vs 49%; • 3 yrs: 9% vs 31% vs 49%; • 4 yrs: 10% vs 33% vs 47%; • 5 yrs: 10% vs 35% vs 50%.
Limitations: Study design issues; Possible clinical exam bias; Data analysis issues					
Thorild et al (2003, 2004) ^{59,60} Sweden	416 mothers with 3-mo-old infants screened; 403 completed study; low MS mothers were the control	Stratified clinical trial 3 ys from when children were 3 mos to 3 ys old	None	High MS mothers divided into 3 treatment groups and chewed gum 3x/day for 1 y starting when infants were 6 mos old: 1) Xylitol (650 mg) gum; 2) CHX 5 mg)/xylitol (533 mg)/ sorbitol gum; 3) NaF (0.55 mg)/xylitol (289 mg)/Sorbitol gum	No significant difference in children's MS colonization or caries prevalence in xylitol vs CHX vs Na Fluoride vs MS control groups at 3 yrs: • MS: 78% vs 70% vs 64% vs 80%; • Caries: 7% vs 14% vs 14% vs 5%
Limitations: Study design issues; No/Inadequate control group					

isolates among family members.^{27,28,65,97} A number of studies consistently demonstrate that fingerprint patterns generated by PCR are capable of detecting polymorphisms among the different isolates of MS strains and can ascertain genetic relatedness of MS for epidemiological analyses.

Application of genotyping suggests that mothers are the primary MS transmission source to children and that saliva may be the principal vehicle by which transmission of MS may occur. Although the numbers of mother-child pairs in some of these studies are small, the percentage of children with at least 1 identical MS strain in these studies is generally over 50%. Additional confidence in these data is due to the fact that these studies were carried out in as many as 8 different countries. We rated the evidence sufficient to say that there is frequent transmission of MS from mothers who are the primary caregivers to their preschool children. It is important to note that most of these studies are cross-sectional, one-time sampling, which limits the ability to control the variability of oral microbiota and confirm microbiological findings.

Despite the fact that mothers are often the major primary caregivers, in many cultures fathers also may play an important role in nurturing children. Among the studies we examined,

several used similar bacterial genotyping or ribotyping techniques to demonstrate that at least 1 MS isolate was identical between father-child pairs. Therefore, one cannot rule out the possibility that fathers also could be a source of MS for their children. More studies that confirm fathers as the source of MS colonization of their children are needed because the studies examined herein appear to include fathers as an afterthought and most of these studies had small sample sizes.

Beyond fathers, other close contacts such as grandparents who are caregivers, siblings, and day care contacts also could be MS sources. Few papers have systematically investigated these as MS sources, but 2 document the possibility of such transmission.^{23,98} Compared to mothers as the primary MS source, however, other sources appear to be of minimal significance. A further complication is the possibility of transmission between fathers and mothers. Several papers^{21,24,25} have documented such sharing of MS strains, while other papers have not.^{16,18} Such potential confounding should be considered when designing new studies.

Other factors besides the source also need to be considered to determine why children become colonized. Increased frequency of sugar consumption,^{45,45,99} the presence of enamel

hypoplasia,^{46,100} Caesarean section delivery,²⁸ and fewer courses of antibiotics¹⁰¹ have been associated with increased risk of MS colonization or of earlier colonization. Additionally, breast-fed children acquire MS with significantly greater fidelity than nonbreast-fed children.⁶⁴ The increased fidelity could result from more frequent and intimate interactions between mothers and their breastfed children, thereby fostering MS transmission through saliva. Previous studies support the hypothesis that saliva may be the principal vehicle by which MS transmission can occur.¹⁰¹⁻³ Lastly, similar to nearly every study on caries risk, low socioeconomic status (**SES**) is a strong risk factor for MS colonization in children, yet few studies have examined the role of SES in the transfer of MS from mothers to their children.²⁸ Beyond these factors, the specific cultural and behavioral practices within families need to be examined for their effect on MS transmission. Factors such as feeding habits—particularly prechewing food, sharing of utensils, closeness of living conditions and parenting styles—can all affect MS transmission.

Identifying the MS colonization source in children opens up the strong possibility that caries preventive interventions involving the primary caregivers may affect the caries outcomes of their children. One factor that has received considerable attention is the effect of the mother's MS colonization level on MS transmission to their children. Of the 14 identified studies that examined the association of MS levels in the mothers with colonization of their children, all but 4 showed a strong association between the mothers' MS levels and children's MS colonization.

Using the concept of altering a child's caries risk by reducing the MS levels in their primary caregivers was the interventional approach of several clinical trials. An early study, reported by Kohler et al,⁴⁸ described significant reductions in mother's MS and, subsequently, the child's MS. A follow-up article in 1994 by the same research team reportedly showed significantly lower caries scores in those children whose mothers were in the treatment group.⁴⁷ Although the differences between control and experimental groups were small and the standard deviations were large, their intervention approach—which included a combination of educational programs, frequent prophylaxis, topical fluoride treatment, restorative care, and chlorhexidine gel treatment every 4 months—has become an example for other clinical trials.

There are at least 11 other reports of interventions on mothers using various combinations of treatments, including antimicrobial agents, fluoride, xylitol chewing gum, and restorative care. Some of these studies found a reduction in MS in the children, but only 2 showed statistically significant caries reductions between the treatment and the control groups. As noted in Table 5, a variety of study limitations were identified in these interventions. Although not listed in Table 5, these clinical trials generally were found to inadequately describe the study population and lacked detail regarding the methods and procedures employed. Overall, these

limitations in the maternal intervention trials make comparisons and generalizability difficult. Furthermore, there are no data regarding the cost-effectiveness of such treatment programs. It is conceivable that, even if there is a significant reduction in caries in the children, the cost of the preventive program in the caretakers would make such programs unacceptable to potential funders.

Conclusions

Based on this literature review, the following conclusions can be made:

1. MS can be transmitted from mothers to their children, especially when mothers have high MS levels. Other transmission variables, such as diet, SES, and behavioral factors, may be factors but have not been systematically studied.
2. There are few investigations of other potential MS colonization sources in children, such as fathers, siblings, peers, grandparents, and other caregivers. The findings are inconclusive, given the relatively small sample size of these studies.
3. Most interventions targeted at reducing MS in mothers found MS reductions in their children, but only 2 showed caries reductions. These intervention studies are limited due to small sample size, lack of blindness of investigators and subjects, and inadequate control groups.
4. Future studies should better elucidate the role of caregivers other than mothers, and cultural practices in understanding MS colonization in children.
5. More rigorously designed clinical trials are needed to establish the efficacy of microbiological approaches on the caregivers to reduce caries risk in their children.

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Abstract of the Scientific Literature

Impact of oral and general health on children's school performance

The purpose of this study was to examine: a) the sociodemographic and health factors associated with poor school performance among North Carolina children; and b) the impact of poor oral health status on school performance while controlling for other health and sociodemographic factors. The authors used data from the 2005 Child Health Assessment and Monitoring Program, a telephone survey involving parents/guardians of 2,871 children ages 0 to 17. The study found that sex, race, parental education, low socioeconomic status, poor general health, poor oral health, and the interaction of poor oral health and general health were significantly related to school performance. Children with both poor oral health and general health were 2.3 times more likely to report poor school performance, while children with either poor oral health or general health were only 1.4 times more likely to report poor school performance. The findings suggest that the improvement of children's oral health may be a vehicle to improve their educational experience.

Comments: It is important for pediatric dentists to be involved with schools and provide oral health education for children. Teachers of children who are struggling in school may recommend that the children be evaluated for oral and general health issues. **KKH**

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13 references