Early Childhood Caries - a major public health problem

Andrew Rugg-Gunn, Callum Durward, Chantana Ungchusak, Chiraporn Khitdee

Dental caries is one of the most prevalent diseases. It causes pain, sepsis and is expensive to treat. It affects all ages, occurring from the youngest age. Dental caries is of medical, social and economic importance. Yet the causes of dental caries are well-known and prevention is possible. Why, then, is it not prevented? Because it is a life-style disease with risk factors common to many other non-communicable diseases. Prevention requires changes in behaviour at the individual level but particularly changes in the environment in which families live. Dental caries can destroy teeth of the infant and young child at an alarming rate, and it is now recognised that the factors responsible are rather unique to the environment of the infant and young child. Because of its rapid onset and its diverse aetiology, it has earned the name 'Early Childhood Caries'.

In response to this public health problem, community preventive programmes have been developed and applied. For ease of organisation, many of these operate in the school environment so that they may reach all children. An example of this is the fluoridated milk programme where some 1.3 million children in Thailand drink fluoridated milk each day in school. However, it has become quite clear that much dental caries develops before a child reaches school age, and there is an urgent need to address this considerable health burden in pre-school children - Early Childhood Caries (ECC).

It is the experience of many public health workers that the prevalence and severity of ECC is particularly high in SE Asia. It was decided, therefore, to hold a meeting in Bangkok, inviting representatives from six countries (Cambodia, Indonesia, Myanmar, Lao PDR, Thailand and Vietnam) to discuss one topic - ECC. This was held on 13 to 15 May 2014, hosted and chaired by the team from Thailand. Health representatives from each country presented an overview of ECC in their country. It was clear that ECC was a very significant public health problem in all of these six countries and plans for collaboration were formulated. One of the outcomes was agreement to carry out a review of literature regarding the epidemiology, aetiology, prevention and treatment of ECC, with special emphasis on SE Asia, with Dr Chiraporn Khitdee, Bureau of Dental Health, Department of Health, Thailand, as co-ordinator.

The review of literature was complete by December 2015, and so a Second Early Childhood Caries Forum was held in Siem Reap, Cambodia, 1 and 2 February 2016, under the local organisation of Dr Chher Tepirou, Chief of Oral Health Office, Ministry of Health, Kingdom of Cambodia. Again, the meeting was attended by representatives from the same six countries. The objective of this meeting was to present the review of literature and to inform delegates of progress made in meeting the challenge of ECC in these countries. The meeting decided that the review of literature was a valuable resource and should be published, and this has

been achieved in this Supplement. The important information presented should be of interest to:

- *Those in public health whose task it is to carry out surveillance of the population's health, and plan preventive and curative services for all ages.*
- *Those in the dental services who provide care for infants and young children.*
- *Governments, since the risk factors for ECC are common to many non-communicable diseases (NCDs) and promotion of good health in infancy and childhood requires co-ordinated effort at several levels.*
- *Industry, since sugar, in one form or another, is the main cause of ECC, industry has a responsibility to work with government and public health, to minimise the harmful effects of sugar consumption.*

Lastly, the First and Second ECC Forums described above, were fully supported by grants from The Borrow Foundation. Publication of this Supplement to the Thai Journal of Dental Public Health was also made possible by a grant from The Borrow Foundation. The Foundation is a Charity, based in Hampshire UK.

The epidemiology of Early Childhood Caries

Chiraporn Khitdee[1]

Bureau of Dental Health, Department of Health, Ministry of Public Health, Thailand

Abstract

This review explores the epidemiology of Early Childhood Caries (ECC) worldwide and in Asian countries. The literature search was carried out through PubMed and ScienceDirect databases. Due to only limited evidence published in the Asian region, the prevalence of ECC in Asian countries was derived from the WHO website, a conference report and a conference proceedings book. A total of 17 papers were extracted, while the total number of papers read for qualitative information in this review was 66. The results show that, currently, there are too few surveys reporting appropriate data to indicate the true seriousness of ECC problem, especially, in Asian countries. Moreover, variations in case definition and diagnostic criteria often made the data incomparable. Failure to address the seriousness of the problem, including the presence of non-cavitated lesions and pulpally involved teeth resulted in ECC being underestimated. The negative consequences of ECC and untreated ECC, affected the quality of life among children, their families, communities and health care systems. Therefore, harmonization of ECC definition, criteria and index age in conducting epidemiological data may lead to more understanding of ECC in each country and within the Asian region, and more appropriate and effective measures to tackle the ECC problem.

Keywords

Early childhood caries, Epidemiology of Early Childhood Caries, Review of Early Childhood Caries, Asian countries

Introduction

Epidemiology is the study of the distribution and determinants of disease or adverse health conditions. Epidemiological data of Early Childhood Caries (ECC) is urgently needed as, currently, appropriate data are not available to indicate the extent and seriousness of the problem. Most of the published data are from surveys of specific groups, e.g. from hospital or dental practice, and these are unlikely to be representative of children in the population. Moreover, variations in case definition and diagnostic criteria have made it difficult to compare studies. Consistent use of standardized case definitions and diagnostic criteria to measure ECC, are needed to indicate the size of the problem of ECC and allow comparisons across different studies.[1-3]

For the last fifty years, dentists and researchers have struggled to define ECC clearly. It has been referred to as 'baby bottle tooth decay', 'nursing bottle syndrome', and 'rampant caries'.[4] Defining ECC has proved challenging and, for this reason, prevalence rates of ECC have varied depending on the definition.[5] The American Academy of Pediatric Dentistry (AAPD) defines Early Childhood Caries (ECC) and severe early childhood caries (S-ECC) as follows:

> *Caries is a biofilm (plaque)-induced acid demineralization of enamel or dentin, mediated by saliva. The disease of early childhood caries (ECC) is the presence of 1 or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger. In children younger than 3 years of age, any sign of smooth-surface caries is indicative of severe early childhood caries (S-ECC). From ages 3 through 5 years, 1 or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth or a decayed, missing, or filled score of ≥4 (age 3), ≥5 (age 4), or ≥6 (age 5) surfaces constitutes S-ECC.*[6]

This article will report the epidemiology of ECC worldwide and in Asian countries. Results will be presented, providing information on diagnostic criteria used, the type of survey, as well as the caries prevalence and pattern, caries progression, severity and consequences of ECC.

Method

Literature to inform this review of aspects of Early Childhood Caries was obtained in several ways.

First, an electronic internet search was made through PubMed and ScienceDirect databases. The primary search term was 'early childhood caries'. Other keywords included tooth decay in young children, dental caries in young children, nursing caries. Other associated terms used in the search included: diagnosis, criteria, epidemiology, prevalence, aetiology, risk factor, prevention, treatment and oral health related quality of life. Eligible studies were included when they met the following criteria: (1) articles in English providing relevant information within the time period 1960 to 2015; (2) presenting evidence relevant to ECC according to the defined themes: epidemiology, aetiology, prevention and treatment; (3) considers dental caries or sequelae in early childhood. Concerning the exclusion criteria, studies were excluded from the review if they focused on either: (1) concerned with other age-groups or other diseases, (2) studies published in languages other than English. A total of 417 articles were identified through database searching; duplicates and references irrelevant to ECC were removed, reducing this list by about one third. Two conference books relevant to the situation in Asian countries were also included.

Second, nine journals where searched by hand: International Journal of Paediatric Dentistry, European Journal of Paediatric Dentistry, Pediatric Dentistry, Journal of Dentistry for Children, Journal Clinical Pediatric Dentistry, Community Dentistry

Oral Epidemiology, Community Dental Health, Caries Research, Journal of Public Health Dentistry. How far back the hand-searches were made, depended on the journal: for most journals it covered 2000 to 2015, while for International Journal of Paediatric Dentistry, the search extended back to 1990.

Third, some back-tracking from the reference lists attached to publications so far discovered was carried out to identify any remaining key articles. This resulted in a database of 380 references on all aspects of ECC, covering the years 1993 to 2016. Out of this database, 66 publications were relevant to this review of the epidemiology and two conference books relevant to the situation in Asian countries were also included.

Results

Caries criteria and outcome measurement

In this part, a total of 17 papers out of 380 articles were obtained. Seven[10,18,48,50,53,56,59] out of the 17 studies (41%) reported using World Health Organization (WHO) examination methods and diagnostic criteria, one[61] out of the 17 studies (6%) used British Association for the Study of Community Dentistry (BASCD) criteria, one study[3] (6%) used National Institute of Dental and Craniofacial Research (NIDCR) criteria, one study[51] (6%) used the Ontario Ministry of Health guidelines, and 7 studies[49,52,54,55,57,58,60] (41%) reported using other criteria. Ten[10,48,49,50,54,56-59,61] out of 17 reviewed studies (59%) used cavitation as a minimal threshold for caries detection. Seven studies[3,18,51-53,55,60] (41%) reported, used non-cavitated carious lesions (white spot lesion) for the presence of a carious lesion. In 1999, Ismail et al.[7] reported a systematic review of clinical diagnostic criteria of early childhood caries and found a wide variation in the case definitions and diagnostic criteria used to diagnose ECC or define S-ECC. 'Cavitation' was the most common criterion used to define dental caries. Several studies measured early or non-cavitated carious lesions. Some studies used the presence of 1 dmf maxillary incisor to classify a child with S-ECC.[7] Other studies defined S-ECC by the presence of 2+ or 3+ dmf maxillary incisors, respectively. In the study of migrant Hispanic children in Stockton, California, the prevalence of ECC varied from 12% to 30%, depending upon the clinical criteria used for diagnosis and the case definition.[8] In several publications there were recommendations to standardize diagnostic criteria and case definitions to enhance study comparability. However, these recommendations have yet to be fully realized.[7-10] This review found that seven[3,48,49,50,51,56,61] out of 17 studies (43%) used Klein's dental caries index, by summing the decayed, missing, and filled teeth (dmft) or decayed, missing, and filled tooth surfaces (dmfs).[11] Three studies[53,54,59] use the modified version of 'dmft' proposed by Gruebbel, where the missing component was specified as 'extracted because of dental caries' (deft).[12] The review of the prevalence and measurement of dental caries in young children by Dye et al.[9] revealed that some studies calculate prevalence using only primary maxillary anterior teeth. However, where studies used definitions based on algorithms proposed by the American Academy of Pediatric Dentistry (AAPD), International Caries Detection and Assessment System (ICDAS), or National Institute of Dental and Craniofacial Research (NIDCR), all teeth were included when estimating the prevalence of ECC or dental caries in young children, and not just the six maxillary anterior teeth.[9]

Prevalence of ECC

ECC is very widespread and severe amongst young children worldwide and in Asian countries. The prevalence of ECC has been shown to be highest among low income and minority populations.[13] This review presents an overview of caries prevalence

reported by studies between 1999 and 2014. Most of these studies were limited to small samples in discrete areas within a population. For instance, some studies evaluating children who presented for treatment to a dental facility, so they cannot be taken to represent caries prevalence for general population. The caries diagnostic criteria and case definition varied. Moreover, there was a broad range of age groups used in the studies. Prevalence, from this search of the literature, varied from 3% to 71%. When looking at the ECC data of 5-year-old children from this review, prevalence varied from 33% to 73%.[33,50,52,53,55,61,62] This can be compared with data reported for ASEAN countries from Oral Health Data Bank website,[14] the International Dental Conference on 'Caries Control throughout life in Asia' 2013,[15] and the 1st ECC forum 2014,[16] which showed that the caries prevalence of 5-year-old children in this region varied from 59% to 94%. (Table I).

Table I: ECC prevalence in 5 -year-old children

Country	Age (y)	% Prevalence	Year of survey
Brunei	3	39	2012
	5	59	2012
Cambodia	3	98	2012
	5-6	93	2011
Indonesia	n/a	n/a	n/a
Lao PDR	3	79	2010
	6	89	2010
Malaysia	5	76	2005
	6	74	2007
Myanmar	5	68	2007
The Philippines	3	85	1999
	5	94	1999
Thailand	3	52	2012
	5	78	2012
Singapore	3-4	25	2005
Vietnam	6	84	2001

Sources

International Dental Conference on 'Caries Control throughout life in Asia' 2013 The report of 'The 1st ECC forum' 2014 Oral Health Database - http://www.mah.se/CAPP/Country-Oral-Health-Profiles/

Caries pattern

The clinical appearance of early childhood caries is seen initially on the maxillary incisors as a band of dull white demineralization on the labial surfaces along the gingival margin, which goes undetected by parents. As the condition progresses, the white lesions develop into cavities that girdle the necks of the teeth in a brown or black collar. In advanced cases, the crowns of the four maxillary incisors may be destroyed completely leaving decayed brownish-black root stumps. The four maxillary incisors are affected most, while the four mandibular incisors usually remain sound. The reason for the unique distribution of caries between the maxillary and mandibular incisors and the unequal severity of the lesions between the incisors and the other teeth is related to four factors: the protective role of saliva for the mandibular incisors but which is much less for maxillary incisors, the chronology of primary tooth eruption, the duration of the deleterious habit, and the muscular pattern of infant sucking.[17] The study by Vachirarojpisan et al.[18] found that, at 9 months of age, the first non-cavitated carious lesion appeared on the maxillary central incisor, and the first cavitated carious lesion appeared in maxillary central incisors at the age of 10 months. Regarding non-cavitated carious lesions, 42% of erupted maxillary central incisors, and 39% of erupted maxillary lateral incisors had these lesions in the 11-14 month-old group. A marked increased proportion of cavitated caries in maxillary anterior teeth was found in 15-19 month-old children.[18]

The typical characteristics of early childhood caries are: (1) rapid development and progress from the enamel into dentine occurs in 6 months or less, (2) maxillary incisors are affected first (these teeth usually erupt around 8 months of age), (3) the next teeth to be affected are the primary maxillary and mandibular molars, which begin to erupt around 12 months of age, and (4) when the disease becomes very severe and remains untreated, the mandibular incisors are also affected.[19] In the longitudinal study of Grindefjord,[20] 64% of children who exhibited dental caries at baseline progressed to manifest caries during the one-year observation period, and the majority of the new lesions were located on the occlusal surfaces of the second molar.[21]

Caries progression and severity

Epidemiologic evidence indicates that non-cavitated carious lesions are more prevalent than cavitated lesions during the first 18 months of life.[22] The study of Weinstein[23] found that early pre-cavitation carious lesions could potentially develop into cavities in 6 to 12 months' time. A longitudinal study of early childhood caries in 9- to 18- month old Thai infants by Thitasomakul[24] found that the prevalence of caries was 2%, 22% and 68% among infants 9-, 12- and 18- months old, respectively. The buccal surface of maxillary incisors was the most affected (45%) followed by lingual (24%), mesial (20%) and distal surfaces (9%), respectively. The only posterior teeth present were first molars- their occlusal surfaces were the most affected surfaces (51%), followed by buccal (40%), lingual (8%) and distal surfaces (1%). The transitional probability of caries progression ranged between 1.8% and 15.4% during the follow-up period from 9 to 12 months of age. It was 3.4 to 39.6% from 12 to 18 months old.[24] Results from the multi-country epidemiological survey of children less than 6 years of age in seven Latin American countries showed caries prevalence in these children in each age-year from 1 to 5 years, with and without cavitated lesions, of 29%, 42%, 62%, 81% and 81% among 1-, 2-, 3-, 4- and 5- year-old children, respectively.[25] Severely decayed teeth have a significant impact on children's general health.[26] The use of only the dmft/DMFT index may be misleading in the interpretation of caries epidemiological data. In 2010, Monse et al.[27] introduced a new clinical index characterizing the consequences of untreated dental caries in primary and permanent teeth:

the pufa/PUFA index; lower case letters (pufa) for primary teeth and upper case letters (PUFA) for permanent teeth. It is calculated as the sum of teeth with four diagnoses concerning different kinds of odontogenic infections: [p] pulpal involvement, [u] ulceration, [f] fistula, [a] abscess. Thus, the pufa index complements the dmft index by displaying the severity of dental decay and quantifying odontogenic infections of the pulp and surrounding tissues due to untreated caries.[27] The study of Grund,[28] showed a significant positive correlation between dmft and pufa scores - high dmft scores were associated with high pufa scores. Prevalence and experience of odontogenic infections, and the 'untreated caries-pufa ratio', increased from the younger to the older children. Also, dmft and pufa scores in primary teeth predict a higher caries risk in permanent teeth.[28]

Consequences of ECC

Dental caries has a major impact on children's quality of life, causing many to suffer pain, abscesses, chewing problems, premature tooth-loss, malnutrition, gastrointestinal disorders, low self-esteem, and delayed growth and mental development.[29-33] In addition, children with caries spend more time out of school than in school and do not engage actively in outdoor activities because of restrictions from caries - associated pain.[34] Moreover, children with ECC are shown to have higher risk for new lesions as they get older, both in the primary and permanent dentitions.[35, 36] Dental caries in primary teeth is one of the major reasons for hospitalization of children.[37] For example, Nalliah[38] found that odontogenic infections as a consequence of untreated dental caries are the most frequent reason for the hospitalization of young children in the USA. Moreover, in extreme cases, ECC and its treatment can lead to serious disability and death.[1] ECC is costly to treat[39] and has a negative impact on the oral health-related quality of life - as quantified by the OHRQoL index.[40, 41]

The study of disparities in early childhood caries and its impact on oral health-related quality of life of preschool children in Thailand[41] found that 28% of children experienced high-level impacts on quality of life, mostly dental pain (58%) and eating difficulties (46%). Children of low socioeconomic status were more likely to have a high level of dental caries and subsequent OHRQoL impact.[41] Studies in Scotland[42] found that the proportion of children with sepsis increased markedly with caries experience. This disadvantage could be mitigated if more of the carious lesions were treated. Around one in 10 children with untreated decay (9% with dt>0) were found to have dental sepsis compared with only around 1 in 100 children who had fillings and no untreated decay. The Scottish data suggest that by not treating primary teeth, particularly where many teeth are affected by caries, the risk of the occurrence of dental sepsis is increased.[42] Moreover, dental treatment makes a very significant impact on the psychological and social aspects of the child's life.[43] These improvements include less pain and improved abilities to eat and sleep. Parents perceived that treatment had positive social impacts on their child: more smiling, improved school performance and increased social interaction.[44] Children with untreated early childhood caries (ECC) have significantly poorer oral health-related quality of life than children without ECC. Treatment in pre-school children makes a very significant difference to the psychological and social aspects of the child's life.[32]

The societal cost of these public health issues were emphasized by Bugis[45] who pointed out that more than 50% of ECC children come from low-income families. Early childhood caries occurs most frequently in disadvantaged families or in those living with economic disadvantages.[46] Oral health promotion and prevention programmes, and early intervention are critical as it may decrease an all-too-common social inequality gap and may improve the oral health, general health, and general well-being of very young children.[47]

Discussion

Although the term early childhood caries is widely used, the use of various diagnostic criteria, definitions and broad age categories continue to limit comparability across studies.[9] The finding of this review showed that there was a variety of diagnostic criteria used to assess the presence of dental caries. For example, Dye et al.[9] revealed that the definitions used in studies varied and they recommended that epidemiologic research would be facilitated by standardizing diagnostic criteria and case definitions. This was echoed by Ramos-Gomez et al.[8] who also reported that the prevalence of ECC varied, depending upon the clinical criteria used for diagnosis and case definition.[8] Moreover, a systemic review of clinical diagnostic criteria of ECC by Ismail et al.[7] presented evidence showing the inconsistency in the case definition and diagnostic criteria of ECC and S-ECC. Kaste[63] suggested that studies should focus on the development of conceptually more adequate and valid case definitions, as well as more reliable and valid case ascertainment procedures. Moreover, this review found that most of data available were often grouped into broad age categories, a point emphasized by Reisine,[64] making comparisons difficult.

A review of the ECC epidemiology literature from many countries in 1996 by Milnes,[13] reported that prevalence rates varied from 1% to 12% in developed countries, while in developing countries, and within disadvantages populations of developed countries (e.g. immigrants, ethnic minorities), the prevalence rate was as high as 70%.[13, 49] The study of caries prevalence and distribution in individuals aged 3 to 20 years in Sweden over 30 years (1973–2003), showed improved dental health among most adolescents. However, during the last 10 years, this improvement was not seen in the primary dentition.[55] This aligns with other studies that found no further decrease in caries prevalence in the primary dentition.[48] In some studies, increasing caries prevalence in the primary dentition has been reported.[49] It is important to continually follow changes in oral health with repeated epidemiological studies to be able to institute necessary preventive measures.[55] Accurate measurement of the prevalence of ECC in a population is, however, very difficult, as toddlers and preschool age children can be difficult to examine. Moreover, they are not readily accessible for examination.[2] The reported prevalence of ECC varies from country to country and from area to area[7, 9] and also varied by case definition. The results from a study in Korea,[3] showed that non-cavitated lesions (d1) were more prevalent than cavitated lesions - ECC excluding d1=40%, including d1= 57%; S-ECC excluding d1=24%, including d1= 47%. In Asian countries, there were a limited number of publications available. Data from the WHO website for the Asian region showed that the age of conducting epidemiological surveys of ECC in very young children varied from ages 3, 3-4, 5, and 5-6 years, making comparisons of data very difficult. Moreover, irregular collection of data may mean that the evidence is not up-to-date. The need for current evidence is very crucial for planning and implementation of effective measures to tackle the ECC problem.

From this study, the majority of studies detected the presence of dental caries diagnosed at the level of cavitation, with only a few studies reporting caries prevalence based on non-cavitated carious lesions. This failure to record non-cavitated lesions may not give a true picture of the extent of the problem of dental caries, as we know from epidemiologic evidence that non-cavitated caries lesions are more prevalent than cavitatedlesions during the first 18 months of life[22] and cavities in the early stages candevelop into cavities in 6 to 12 months' time.[23] Data from Thailand[18] showed that initial caries detected at the age of 9 months developed into a frank cavity within one month (at the age of 10 months). The transitional probability of caries progression ranged between 1.8% and 15.4% during

the follow-up period from 9 to 12 months old, and it was 3.4% to 39.6% from 12 to 18 months old.[24] Early detection of carious lesion as soon as possible was recommended for effective prevention in order to prevent the development of ECC[65] and reduce the severity of it.[62] The importance of detecting pulpal involvement was also mentioned in order to provide proper treatment to children to maintain a well-functioning dentition, as this improves the psychological and social aspects of the child's life[43] and quality of life.[32]

Failures to treat caries in very young children have negative effects on the child's health, their well-being and their quality of life. The impact of dental treatment makes a very significant difference to the psychological, social aspects of the child's life, social interaction and oral health related quality of life.[32,42-44,66] Evidence showed that ECC occurs most frequently in disadvantaged families or in conditions of economic disadvantage.[45,46] Regarding treatment, the use of minimal restorative techniques may decrease the trauma to both child and parents.[2] To ensure that oral health gets its rightful share of child health care legislation, there is a need to address access to health care through policy and legislation. Horowitz[2] also mentioned the importance of a public health approach to preventing and controlling ECC but, as ECC is not life threatening, public health has not focused resources on this issue. The emphasis should be on "through organized community effort". Prevention of disease is a prime objective of public health and one where teamwork is essential.[2]

Conclusions

It is clear that there are inconsistencies in the way that ECC is described. The lack of reliable, current and comparable data has led to poor awareness about the seriousness of the ECC problem, especially in the South East Asia region, where prevalence of ECC is high. The general failure to report oral health data from preschool children and a failure to report data on non-cavitated lesions have meant that the problem of ECC has been underestimated and not given prominence it deserves. ECC should be reported for children below the age of 5 years, including the presence of white spot lesions and pulpally involved teeth. Failure to treat ECC has a negative impact to the child's health and quality of life. There is a general consensus within the existing literature that ECC has a negative impact on the quality of life among children, their parents, especially in vulnerable groups and the health systems. There is a need for each country, especially where ECC is the problem, to develop their oral health data systems, to regularly collect data, and use these data to design effective oral health systems, effective plans, and effective measures to tackle ECC.

Acknowledgments

The author would like to thank Prof. Andrew Rugg-Gunn, Prof. Callum Durward, Dr. Chantana Ungchusak and Dr. Piyada Prasertsom for their kind technical support and academic advice.

References

1. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft: the human and economic cost of early childhood caries. J Am Dent Assoc 2009;140 (6):650-7.

2. Horowitz AM. Response to Weinstein: public health issues in early childhood caries. Community Dent Oral Epidemiol 1998;26(1 Suppl):91-5.

3. Jin BH, Ma DS, Moon HS, Paik DI, Hahn SH, Horowitz AM. Early childhood caries: prevalence and risk factors in Seoul, Korea. J Public Health Dent 2003;63(3):183-8.

4. Huntington NL, Kim IJ, Hughes CV. Caries - risk factors for Hispanic children affected by early childhood caries. Pediatr Dent 2002;24(6):536-42.

5. Sally Chu. Review - Early Childhood Caries: Risk and Prevention in Underserved Populations. 2006 [cited 2016 2 February]; Available from: http://www.jyi.org/issue/review-early-childhood-caries-risk-and-prevention-in-underserved-populations/.

6. American Academy of Pediatric Dentistry. editor. Definition of Early Childhood Caries (ECC); 2008.

7. Ismail AI, Sohn W. A systematic review of clinical diagnostic criteria of early childhood caries. J Public Health Dent. 1999;59(3):171-91.

8. Ramos-Gomez FJ, Tomar SL, Ellison J, Artiga N, Sintes J, Vicuna G. Assessment of early childhood caries and dietary habits in a population of migrant Hispanic children in Stockton, California. J Dent Child. 1999;66(6):395-403.

9. Dye BA, Hsu KL, Afful J. Prevalence and Measurement of Dental Caries in Young Children. Pediatr Dent. 2015;37(3):200-16.

10. Seow WK, Amaratunge A, Sim R, Wan A. Prevalence of caries in urban Australian aborigines aged 1-3.5 years. Pediatr Dent. 1999;21(2):91-6.

11. Klein H, Palmer C. Studies on dental caries: V. Familial resemblance in the caries experience of siblings. Public Health Reports. 1938;53(31):1353-64.

12. Gruebbel AO. The measurement of dental cavities prevalence and treatment services for deciduos teeth. J Dent Res. 1944;23:163-8.

13. Milnes AR. Description and epidemiology of nursing caries. J Public Health Dent 1996;56(1):38-50

14. Malmo university. Oral Health Database: Country Oral Health Profiles. 2016; Available from: http://www.mah.se/CAPP/Country-Oral-Health-Profiles/.

15. Yupin Songpaisan, editor. "Caries Control throughout life in Asia" International Dental Conference on "Caries Control throughout life in Asia"; 2013; Beyond Resort Krabi, Krabi, Thailand.

16. Chantana Ungchusak, editor. the 1st ECC forum 2014, Thailand. The 1st Early Childhood Caries Forum; 2014; Bangkok, Thailand.

17. Ripa LW. Nursing caries: a comprehensive review. Pediatric Dent. 1988;10(4):268-82.

18. Vachirarojpisan T, Shinada K, Kawaguchi Y. The process and outcome of a programme for preventing early childhood caries in Thailand. Community Dent Health. 2005;22(4):253-9.

19. De Grauwe A, Aps JK, Martens LC. Early Childhood Caries (ECC): what's in a name? Eur J Paediatr Dent. 2004;5(2):62-70.

20. Grindefjord M DG, Ekström G, Höjer B, Modéer T. Caries prevalence in 2.5-year-old children. Caries Res. 1993;27:505-10.

21. Ferreira SH, Beria JU, Kramer PF, Feldens EG, Feldens CA. Dental caries in 0- to 5-year-old Brazilian children: prevalence, severity, and associated factors. Int J Paediatr Dent. 2007;17(4):289-96.

22. Mattos-Graner Rde O, Rontani RM, Gavião MB, Bocatto HA. Caries prevalence in 6 to 36 month old Brazilian children. Community Dent Health. 1996;13 (2):96-8.

23. Weinstein P et al. Results of a promising open trial to prevent baby bottle tooth decay: a fluoride varnish study. ASDC J Dent Child. 1994;61(5):338-41.

24. Thitasomakul S, Thearmontree A, Piwat S, Chankanka O, Pithpornchaiyakul W, Teanpaisan R, et al. A longitudinal study of early childhood caries in 9- to 18-month-old Thai infants. Community Dent Oral Epidemiol. 2006;34(6):429-36.

25. Villena R. “The 1st Early Children Caries Forum”. The 1st Early Childhood Caries Forum2014; Bangkok, Thailand
26. Benzian H, Monse B, Heinrich - Weltzien R, Hobdell M, Mulder J, van Palenstein Helderman W. Untreated severe dental decay: a neglected determinant of low Body Mass Index in 12-year-old Filipino children. BMC Public Health. 2011;11:558.
27. Monse B, Heinrich-Weltzien R, Benzian H, Holmgren C, van Palenstein Helderman W. PUFA--an index of clinical consequences of untreated dental caries. Community Dent Oral Epidemiol. 2010;38 (1):77-82.
28. Grund K, Goddon I, Schüler IM, Lehmann T, Heinrich - Weltzien R. Clinical consequences of untreated dental caries in German 5- and 8-year-olds. BMC Oral Health. 2015;15(1):140.
29. Bhoomika W, Ramakrishna Y, Munshi AK. Relationship between severe early childhood caries and body mass index. J Clin Pediatr Dent. 2013;37(3):235-42.
30. Clarke M, Locker D, Berall G, Pencharz P, Kenny DJ, Judd P. Malnourishment in a population of young children with severe early childhood caries. Pediatr Dent. 2006;28(3):254-9.
31. Zhao Y, Ge LH, Yu C, Liu Z, Wang YF. The relationship between early childhood caries and child temperament. Zhonghua Kou Qiang Yi Xue Za Zhi. 2006;41(7):422-5.
32. Sheiham A. Dental caries affects body weight, growth and quality of life in pre-school children. Br Dent J. 2006;201(10):625–6.
33. Ramos - Gomez FJ, Weintraub JA, Gansky SA, Hoover CI, Featherstone JD. Bacterial, behavioral and environmental factors associated with early childhood caries. J Clin Pediatr Dent. 2002;26(2):165-73.
34. Weinstein P. Public health issues in early childhood caries. . Community Dent Oral Epidemiol. 1998;26(1 Suppl):84-90.
35. Tinanoff N, O'Sullivan DM. Early childhood caries: overview and recent findings. Pediatr Dent. 1997;19 (1):12-6.
36. Li Y, WW. Predicting caries in permanent teeth from caries in primary teeth: an eight-year cohort study. J Dent Res. 2002;81(8):561–6.
37. Sheller B, Churchill SS, Williams BJ, Davidson B. Body mass index of children with severe early childhood caries. Pediatr Dent. 2009;31(3):216-21.
38. Nalliah RP, Allareddy V, Elangovan S, Karimbux N, Allareddy V. Hospital based emergency department visits attributed to dental caries in the United States in 2006. J Evid Based Dent Pract. 2010;10(4):212-22.
39. Jones DB SC, Phipps KR. An oral health survey of Head Start children in Alaska: oral health status, treatment needs, and cost of treatment. J Public Health Dent. 1992;52:86-93.
40. Martins-Junior PA, Vieira-Andrade RG, Correa - Faria P, Oliveira-Ferreira F, Marques LS, Ramos - Jorge ML. Impact of early childhood caries on the oral health-related quality of life of preschool children and their parents. Caries Res. 2013;47(3):211-8.
41. Krisdapong S, Somkotra T, Kueakulpipat W. Disparities in Early Childhood Caries and Its Impact on Oral Health-Related Quality of Life of Preschool Children. Asia Pac J Public Health. 2012;26(3):285-94.
42. Pine CM. An investigation of the relationship between untreated decayed teeth and dental sepsis in 5-year-old children. Br Dent J. 2006;200(1):45-7.
43. Anderson HK, Drummond BK, Thomson WM. Changes in aspects of children's oral-health-related quality of life following dental treatment under general anaesthesia. Int J Paediatr Dent. 2004;14 (5):317-25.
44. White H, Lee JY, Vann WF Jr. Parental evaluation of quality of life measures following pediatric dental treatment using general anesthesia. Anesth Prog. 2003;50(3):105-10.
45. Bugis BA. Early childhood caries and the impact of current u.s. Medicaid program: an overview. Int J Dent. 2012;2012:348237.
46. Baggio S, Abarca M, Bodenmann P, Gehri M, Madrid C. Early childhood caries in Switzerland: a marker of social inequalities. BMC Oral Health. 2015;Jul 22;15:82.
.

47. Do LG, Spencer AJ, Slade GD, Ha DH, Roberts-Thomson KF, Liu P. Trend of income-related inequality of child oral health in Australia. J Dent Res. 2010; 89(9):959-64.
48. Wyne A, Darwish S, Adenubi J, Battata S, Khan N. The prevalence and pattern of nursing caries in Saudi preschool children. Int J Paediatr Dent. 2001;11 (5):361-4.
49. Rosenblatt A, Zarzar P. The prevalence of early childhood caries in 12- to 36-month-old children in Recife, Brazil. ASDC J Dent Child. 2002;69(3):319-24, 236.
50. Nomura Y, Tsuge S, Hayashi M, Sasaki M, Yamauchi T, Ueda N, et al. A survey on the risk factors for the prevalence of dental caries among preschool children in Japan. Pediatric Dental Journal. 2004;14 (1):79-85.
51. Peressini S, Leake JL, Mayhall JT, Maar M, Trudeau R. Prevalence of early childhood caries among First Nations children, District of Manitoulin, Ontario. Int J Paediatr Dent. 2004;14(2):101-10.
52. Skeie MS, Espelid I, Skaare AB, Gimmestad A. Caries patterns in an urban preschool population in Norway. Eur J Paediatr Dent. 2005;6(1):16-22.
53. Ferreira SH, Beria JU, Kramer PF, Feldens EG, Feldens CA. Dental caries in 0- to 5-year-old Brazilian children: prevalence, severity, and associated factors. Int J Paediatr Dent. 2007;17(4):289-96.
54. Schroth RJ, Cheba V. Determining the prevalence and risk factors for early childhood caries in a community dental health clinic. Pediatr Dent. 2007;29(5):387-96.
55. Hugoson A, Koch G, Helkimo AN, Lundin SA. Caries prevalence and distribution in individuals aged 3-20 years in Jönköping, Sweden, over a 3-year period (1973-2003). Int J Paediatr Dent. 2008;18(1):18-26.
56. Postma TC, Ayo-Yusuf OA, van Wyk PJ. Socio-demographic correlates of early childhood caries prevalence and severity in a developing country--South Africa. Int Dent J. 2008;58(2):91-7.
57. Valencia-Rojas N, Lawrence HP, Goodman D. Prevalence of early childhood caries in a population of children with history of maltreatment. J Public Health Dent. 2008;68(2):94-101.
58. Nunn ME, Dietrich T, Singh HK, Henshaw MM, Kressin NR. Prevalence of early childhood caries among very young urban Boston children compared with US children. J Public Health Dent. 2009;69 (3):156-62.
59. Prakash P, Subramaniam P, Durgesh BH, Konde S. Prevalence of early childhood caries and associated risk factors in preschool children of urban Bangalore, India: A cross-sectional study. Eur J Dent. 2012;6 (2):141-52.
60. Hong CH, Bagramian RA, Hashim Nainar SM, Straffon LH, Shen L, Hsu CY. High caries prevalence and risk factors among young preschool children in an urban community with water fluoridation. Int J Paediatr Dent. 2014;24(1):32-42.
61. Monaghan N, Davies GM, Jones CM, Neville JS, Pitts NB. The caries experience of 5-year-old children in Scotland, Wales and England in 2011-2012: reports of cross-sectional surveys using BASCD criteria. Community Dent Health. 2014;31:105-10.
62. Hallett KB, O'Rourke PK. Pattern and severity of early childhoos caries. Community Dent Oral Epidemiol. 2006;34(1):25-35.
63. Kaste LM, Drury TF, Horowitz AM, Beltran E. An evaluation of NHANES III estimates of early childhood caries. J Public Health Dent. 1999;59(3):198-200.
64. Reisine S, Douglass JM. Psychosocial and behavioral issues in early childhood caries. Community Dent Oral Epidemiol. 1998;26(1 Suppl):32-44.
65. Ismail AI. Prevention of early childhood caries. Community Dent Oral Epidemiol 1998;26(1 Suppl):49-61.
66. Low W, Tan S, Schwartz S. The effect of severe caries on the quality of life in young children. Pediatr Dent. 1999;21(6)

Review of the aetiology of Early Childhood Caries

Andrew Rugg-Gunn [1]

Margaret Woodward [2]

[1] Professor Emeritus, Newcastle University UK; Trustee, The Borrow Foundation UK

[2] Programme coordinator / Public Health Specialist, The Borrow Foundation UK

Abstract

Without a full understanding of the aetiology of Early Childhood Caries (ECC), it is not possible to recommend appropriate interventions to prevent ECC. The extensive literature on the aetiology of ECC has been reviewed. Potential risk factors range from those inherent in the individual, such as genetic profile, to the environment, which influences family choices and behaviour. These have been considered in ten groups: genetics, saliva, nutrition, enamel hypoplasia, oral flora, oral hygiene and dental plaque, breast-feeding, sugar in bottles, dietary sugar, and family behaviour and environment. All of these have been shown to be related to the occurrence of ECC, although some risk factors appear to be much more important than others, and there are strong interactions and synergies between them. Most emphasis has been put on high and frequent consumption of dietary sugars, infant feeding practices, poor removal of dental plaque, and formation of a dental plaque flora which is particularly conducive to caries development – the growth of this plaque is strongly encouraged by poor plaque control and a high sugar diet. Reasons for these caries-inducing behaviours lie in the family – their own experiences, circumstances and lifestyles. However, the family, or carers, are subject to strong pressures which shape belief, attitude and behaviour. The use, or lack of use, of fluoride has not been discussed in this review. The beneficial role of fluoride in caries prevention is well-known, and lack of use of fluoride should be seen as an important risk factor for ECC.

Keywords

Early childhood caries, ECC, Aetiology of Early Childhood Caries, Review of Early Childhood Caries

Introduction

Without a full understanding of the aetiology of Early Childhood Caries (ECC), it is not possible to recommend appropriate interventions to prevent ECC. Although the basics of the aetiology of dental caries are very well known – a tooth, plaque and dietary sugars – the aetiology of ECC is more complicated compared with caries development later in life, due to the strong influence of infant feeding practices and behaviour of the family, particularly the mother (or primary care giver).

There is extensive literature on the aetiology of ECC. This will be reviewed, looking first at the published reviews of aetiology of ECC, followed by an examination of information on the many potential risk factors for ECC. These potential risk factors range from those inherent in the individual, such as genetic profile, to the environment, which influences family choices and behaviour. These will be considered in ten groups (Table 1). All of these have been shown to be related to the occurrence of ECC, although it has to be appreciated that some risk factors appear to be much more important than others, and there are strong interactions and synergies between them.

Method

Literature to inform this review of aspects of Early Childhood Caries was obtained in several ways.

First, an electronic internet search was made through PubMed and ScienceDirect databases. The primary search term was 'early childhood caries'. Other keywords included tooth decay in young children, dental caries in young children, nursing caries. Other associated terms used in the search included: diagnosis, criteria, epidemiology, prevalence, aetiology, risk factor, prevention, treatment and oral health related quality of life. Eligible studies were included when they met the following criteria: (1) articles in English providing relevant information within the time period 1990 to 2015; (2) presenting evidence relevant to ECC according to the defined themes: epidemiology, aetiology, prevention and treatment; (3) considers dental caries or sequelae in early childhood. Concerning the exclusion criteria, studies were excluded from the review if they focused on either: (1) concerned with other age-groups or other diseases, (2) studies published in languages other than English. A total of 417 articles were identified through database searching; duplicates and references irrelevant to ECC were removed, reducing this list by about one third. Two conference books relevant to the situation in Asian countries were also included.

Second, nine journals were searched by hand: International Journal of Paediatric Dentistry, European Journal of Paediatric Dentistry, Pediatric Dentistry, Journal of Dentistry for Children, Journal Clinical Pediatric Dentistry, Community Dentistry Oral Epidemiology, Community Dental Health, Caries Research, Journal of Public Health Dentistry. How far back the hand-searches were made, depended on the journal: for most journals it covered 2000 to 2015, while for International Journal of Paediatric Dentistry, the search extended back to 1990.

Third, some back-tracking from the reference lists attached to publications so far discovered was carried out to identify any remaining key articles. This resulted in a database of 380 references on all aspects of ECC, covering the years 1993 to 2016. Out of this database, 227 publications were relevant to this review of the aetiology of ECC.

General Reviews of the Aetiology of ECC

The twenty-seven general reviews of the aetiology of ECC are indicated in the first column in Table 1. A major review of ECC took place at a conference in the USA, the proceedings of which were published in a supplement to Community Dentistry Oral Epidemiology, in 1998.[1] This established the definition and scope of aetiological factors in ECC. Diagnosis and reporting of ECC was discussed further in the reviews of Drury[2] and Ismail[3] in J Publ Health Dent, a year later. A very good earlier review by Litt,[4] presented models of aetiological pathways leading to ECC, including factors such as sugar, Streptococcus mutans (SM, an important bacterium in dental plaque), knowledge and behaviour. The most recent systematic review appears to be by Harris.[5] This review considered 77 studies worthy of analysis – Including 43 cross-sectional studies, 19 cohort studies, 8 case-control studies and 7 intervention studies. Topics covered included SM, diet, oral hygiene, enamel hypoplasia, and family factors. A more recent review by Gussy6 included 84 references and discussed aetiology and prevention of ECC, partly from an Australian perspective. It appears that each year the American Academy of Pediatric Dentistry reviews their policy documents; this includes ECC, and the latest (2013/4) is included in the list – they are not extensive reviews but they are authoritative. The list of references given by Seow[7] is particularly extensive and an excellent source of references (259 references listed) before this date. It should be noted that Seow added to this literature in another large article published in 2012 in Int J Paed Dent (103 references listed). This latter article considered family and environment factors, in detail. The review of Chaffee[8] provides information on the number of publications from various regions of the world, on 'early life feeding practice and ECC'. The recent review by Fontana[9] iscussed prediction of caries, through the knowledge of aetiological factors, concluding that the 'best predictor' is still past caries experience.

It can be concluded from these review articles that several diverse factors are relevant in the aetiology of ECC. While dietary sugars remain central to the aetiology of ECC, the impact of dietary sugars can be modified considerably by factors such as genetics, structure of primary teeth, infant and child feeding habits, development of the dental biofilm, and tooth brushing with a fluoride-containing toothpaste. In turn, these factors will be strongly influenced by mother's health and well-being, poverty, education, societal influences, knowledge, attitude and behaviour. These factors will be considered individually in the next 10 sections, and considered together in a concluding section.

Genetics

This is a new field of research made possible by affordable genetic profiling: the three articles considering genetics are indicated in the second column of Table 1. The very recent article by Abbasoglu[10] is an important one. Information on diet and oral hygiene was obtained from 259 2 to 5 year-olds, in Turkey, and used as co-variates in multivariate analyses. These analyses showed several genotypes to be related to increased or decreased caries risk. Romanos[11] found weak correlations between polymorphisms in bone morphogenetic proteins (BMP) in DNA, harvested from buccal cells in 1731 Brazilian 3 to 5 year-olds, in relation to BMP2. These initial studies show the potential for understanding how genetics may affect caries susceptibility.

Saliva

This too is a fairly new area of research, made easier by newer methods of rapid analyses: eight publications which considered saliva are indicated in the third column of Table 1. Fonteles,[12] in a study of 78 1 to 6 year-old Brazilians, suggested the relationship between caries risk and salivary amino acids – proline levels were positively, and glycine levels negatively related to caries experience.

Jurczak[13] reported that histatin-5 and β-defensin-2 were positively related to dental caries. Two papers[14, 15] investigated salivary total antioxidant capacity (TAC) in saliva in relation to caries experience. Antioxidants are enzymes or similar compounds produced to counter inflammation: thus, TAC is a measure of inflammatory response. Both found higher levels of TAC in S-ECC (severe early childhood caries) and suggested its use as a marker of susceptibility to ECC. Another recent article[16] found that salivary protein profiles were different in S-ECC children compared with caries free (CF) children – 8 peptides being positively related and 3 peptides negatively related to ECC. Neves[17] reported that the use of pacifiers (unsweetened) was related to lower caries experience. While this type of study is very different from those mentioned above, the authors suggested that the increased salivary flow caused by sucking on unsweetened pacifiers is protective.

In summary, while differences in composition of saliva in relation to the occurrence of ECC have been recorded, their importance as a risk factor has not yet been demonstrated. TAC may be a marker of ECC but has not yet been shown to predict ECC. The microbial composition of saliva is likely to be much more important – see Oral Flora, below.

Nutrition

This section includes nutrition of the mother during pregnancy and early general nutrition of the child, but excludes infant feeding practices since these are discussed below. Thus, the scope is broad as can be seen in the 14 articles listed in the fourth column in Table 1. The issues are complicated since under-nutrition is linked to enamel hypoplasia (see below) which in turn may predispose to caries development. Health status during pregnancy and birth weight have been considered as potential risk factors for ECC. In a study of 495 0 to 18 month Thai infants, Thitasomakul[18] reported that lack of calcium supplementation and low milk consumption during pregnancy were related to increased incidence of ECC in the infants. In a study of vitamin D status during pregnancy, Schroth[19] found lower serum levels of 250HD to be related to increased risk of enamel hypoplasia and ECC in 133 1 year-old Canadians. Both low birth weight[20] and high birthweight (macrosomia)[21] have been linked to increased risk of ECC. The latter study was a particularly large 117,175 birth cohort in Japan: macrosomia being defined as >4000g. Results of studies relating infant's weight and height to incidence of ECC are mixed; some suggesting low weight/height is related to incidence of ECC[22] while others[23,24] reported no difference. A Brazilian study[20] recorded a U-shaped relation between ECC and child's weight (both under-weight and over-weight having higher caries experience). Children about to have a GA for tooth extraction are weighed and a blood sample taken. Four studies in Canada[25-27] and Iran[28] indicate that these children have sub-optimal nutrition status. However, low weight and poor nutritional status in children with ECC may be effect rather than cause. One publication on water fluoridation has been included[29] since it specifically mentions ECC: of course, there have been many other studies showing the effectiveness of water fluoridation at preventing caries in primary teeth (usually at age 5y) – see Rugg-Gunn and Do.[30]

In summary, the occurrence of ECC appears to be influenced by the nutritional status of the mother during pregnancy. The inverse relation between the child's nutritional status and ECC incidence may be cause or effect, or both. Most attention has been given to vitamin D, although calcium and iron have also been considered. The caries-protective role of fluoride in early life is well-established.

Enamel Hypoplasia

Ever since the research by Mellanby in the UK, over 80 years ago, it has been recognised that enamel hypoplasia predisposes to caries development. Mellanby suspected vitamin D deficiency was the cause of enamel hypoplasia and increased susceptibility to dental caries. Considering more recent studies, it was mentioned in the section on nutrition that Schroth[27] reported that poor vitamin D status during pregnancy was related to increased prevalence of enamel hypoplasia and ECC in the child. The 17 papers indicated in the fifth column in Table 1 confirm this. There are some key papers. Alaluusua[31] gives a good introductory paper for a conference at which Caufield[32] presents the main paper. Caufield discusses many causes of enamel hypoplasia in primary teeth. He maintains that the rough hypoplastic enamel surface allows bacteria to adhere to enamel more easily (especially S. mutans), encouraging caries development. He feels hypoplasia to be such an important risk factor for caries that he uses the term 'Hypoplasia-associated severe early childhood caries' (HAS-ECC). The earlier study by Seow[33] in Brisbane is historically important, together with her study in 2009; she then supervised the cohort study of Plonka.[34] In Plonka's study, hypoplasia was a significant risk factor and, importantly, the hypoplasia was recorded before caries developed, since diagnosing the presence of hypoplasia, in cross-sectional studies, is not easy as caries may have destroyed the areas of hypoplasia. Two *in vitro* analyses of the structure of teeth either with or without ECC, indicated that ECC teeth were more porous[35] and had lower calcium, phosphorus concentrations and a lower Ca:P ratio,[36] than sound teeth.

In summary, there is good evidence that enamel hypoplasia is a risk factor for ECC. There is moderately strong evidence that poor nutritional status, particularly vitamin D, is a risk factor for enamel hypoplasia.

Oral flora (salivary and plaque bacteria)

As can be discerned from the 55 articles indicated in the sixth column of Table 1, there is a strong opinion that ECC is an infectious disease with bacterial specificity. In simplest terms, the mother infects the infant with Streptococcus mutans (SM). Nearly all of the 55 publications confirmed the strong relationship between the presence of SM in plaque (and saliva) and ECC. Two review articles [37,38] confirm the predominant role of SM. Eleven cohort studies have enabled recording of the acquisition of SM and subsequent ECC experience. Infants who develop ECC acquire SM at an early age.[37,39-41] The study of Pattanaporn,[42] working in a Chiang Mai hospital, found mode of birth delivery to be significantly related to MS colonisation and caries development (vaginal birth greater risk than C-section). Infants mainly acquire MS and other organisms from the mother by kissing and food-tasting. A habit common in some countries, e.g. Japan[43] and Myanmar,[44] is pre-chewing of foods, such as rice, by mother or grandmother. Caufield[45] proposed the term 'discrete window of infectivity' (19 to 31mo), but this is questioned in several of the papers listed in Table 1. For example, Tankkunnasombut[46] examined young children attending a Well Baby Clinic in Bangkok, and found SM colonisation in 5% of infants as young as 2 months old, before first tooth eruption (about 6 months). By the age of 27 months (about 20 teeth present), 32% were infected with SM. As indicated by Ersin,[47] a high sugar diet encourages SM growth. Identifying organisms in plaque has become easier with modern profiling techniques and it can be seen from the publications that SM is not the only organism to be closely associated with development of ECC. For example, Ma[48] identified 379 species in plaque and saliva of 60 3 to 4 year old Chinese children – 13 species in plaque and 2 in saliva were positively associated with ECC. Other relevant organisms are Lactobacillus (LB), Streptococcus sobrinus, Candida albicans and Veillonella. The combined presence of these organisms

may increase the likelihood of ECC development. For example, Saraithong[49] working in Chiang Mai, Thailand, reported that if both SM and S. sobrinus were present, caries prevalence was five times greater than if both were absent. There is growing interest in individual genotypes of these organisms. For example, Qiu[50] reported that Candida albicans genotype A was associated with lower caries experience, while genotype B was associated with higher caries experience. Papers that chart colonisation over time are particularly relevant.[34,51,52] Various quick tests have been proposed and tested, two old ones being Dentocult SM and Dentocult LB (from Finland). Researchers in Japan[43,53] have developed the Caries Activity Test (CAT) and Cariostat – these largely measure acid production – reporting their ability to predict caries development.

In summary, there is strong evidence that SM is closely associated with development of ECC. Other organisms in plaque and saliva may have a similar and complementary role but their relative importance appears to be less. The primary source of SM for the infant is the mother or carer. Identification of plaque organisms is becoming more rapid and less reliant on cultivation in the laboratory.

Oral hygiene and dental plaque

The conclusion from the review of the 57 articles indicated in the seventh column in Table 1 is quite straight-forward – dental plaque and poor oral hygiene are strong risk factors for ECC. Because they are closely linked, presence of plaque and oral hygiene/toothbrushing have been included in the same section. Several ways of quantifying plaque on teeth were used, such as the 'plaque index', but the conclusions were the same – more plaque, more caries. A recent review of this subject[37] confirms this conclusion. Toothbrushing is the principal way of reducing/removing plaque and should be done by the carer in infancy and childhood. In surveys of This type, it should be noted that toothbrushing activity was almost always obtained by questionnaire and can be subject to recall bias. Questions relate to: age when brushing began, who brushed the teeth, frequency of brushing, and age of toothbrush. The type of toothpaste has not been investigated in this review, as it is well known that fluoride-containing toothpastes are effective in caries prevention. Most studies were cross-sectional although a few[34] were longitudinal allowing plaque levels to be recorded before caries development. Several studies[54-61] indicated that the earlier the age toothbrushing began, the lower the incidence of ECC. Several studies[18,43,62-66] showed that toothbrushing by parent and carer was important in that it was related to lower incidence of ECC. As far as frequency of toothbrushing was concerned, while several studies showed the benefit of brushing at least twice per day, other studies showed no relation between frequency of toothbrushing and incidence of ECC. One study[67] reported that low toothbrushing frequency in the carer was passed on to the child, resulting in increased caries levels in the child. Carvalho[62] reported on toothbrushing both at home and at nursery in 2411 1 to 5 year-old Brazilian children. Both were important and the incidence of ECC was very much higher when the child was not assisted with toothbrushing at home and did not brush their teeth at nursery. The interaction between toothbrushing habits and sugar-consumption habits was studied by Stecksén-Blicks[68] and Masson[69] – they reported a synergistic effect of poor plaque control and high sugar consumption in relation to the development of ECC.

In summary, the quantity of plaque recorded on teeth is positively related to incidence of ECC. Toothbrushing is the main way of removing/ reducing plaque. There is strong evidence that toothbrushing is related to lower occurrence of ECC. Early introduction of toothbrushing (before the first birthday), brushing by parent or carer, and brushing more than once a day are related to lower occurrence of ECC. The benefit of using a fluoride-containing toothpaste is very well documented.

Toothbrushing is not a substitute for a reduction in sugar consumption.

Breast-feeding

Thirty-eight articles discussing breast-feeding and the occurrence of ECC are indicated in the eighth column in Table 1. This is a contentious issue since breast-feeding is promoted strongly for the infant's general health and well-being. In many cultures, prolonging breast-feeding is an important method of birth-control. Another consideration is the cost of formula feed and the quality of water used to mix with the formula feed powder. WHO recommends exclusive breast-feeding until 6 months and complimentary breast-feeding up to two years of age. A good discussion of this can be found in the paper by van Palenstein Helderman[44] who describes a survey in Myanmar and presents a rather fatalistic attitude to ECC. In general, breast-feeding up to 12 months is not seen as a risk for dental caries, while continuing after 12 months increases risk. For example, the well-respected cohort Iowa study [94] found breast-feeding for 6 months protective after adjustment for confounding factors; Majorana[70] in Italy and Olatosi[71] in Nigeria found the same result. Another Italian study[72] found longer duration of breast-feeding (20 months) increased caries risk. In Japan, two studies identified breast-feeding beyond 18 months a risk for dental caries: Tanaka,[73] in a birth cohort study in Japan, found a cut-off at 18 months with low caries before then and high caries experience after that age, and Ibrahim,[43] also in Japan, reported increased caries experience in children breast - fed beyond 18 months. Turton,[54] in Cambodia, and Jain,[74] in India, reported that breast-feeding longer than 2 years was associated with increased incidence of ECC. In the Myanmar study of van Palenstein Helderman,[44] the cut-off age was 12 months, with caries risk increasing beyond that age.

While the above publications have considered breast-feeding, few have mentioned what the alternative to breast-feeding was. It is very likely that the alternative, during the first 6 months at least, was a formula feed, but was anything, such as sugar, added to that feed? One study in Nigeria, [71] which compared breast- and bottle-feeding directly, reported lower incidence of ECC in infants breast - fed for the first 6 months compared with infants fed by bottle. Superimposed on the consideration of duration of breast-feeding, is 'on-demand' breast-feeding, the frequency of breast-feeding, and nocturnal breast-feeding. These are seen as risk factors in several studies; for example, in the Thai cohort study of Thitasomakul,[18] where 495 infants were followed through to 18 months, 'on demand' feeding was associated with increased risk of ECC. In a study of 362 0 to 5 year-old Cambodian children, Turton[54] reported that 70% of the children were still sleeping with their mother at the age of 4 years. Apart from the interesting study of van Palenstein Helderman[44] in Myanmar, mentioned above, two other analyses are worth close study. First, by a group of paediatricians in Sri Lanka[75] who emphasised overnight feeding as a key risk factor. Second, the systematic review by Tham[76] from Melbourne, Australia. These authors concluded that: (a) breast-feeding up to 12 months of age was associated with lower risk of ECC, (b) breast-feeding more than 12 months was associated with increased risk of ECC, and (c) nocturnal breast-feeding was associated with increased risk of ECC.

In summary, the number of publications on this subject has increased considerably during the past few years; out of the 38 publications listed, seven were published in 2015 and nine in 2014. The research has been reviewed recently and thoroughly by Tham[76] and their conclusions, given above, provide the best summary.

Sugar in bottles

Although 'bottle feeding' was recorded in the 38 studies indicated in the ninth column in Table 1, an important difficulty in interpreting the information is that the content of the bottle was not always specified. In the 15 studies that did say that sugar was added to the feeding bottle [33,34,47,65,70,73,75,77-84] this was invariably related to increased risk of ECC. In the study by Majorana[70] in Italy, bottle-feeding with sugar added was associated with higher caries experience compared with breast-feeding. Avila[85] reported a systematic review of breast- versus bottle-feeding and concluded that breast-feeding was associated with lower caries experience. However, the contents of the bottle were not given. In a high proportion of the studies listed in the table, the effect of night-time use of a bottle was investigated and found to be strongly associated with increased caries experience. In some of the studies listed, multivariate analyses were used to control for confounding factors, but in many studies the analyses were univariate. Interpretation of these latter studies requires caution as 'bad habits' (e.g. use of sugar, poor toothbrushing) tend to occur in the same individuals. The 1999 article by Seow [33] describes a well-conducted cross-sectional study which found that sugared milk in a bottle at night-time a significant caries risk. One of the few studies to report the effect of juice or soft-drinks (not milk) in feeding bottles [86] found that use of these bottles at age 12 months was associated with increased caries experience at age 5 years. The list includes five cohort studies [21,34,73,84,86,87] (Chaffee [84] and Feldens [86] were the same study) in which feeding practices were recorded at a young age and subsequently related to the development of ECC. For example, in the Brazilian study of Chaffee,[84] ECC observed at examinations at age 5 years was related to diet which had been recorded at 6 and 12 months. In the cohort study of Peltzer[87] carried out in Han Province, Thailand, 597 children were followed from birth through to examination at age 36 months: sleeping with a bottle at 30 months was associated with increased risk of ECC. In three of these birth cohort studies[34,73,84,86] sugar in a bottle was recorded and found to be associated with higher caries experience.

In summary, bottle-feeding is the alternative to breast-feeding in early life and is continued, for variable lengths of time, after weaning. Very little information on the contents of the bottle (e.g. formula or bovine milk) was given in the publications reviewed, although this information may be available in the wider medical literature. It would appear to be a common practice to add sugar to bottle feeds. Reasons for this practice were not given in the publications reviewed but, again, may be included in the wider medical literature. It is unclear if the custom of adding sugar to feeding bottles is more common in some countries, some social groups, or other groupings, than in others. In the small number of straight comparative studies, bottle feeding is associated with higher caries incidence compared with breast-feeding: however, it is unclear whether this difference was solely due to the addition of sugar to bottle feeds. A comparatively large amount of evidence indicates that sugar added to bottle feeds is strongly associated with increased incidence of ECC. Likewise, nocturnal feeding with a bottle is associated with increased caries incidence. The most useful information can be obtained from the five birth cohort studies.

Sugar

A total of 77 papers are indicated in the tenth column in Table 1. The form 'sugar' takes in the infant's/child's diet varies – for example, as candies, soda, sugary snacks, dummy dipped in syrup, medicines etc. The vast majority of these papers recorded that sugar consumption was associated with increased caries experience. A few reported no effect and one [88] reported 'non-exposure to

sugar snacks' to be associated with increased risk of ECC; although this was obtained by univariate analysis. Multivariate analyses were used in many of the more recent studies and nearly all of these showed positive relations between sugar consumption and caries experience. For reasons given in previous sections, cohort studies are a valuable source of information. There are reports on twelve cohort studies [18,39,56,59,84,86,89-95] investigating the relation between sugars consumption and ECC: all of these found caries experience to be related to sugar consumption, either as drinks or food. Importantly, one study,[96] in Japan, reported consumption of water to be associated with low caries risk. An American study [97] reported that milk was not associated with caries experience, while five studies [21,69,98-100] found milk consumption to be associated with decreased caries risk. While Al - Malik[58] reported that consumption of fruit juices was associated with increased incidence of ECC, five studies[69,89,98,101,102] reported that fruit juice was either associated with reduced incidence of ECC or reported no effect. A good analysis of the US NHANES (national) data and discussion regarding 100% fruit juice and the occurrence of ECC is given by Vargas.[102] In contrast, the study of Wulaerhan[103] of Ughur children in Kashgar, China, found 'fruit, sweet water and milk/yoghurt' to be associated with higher caries experience. In a cohort study in Umea, Sweden, Ohlund[93] reported lower caries experience in 4 year-old children who had consumed high amounts of cheese. Also from Umea, the paper by Stecksén–Blicks[104] describes an interesting interaction (strongly additive) between sugar consumption and poor toothbrushing habits. Only one study,[105] in Italy, mentioned 'sweetened baby pacifiers' – their use was associated with increased caries incidence. In only two publications was sugar in medicines discussed[106,107] – in both cases, their long-term use was related to increased incidence of ECC: this topic has been well-reviewed elsewhere. Locally in SE Asia, studies have been undertaken in Thailand,[18] Vietnam[108] and Lao PDR [61] – in all three, sweets/candies and sweetened soft drinks were associated with higher incidence of ECC.

In summary, there seems to be little doubt that sugars added to the diets of infants and young children are associated with incidence of ECC. These added sugars may be in the form of drinks (bottles and soft drinks), foods (sweets, candies, biscuits), applied to pacifiers/dummies, and given as medicines. This evidence comes from many types of study (birth cohort and cross-sectional) and from a wide spectrum of countries and cultures. In contrast, plain milk, fruit and fruit juice (all of which contain sugars naturally) are not associated with ECC or are associated with lower incidence of ECC. One study reported that consumption of plain water was associated with lower incidence of ECC.

Family, behaviour and environment

Although sugar intake, poor tooth cleaning, and dental plaque with high levels of Streptococcus mutans, are rightly given prominence as primary risk factors (see above), reasons for these unfavourable behaviours need to be understood if preventive strategies are to be successful. An excellent review of these aspects of ECC risk has been published by Seow[109] 'Environmental, maternal, and child factors which contribute to early childhood caries: a unifying conceptual model'; it contains 103 references. As Seow says: "The rates of ECC are highest among the socially disadvantaged such as low socioeconomic groups and indigenous and ethnic minorities". A large proportion of the 75 articles indicated in the right-hand (eleventh) column in Table 1 report that a low level of education and low family income are associated with high prevalence of ECC.

Table 1. Aspects of Aetiology of ECC.

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Das (2016) [36] Int J Paed D					★						
Turton (2016) [54] Eur Arch Paed D							★	★		★	
Abbasoglu (2015) [10] Caries Res		★					★			★	
AbdelAziz (2015) [101] Ped D										★	
Avila (2015) [85] PLoS One								★	★		
Baggio (2015) [110] BMC Oral H											★
Birungi (2015) [126] PLoS One								★			
Chaffee (2015) [84] CDOE									★	★	
Correa-Faria (2015) [127] Int J Paed D					★		★				★
de Souza (2015) [121] Eur J D.											★
Folayan (2015) [128] BMC OH										★	
Fontana (2015) [9] Ped D	★										
Ghazal (2015) [89] CDOE										★	
Hao (2015) [39] Caries Res						★				★	
Jain (2015) [74] JODDD							★	★	★		
Jurczak (2015) [13] Biol Res			★								
Kato (2015) [129] BMJ Open								★			
Khanh (2015) [108] Am J Publ H										★	
Liang (2015) [130] Oral H Prev D											★
Lim (2015) [90] CDOE										★	
Ma (2015) [48] PLoS One						★					
Nakayama (2015) [131] J Epi.							★	★		★	
Nakayama (2015) [124] J Pub H D										★	★
Narrenthran (2015) [35] Caries Res					★						
Neves (2015) [17] J Clin Paed D			★			★					
Paglia (2015) [132] Eur J Ped D								★			
Peltzer (2015) [87] BMC O H									★		★
Qiu (2015) [50] BMC Oral H.						★					

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Romanos (2015) [11] Caries Res		★									
Saraithon (2015) [49] Cl Oral Inv						★					
Si (2015) [16] Caries Res			★								
Tham (2015) [76] Acta Paed								★			
Wigen (2015) [91] Acta Od Scand							★			★	
Winter (2015) [59] Clin Oral Inv							★			★	★
Yokomichi (2015) [21] PLoS One				★			★		★	★	★
Zaki (2015) [98] Int J Paed D										★	
Albino (2014) [133] J Pub H D											★
Aminabadi (2014) [55] Caries Res							★				★
Batliner (2014) [134] J Pub H D											★
Bissar (2014) [60] Clin Oral Inv							★	★	★		★
Carvalho (2014) [62] Caries Res							★		★	★	★
Chaffee (2014) [135] Ann Epid.								★			
Chaffee (2014) [8] J Oral Dis	★										
Chaffee (2014) [40] JDR						★					
Congiu (2014) [105] J Pub H D									★	★	★
Congiu (2014) [136] O Health Pr D	★										
dos Santos (2014) [20] BMC				★							
Duijster (2014) [119] CDOE											★
Gao (2014) [137] Ped D						★	★				
Gilbert (2014) [138] J Oral Micr.						★					
Han (2014) [139] CDOE										★	
Hong (2014) [29] Int J Paed D							★	★		★	
Hong (2014) [94] Ped D				★	★			★		★	★
Hsieh (2014) [67] As Pa J P H							★				
Jabin (2014) [140] J Clin Diag Res											★
Koo (2014) [141] Future Microb						★					

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Krisdapong (2014) [142] A P J Pub H											★
Li (2014) [143] Int J Mol Sci.						★					
Mahjoub (2014) [15] Caries Res			★								
Majorana (2014) [70] BMC								★	★		★
Masumo (2014) [144] Acta Od Scand					★		★			★	
Nobile (2014) [72] BMC								★	★		★
Nunes (2014) [63] BMC Publ H							★	★		★	
Olatosi (2014) [71] J West Afr Coll Surg.								★	★		
Peng (2014) [145] Int J Paed D				★							★
Perera (2014) [75] Asia Pac J Clin Nutr								★	★		
Piovesan (2014) [146] J Pub H D											★
Reyes-Perez (2014) [147] J P H D				★							
Schroth (2014) [148] Pediatr				★	★						
Stecksén-Blicks (2014) [111] Acta Od Sc											★
Torriani (2014) [149] Caries Res											★
Vargas (2014) [102] JADA										★	
Wulaerhan (2014) [103] BMC Oral .							★			★	★
Xu (2014) [150] PLoS One						★					
Am Acad Ped (2013/4) [151] Am Acad Ped	★										
Am Acad Ped (2013/4) [152] Am Acad Ped	★										
Alanzi (2013) [153] Ped Dent		★									
Bhoomika (2013) [24] J Clin Ped D				★							
Feldens (2013) [154] Caries Res											★
Leong (2013) [37] Int J Paed D						★	★	★	★	★	★
Masumo (2013) [88] Acta Od Sc								★		★	
Menon (2013) [115] Int J Paed D							★				★

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Naidu (2013) [155] BMC										★	
O'Keefe (2013) [156] Evid-based D	★										
Pani (2013) [157] Int J Dent											★
Pattanaporn (2013) [42] CDOE						★					
Plonka (2013) [34] Caries Res					★	★	★		★		★
Schroth (2013) [26] BMC				★							
Schroth (2013) [27] BMC				★							
Smith (2013) [158] J Ped Nursing	★										
Tanaka (2013) [73] Ped Dent								★	★		
Tao (2013) [51] Arch O Biol						★					
Whitney-Evans (2013) [159] J Acad Nut Diet										★	
Alaluusua (2012) [31] JDR					★						
Caufield (2012) [32] JDR					★	★					
Hughes (2012) [160] Ped D						★					
Masumo (2012) [161] BMC					★			★		★	★
Nunes (2012) [162] CDOE							★	★		★	
Plutzer (2012) [163] Int J Ped											★
Prakash (2012) [77] Eur J D							★	★	★	★	
Qadri (2012) [164] Quint Int								★	★		
Sadeghi (2012) [28] D Res (Iran)				★							
Seow (2012) [109] Int J Paed D											★
Subramaniam (2012) [64] Cont Clin D							★	★	★	★	
Wong (2012) [56] Int J Paed D							★		★	★	★
Yang (2012) [165] Arch O Biol						★					
Zhang (2012) [166] Arch O Biol						★					
Zhou (2012) [22] Caries Res				★	★	★	★				★

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Agarwal (2011) [167] Int J Paed D											★
Duran-Contreras (2011) [168] Eur J Paed D						★					
Hart (2011) [169] Int J D			★			★					
Kawashita (2011) [170] Int J D	★										
Kumar (2011) [14] Int J Paed D			★								
Kumarihamy (2011) [106] BMC Res Notes										★	
Li (2011) [99] Int J P D										★	
Lindemeyer (2011) [171] NY State D J											★
Mathur (2011) [172] Ped Dent J								★	★		
Ozer (2011) [78] Eur J Paed D									★		★
Tanner (2011) [52] JDR						★	★			★	
Zhou (2011) [173] Austral D J						★	★			★	★
Zhou (2011) [174] Int J Paed D						★					
Begzati (2010) [79] BMC						★			★	★	
Elfrink (2010) [175] Int J Paed D					★		★				★
Feldens (2010) [86] Caries Res								★	★	★	★
Johansson (2010) [176] Caries Res							★			★	★
Kanasi (2010) [177] Caries Res						★	★				
Masson (2010) [69] Br J Nut							★			★	
Meurman (2010) [92] Caries Res						★				★	★
Niji (2010) [53] Ped D						★	★			★	★
Palmer (2010) [97] Caries Res						★				★	
Parisotto (2010) [178] Arch O Biol						★	★			★	
Parisotto (2010) [38] Oral H Prev D						★					
Petti (2010) [179] J Dent	★										

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Senesombath (2010) [61] SE Asia J Trop Med P H.							★			★	
Tuli (2010) [180] Eur J Paed D	★										
Adeniyi (2009) [181] Int J Paed D											★
Alaki (2009) [182] Ped Dent	★				★						
Irigoyen-Camacho (2009) [183] J Clin P D											★
Choi (2009) [184] Int J Paed D						★					
Fonteles (2009) [12] Arch O Biol			★								
Ibrahim (2009) [43] Ped Dent J						★	★	★		★	
Jigjid (2009) [185] Com D Hlth						★		★		★	
Mitchell (2009) [41] Ped D						★					
Nunn (2009) [186] JDR										★	★
Nunn (2009) [187] J Pub H D											★
Seow (2009) [116] Caries Res					★	★	★			★	★
Tankkunnasombut (2009) [46] Ped Dent						★					
Thitasomakul (2009) [18] JDR				★			★	★		★	★
Uribe (2009) [188] Evid-Based D	★										
Warren (2009) [95] CDOE						★				★	
Coşulu (2008) [189] Int J P D						★	★	★		★	
Alaki (2008) [190] Ped D	★										
Declerck (2008) [191] CDOE							★			★	
Hong (2008) [23] J Pub H D				★							★
Ismail (2008) [120] Ped Dent										★	★
Maruyama (2008) [96] Ped D						★	★			★	
Mohebbi (2008) [192] CDOE								★	★	★	
Qin (2008) [80] Ped D						★			★	★	★

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Warren (2008) [193] J Pub H D						★	★				★
Du (2007) [194] Quint Int									★		★
Ferreira (2007) [195] Int J Paed D											★
Finlayson (2007) [117] CDOE											★
Kolker (2007) [100] Ped D							★			★	
Kramer (2007) [196] Caries Res								★			
Iida (2007) [125] Pediatrics								★			★
Ohlund (2007) [93] Caries Res						★				★	
Olak (2007) [197] Int J Paed D						★					
Schroth (2007) [198] Ped D											★
Tiberia (2007) [199] Ped D									★		
Williamson (2007) [113] Ped D											★
De Carvalho (2006) [200] Arch O Biol						★					
Clarke (2006) [25] Ped D				★							
Ersin (2006) [47] J Dent Ch						★	★		★		★
Gussy (2006) [6] J Paed Ch H	★										
Hallett (2006) [201] CDOE									★		★
Law (2006) [202] Ped D					★	★	★			★	
Psoter (2006) [203] J Pub H D											★
Tsai (2006) [204] CDOE							★			★	
Van Palenstein Helderman (2006) [44] JDR						★		★			
Tang (2005) [118] CDOE											★
Campus (2004) [65] Eur J Paed D							★		★	★	
Harris (2004) [5] Com Dent Hlth	★										
Kiwanuka (2004) [107] Int J Paed D							★			★	★
Nomura (2004) [205] Ped Dent J						★				★	

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Rosenblatt (2004) [206] Int J Paed D								★		★	
Stevens (2004) [207] Eur J P D											★
Vachirarojpisan (2004) [208] CDOE						★					★
Carino (2003) [57] CDOE							★			★	
Ismail (2003) [209] Ped D	★										
Jin (2003) [210] J Pub H D										★	
Jose (2003) [211] Ped D							★			★	★
Shiboski (2003) [81] J Pub H D									★		★
Chan (2002) [212] Int J Paed D							★			★	★
Huntington (2002) [66] Ped D							★		★		★
Rosenblatt (2002) [213] J Dent Ch										★	
Tinanoff (2002) [214] Ped D	★										
Al-Malik (2001) [58] Int J Paed D							★			★	★
Maciel (2001) [215] Int J Paed D						★				★	
Tsai (2001) [123] Int J Paed D							★				★
Ansai (2000) [216] Ped Dent			★			★					
Rodrigues (2000) [217] Int J Paed D					★		★			★	
Tinanoff (2000) [218] J Publ H D	★										
Drury (1999) [2] J Pub H D	★										
Ismail (1999) [3] J Pub H D	★										
Oulis (1999) [219] Ped D									★		
Ramos - Gomez (1999) [82] J Dent Ch								★	★		
Seow (1999) [33] Ped Dent					★	★	★		★		
al-Ghanim (1998) [83] Int J Paed D							★		★	★	
Bowen (1998) [220] CDOE	★										
Davies (1998) [221] CDOE	★										

Table 1. Aspects of Aetiology of ECC (continued).

Reference	ECC Review articles	Genetics	Saliva	Nutrition	Enamel hypoplasia	Oral flora	Oral hygiene and dental plaque	Breast - feeding	Sugar in bottles	Sugar	Family behaviour and environment
Reisine (1998) [222] CDOE	★										
Seow (1998) [7] CDOE	★										
Tinanoff (1998) [223] CDOE	★										
Del Valle (1998) [224] J Dent Ch									★		
Peretz (1997) [225] Ped D											★
Tinanoff (1997) [226] Ped D	★										
Shantinath (1996) [114] Ped D									★		★
Litt (1995) [4] Publ H Rep	★					★				★	★
Stecksén-Blicks (1995) [104] Int J Paed D							★			★	
Todd (1994) [227] Int J Paed D								★			

Poor oral health of infants and children of immigrant families has been recorded in several countries.[60,110,111] A good investigation into reasons for this was published by Stecksén–Blicks,[111] with poor dietary and oral hygiene habits being important. The child's temperament has been considered by some researchers – there is a good recent study by Aminabadi[55] in Tabriz, Iran, where the Early Childhood Behaviour Questionnaire (designed by Putnam[112]) was used. This questionnaire is relevant for children aged 18 to 36 months and measures 18 traits: the nine traits which were positively related and the nine traits which were negatively related to ECC are listed. An infant's 'difficulty sleeping' is listed as a risk factor in two papers.[113,114] Mother's high levels of stress were mentioned by some[115,116] as a risk factor although some reports disagreed with this.[117,118] There was a good paper on 'family functioning' in relation to ECC by Duijster[119] with emphasis on the negative impact of poor organisation within the home. Carer's 'fatalistic oral health beliefs' were investigated and discussed by Ismail.[120] Single parenthood and age of the mother are other variables reported in the articles. The poor oral health of the mother was recorded as a risk factor for ECC in the infant in several studies.[37,121-123] Several studies reported that mothers who smoked was a risk factor for ECC in the infant/child.[21,70,124,125]

In summary, family attributes, dynamics and behaviour are drivers of the primary risk factors for ECC - sugar intake, feeding habits, poor tooth cleaning and acquisition of SM. These family risk factors are themselves driven by the environment in which the family lives. Unfavourable environmental factors include food availability and relative costs of foods, educational experience and finance, advertising, society cultures and customs. These factors need to be considered if progress is to be made in controlling the primary risk factors for ECC.

Concluding remarks

227 articles have been examined in this review of the aetiology of ECC. Potential risk factors for ECC have been grouped under 10 headings. The literature indicated that all ten were relevant risk factors. Although each has been considered separately, there are strong interactions between them. Most emphasis has been put on high and frequent consumption of dietary sugars, infant feeding practices, poor removal of dental plaque, and formation of a dental plaque flora which is particularly conducive to caries development – the growth of this plaque is strongly encouraged by poor plaque control and a high sugar diet. Reasons for these caries-inducing behaviours lie in the family – their own experiences, circumstances and lifestyles. However, the family, or carers, are subject to strong pressures which shape belief, attitude and behaviour. The use, or lack of use, of fluoride has not been discussed in this review. The beneficial role of fluoride in caries prevention is well-known, and lack of use of fluoride should be seen as an important risk factor for ECC. Vehicles for fluoride relevant to ECC are water, salt, milk, toothpaste, and varnish.

References

1. Conference Proceedings. Early Childhood Caries Conference. Community Dent Oral Epidemiol. 1998;26(Suppl1):5 - 119.

2. Drury TF, Horowitz AM, Ismail AI, Maertens MP, Rozier RG, Selwitz RH. Diagnosing and reporting early childhood caries for research purposes. A report of a workshop sponsored by the National Institute of Dental and Craniofacial Research, the Health Resources and Services Administration, and the Health Care Financing Administration. J Public Health Dent. 1999;59(3):192-7.

3. Ismail AI, Sohn W. A systematic review of clinical diagnostic criteria of early childhood caries. J Public Health Dent. 1999;59(3):171-91.

4. Litt MD, Reisine S, Tinanoff N. Multidimensional causal model of dental caries development in low-income preschool children. Public Health Rep. 1995;110(5):607-17.

5. Harris R, Nicoll AD, Adair PM, Pine CM. Risk factors for dental caries in young children: a systematic review of the literature. Community Dent Health. 2004;21(1 Suppl):71-85.

6. Gussy MG, Waters EG, Walsh O, Kilpatrick NM. Early childhood caries: current evidence for aetiology and prevention. J Paediatr Child Health. 2006;42(1-2):37-43.

7. Seow WK. Biological mechanisms of early childhood caries. Community Dent Oral Epidemiol. 1998;26(1 Suppl):8-27.

8. Chaffee BW, Cheng A. Global research trends on early-life feeding practices and Early Childhood Caries: a systematic review. J Oral Dis. 2014;2014:675658.

9. Fontana M. The clinical, environmental, and behavioral factors that foster Early Childhood Caries: evidence for caries risk assessment. Pediatr Dent. 2015;37(3):217-25.

10. Abbasoglu Z, Tanboga I, Kuchler EC, Deeley K, Weber M, Kaspar C, et al. Early childhood caries is associated with genetic variants in enamel formation and immune response genes. Caries Res. 2015;49(1):70-7.

11. Romanos HF, Antunes LS, Lopes LB, Saboia T de M, Tannure PN, Lips A, et al. BMP2 is associated with caries experience in primary teeth. Caries Res. 2015;49(4):425-33.
12. Fonteles CS, Guerra MH, Ribeiro TR, Mendonca DN, de Carvalho CB, Monteiro AJ, et al. Association of free amino acids with caries experience and mutans streptococci levels in whole saliva of children with early childhood caries. Arch Oral Biol. 2009;54(1):80-5.
13. Jurczak A, Koscielniak D, Papiez M, Vyhouskaya P, Krzysciak W. A study on beta-defensin-2 and histatin-5 as a diagnostic marker of early childhood caries progression. Biol Res. 2015;48:61.
14. Kumar D, Pandey RK, Agrawal D, Agrawal D. An estimation and evaluation of total antioxidant capacity of saliva in children with severe early childhood caries. Int J Paediatr Dent. 2011;21(6):459-64.
15. Mahjoub S, Ghasempour M, Gharage A, Bijani A, Masrourroudsari J. Comparison of total antioxidant capacity in saliva of children with severe early childhood caries and caries-free children. Caries Res. 2014;48(4):271-5.
16. Si Y, Ao S, Wang W, Chen F, Zheng S. Magnetic bead-based salivary peptidome profiling analysis for severe early childhood caries. Caries Res. 2015;49 (1):63-9.
17. Neves AB, Lobo LA, Pinto KC, Pires ES, Requejo M, Maia LC, et al. Comparison between clinical aspects and salivary microbial profile of children with and without Early Childhood Caries: a preliminary study. J Clin Pediatr Dent. 2015;39(3):209-14.
18. Thitasomakul S, Piwat S, Thearmontree A, Chankanka O, Pithpornchaiyakul W, Madyusoh S. Risks for early childhood caries analyzed by negative binomial models. J Dent Res. 2009;88(2):137-41.
19. Schroth RJ, Pang JL, Levi JA, Martens PJ, Brownell MD. Trends in pediatric dental surgery for severe early childhood caries in Manitoba, Canada. J Can Dent Assoc. 2014;80:e65.
20. dos Santos Junior VE, de Sousa RM, Oliveira MC, de Caldas Junior AF, Rosenblatt A. Early childhood caries and its relationship with perinatal, socioeconomic and nutritional risks: a cross-sectional study. BMC Oral Health. 2014;14:47.
21. Yokomichi H, Tanaka T, Suzuki K, Akiyama T, Okinawa Child Health Study Group, Yamagata Z. Macrosomic neonates carry increased risk of dental caries in early childhood: findings from a cohort study, the Okinawa Child Health Study, Japan. PLoS One. 2015;10(7):e0133872.
22. Zhou Y, Yang JY, Lo EC, Lin HC. The contribution of life course determinants to early childhood caries: a 2-year cohort study. Caries Res. 2012;46(2):87-94.
23. Hong L, Ahmed A, McCunniff M, Overman P, Mathew M. Obesity and dental caries in children aged 2-6 years in the United States: National Health and Nutrition Examination Survey 1999-2002. J Public Health Dent. 2008;68(4):227-33.
24. Bhoomika W, Ramakrishna Y, Munshi AK. Relationship between severe early childhood caries and body mass index. J Clin Pediatr Dent. 2013;37(3):235-42.
25. Clarke M, Locker D, Berall G, Pencharz P, Kenny DJ, Judd P. Malnourishment in a population of young children with severe early childhood caries. Pediatr Dent. 2006;28(3):254-9.
26. Schroth RJ, Levi J, Kliewer E, Friel J, Moffatt ME. Association between iron status, iron deficiency anaemia, and severe early childhood caries: a case-control study. BMC Pediatr. 2013;13:22.
27. Schroth RJ, Levi JA, Sellers EA, Friel J, Kliewer E, Moffatt ME. Vitamin D status of children with severe early childhood caries: a case-control study. BMC Pediatr. 2013;13:174.
28. Sadeghi M, Darakhshan R, Bagherian A. Is there an association between early childhood caries and serum iron and serum ferritin levels? Dent Res J (Isfahan). 2012;9(3):294-8.
29. Hong CH, Bagramian RA, Hashim Nainar SM, Straffon LH, Shen L, Hsu CY. High caries prevalence and risk factors among young preschool children in an urban community with water fluoridation. Int J Paediatr Dent. 2014;24(1):32-42.

30. Rugg-Gunn AJ, Do L. Effectiveness of water fluoridation in caries prevention. Community Dent Oral Epidemiol. 2012;40 Suppl 2:55-64.
31. Alaluusua S. Defining developmental enamel defect-associated childhood caries: where are we now? J Dent Res. 2012;91(6):525-7.
32. Caufield PW, Li Y, Bromage TG. Hypoplasia-associated severe early childhood caries - a proposed definition. J Dent Res. 2012;91(6):544-50.
33. Seow WK, Amaratunge A, Sim R, Wan A. Prevalence of caries in urban Australian aborigines aged 1 -3.5 years. Pediatr Dent. 1999;21(2):91-6.
34. Plonka KA, Pukallus ML, Barnett AG, Holcombe TF, Walsh LJ, Seow WK. A longitudinal case-control study of caries development from birth to 36 months. Caries Res. 2013;47(2):117-27.
35. Narrenthran JS, Muthu MS, Renugalakshmi A. In vivo scanning electron microscope assessment of enamel permeability in primary teeth with and without early childhood caries. Caries Res. 2015;49 (3):209-15.
36. Das B, Muthu MS, Farzan JM. Comparison of the chemical composition of normal enamel from exfoliated primary teeth and teeth affected with early childhood caries: an in vitro study. Int J Paediatr Dent. 2016;26(1):20-5.
37. Leong PM, Gussy MG, Barrow SY, de Silva-Sanigorski A, Waters E. A systematic review of risk factors during first year of life for early childhood caries. Int J Paediatr Dent. 2013;23(4):235-50.
38. Parisotto TM, Steiner-Oliveira C, Silva CM, Rodrigues LK, Nobre-dos-Santos M. Early childhood caries and mutans streptococci: a systematic review. Oral Health Prev Dent. 2010;8(1):59 - 70.
39. Hao W, Xu H, Chen X, Zhou Q, Zhang P, Chen F, et al. Changes in dental plaque microbial richness and oral behavioral habits during caries development in young Chinese children. Caries Res. 2015;49 (2):116-23.
40. Chaffee BW, Gansky SA, Weintraub JA, Feather stone JD, Ramos-Gomez FJ. Maternal oral bacterial levels predict early childhood caries development. J Dent Res. 2014;93(3):238-44.
41. Mitchell SC, Ruby JD, Moser S, Momeni S, Smith A, Osgood R, et al. Maternal transmission of mutans streptococci in severe-early childhood caries. Pediatr Dent. 2009;31(3):193-201.
42. Pattanaporn K, Saraithong P, Khongkhunthian S, Aleksejuniene J, Laohapensang P, Chhun N, et al. Mode of delivery, mutans streptococci colonization, and early childhood caries in three- to five-year-old Thai children. Community Dent Oral Epidemiol. 2013;41(3):212-23.
43. Ibrahim S, Nishimura M, Matsumura S, Rodis OMM, Nishida A, Yamanaka K, et al. A longitudinal study of early childhood caries risk, dental caries, and life style. Pediatric Dental Journal. 2009;19 (2):174-80.
44. Van Palenstein Helderman WH, Soe W, van 't Hof MA. Risk factors of early childhood caries in a Southeast Asian population. J Dent Res. 2006;85 (1):85-8.
45. Caufield PW, Cutter GR, Dasanayake AP. Initial acquisition of mutans streptococci by infants: evidence for a discrete window of infectivity. J Dent Res. 1993;72(1):37-45.
46. Tankkunnasombut S, Youcharoen K, Wisuttisak W, Vichayanrat S, Tiranathanagul S. Early colonization of mutans streptococci in 2- to 36-month-old Thai children. Pediatr Dent. 2009;31(1):47-51.
47. Ersin NK, Eronat N, Cogulu D, Uzel A, Aksit S. Association of maternal-child characteristics as a factor in early childhood caries and salivary bacterial counts. J Dent Child. 2006;73(2):105-11.
48. Ma C, Chen F, Zhang Y, Sun X, Tong P, Si Y, et al. Comparison of oral microbial profiles between children with severe early childhood caries and caries - free children using the human oral microbe identification microarray. PLoS One. 2015;10 (3):e0122075.

49. Saraithong P, Pattanaporn K, Chen Z, Khongkhunthian S, Laohapensang P, Chhun N, et al. Streptococcus mutans and Streptococcus sobrinus colonization and caries experience in 3- and 5-year -old Thai children. Clin Oral Investig. 2015;19(8):1955-64.
50. Qiu R, Li W, Lin Y, Yu D, Zhao W. Genotypic diversity and cariogenicity of Candida albicans from children with early childhood caries and caries-free children. BMC Oral Health. 2015;15(1):144.
51. Tao Y, Zhou Y, Ouyang Y, Lin H. Dynamics of oral microbial community profiling during severe early childhood caries development monitored by PCR-DGGE. Arch Oral Biol. 2013;58(9):1129-38.
52. Tanner AC, Kent RL, Jr., Holgerson PL, Hughes CV, Loo CY, Kanasi E, et al. Microbiota of severe early childhood caries before and after therapy. J Dent Res. 2011;90(11):1298-305.
53. Niji R, Arita K, Abe Y, Lucas ME, Nishino M, Mitome M. Maternal age at birth and other risk factors in early childhood caries. Pediatr Dent. 2010;32(7):493-8.
54. Turton B, Durward C, Manton D, Bach K, Yos C. Socio-behavioural risk factors for early childhood caries (ECC) in Cambodian preschool children: a pilot study. Eur Arch Paediatr Dent. 2016;17(2):97-105.
55. Aminabadi NA, Ghoreishizadeh A, Ghoreishizadeh M, Oskouei SG, Ghojazadeh M. Can child temperament be related to early childhood caries? Caries Res. 2014;48(1):3-12.
56. Wong MCM, Lu HX, Lo ECM. Caries increment over 2 years in preschool children: a life course approach. Int J Paediatr Dent. 2012;22(2):77-84.
57. Carino KM, Shinada K, Kawaguchi Y. Early childhood caries in northern Philippines. Community Dent Oral Epidemiol. 2003;31(2):81-9.
58. Al-Malik MI, Holt RD, Bedi R. The relationship between erosion, caries and rampant caries and dietary habits in preschool children in Saudi Arabia. Int J Paediatr Dent. 2001;11(6):430-9.
59. Winter J, Glaser M, Heinzel-Gutenbrunner M, Pieper K. Association of caries increment in preschool children with nutritional and preventive variables. Clin Oral Investig. 2015;19(8):1913-9.
60. Bissar A, Schiller P, Wolff A, Niekusch U, Schulte AG. Factors contributing to severe early childhood caries in south-west Germany. Clin Oral Investig. 2014;18(5):1411-8.
61. Senesombath S, Nakornchai S, Banditsing P, Lexomboon D. Early childhood caries and related factors in Vientiane, Lao PDR. Southeast Asian J Trop Med Public Health. 2010;41(3):717-25.
62. Carvalho JC, Silva EF, Vieira EO, Pollaris A, Guillet A, Mestrinho HD. Oral health determinants and caries outcome among non-privileged children. Caries Res. 2014;48(6):515-23.
63. Nunes AM, da Silva AA, Alves CM, Hugo FN, Ribeiro CC. Factors underlying the polarization of early childhood caries within a high-risk population. BMC Public Health. 2014;14:988.
64. Subramaniam P, Prashanth P. Prevalence of early childhood caries in 8 - 48 month old preschool children of Bangalore city, South India. Contemp Clin Dent. 2012;3(1):15-21.
65. Campus G, Lumbau A, Sanna AM, Solinas G, Luglie P, Castiglia P. Oral health condition in an Italian preschool population. Eur J Paediatr Dent. 2004;5 (2):86-91.
66. Huntington NL, Kim IJ, Hughes CV. Caries-risk factors for Hispanic children affected by early childhood caries. Pediatr Dent. 2002;24(6):536-42.
67. Hsieh HJ, Huang ST, Tsai CC, Hsiao SY. Tooth-brushing habits and risk indicators of severe early childhood caries among aboriginal Taiwanese. Asia Pac J Public Health. 2014;26(3):238-47.
68. Stecksén - Blicks C, Holm AK. Dental caries, tooth trauma, malocclusion, fluoride usage, tooth-brushing and dietary habits in 4-year-old Swedish children: changes between 1967 and 1992. Int J Paediatr Dent. 1995;5(3):143-8.

69. Masson LF, Blackburn A, Sheehy C, Craig LC, Macdiarmid JI, Holmes BA, et al. Sugar intake and dental decay: results from a national survey of children in Scotland. Br J Nutr. 2010;104(10):1555-64.
70. Majorana A, Cagetti MG, Bardellini E, Amadori F, Conti G, Strohmenger L, et al. Feeding and smoking habits as cumulative risk factors for early childhood caries in toddlers, after adjustment for several behavioral determinants: a retrospective study. BMC Pediatr. 2014;14:45.
71. Olatosi OO, Sote EO. Association of Early Childhood Caries with breastfeeding and bottle feeding in southwestern Nigerian children of preschool age. J West Afr Coll Surg. 2014;4(1):31-53.
72. Nobile CG, Fortunato L, Bianco A, Pileggi C, Pavia M. Pattern and severity of early childhood caries in Southern Italy: a preschool-based cross-sectional study. BMC Public Health. 2014;14:206.
73. Tanaka K, Miyake Y, Sasaki S, Hirota Y. Infant feeding practices and risk of dental caries in Japan: the Osaka Maternal And Child Health Study. Pediatr Dent. 2013;35(3):267-71.
74. Jain M, Namdev R, Bodh M, Dutta S, Singhal P, Kumar A. Social and behavioral determinants for Early Childhood Caries among preschool children in India. J Dent Res Dent Clin Dent Prospects. 2015;9 (2):115-20.
75. Perera PJ, Fernando MP, Warnakulasooriya TD, Ranathunga N. Effect of feeding practices on dental caries among preschool children: a hospital based analytical cross sectional study. Asia Pac J Clin Nutr. 2014;23(2):272-7.
76. Tham R, Bowatte G, Dharmage SC, Tan DJ, Lau MX, Dai X, et al. Breastfeeding and the risk of dental caries: a systematic review and meta-analysis. Acta Paediatr. 2015;104(467):62-84.
77. Prakash P, Subramaniam P, Durgesh BH, Konde S. Prevalence of early childhood caries and associated risk factors in preschool children of urban Bangalore, India: a cross-sectional study. Eur J Dent. 2012;6 (2):141-52.
78. Ozer S, Sen Tunc E, Bayrak S, Egilmez T. Evaluation of certain risk factors for early childhood caries in Samsun, Turkey. Eur J Paediatr Dent. 2011;12(2):103-6.
79. Begzati A, Berisha M, Meqa K. Early childhood caries in preschool children of Kosovo - a serious public health problem. BMC Public Health. 2010;10:788.
80. Qin M, Li J, Zhang S, Ma W. Risk factors for severe early childhood caries in children younger than 4 years old in Beijing, China. Pediatr Dent. 2008;30 (2):122-8.
81. Shiboski CH, Gansky SA, Ramos-Gomez F, Ngo L, Isman R, Pollick HF. The association of early childhood caries and race/ethnicity among California preschool children. J Public Health Dent. 2003;63 (1):38-46.
82. Ramos-Gomez FJ, Tomar SL, Ellison J, Artiga N, Sintes J, Vicuna G. Assessment of early childhood caries and dietary habits in a population of migrant Hispanic children in Stockton, California. J Dent Child. 1999;66(6):395-403, 366.
83. al Ghanim NA, Adenubi JO, Wyne AA, Khan NB. Caries prediction model in pre-school children in Riyadh, Saudi Arabia. Int J Paediatr Dent. 1998;8 (2):115-22.
84. Chaffee BW, Feldens CA, Rodrigues PH, Vitolo MR. Feeding practices in infancy associated with caries incidence in early childhood. Community Dent Oral Epidemiol. 2015;43(4):338-48.
85. Avila WM, Pordeus IA, Paiva SM, Martins CC. Breast and bottle feeding as risk factors for dental caries: a systematic review and meta-analysis. PLoS One. 2015;10(11):e0142922.
86. Feldens CA, Giugliani ER, Vigo A, Vitolo MR. Early feeding practices and severe early childhood caries in four-year-old children from southern Brazil: a birth cohort study. Caries Res. 2010;44(5):445-52.
87. Peltzer K, Mongkolchati A. Severe early childhood caries and social determinants in three-year-old children from Northern Thailand: a birth cohort study. BMC Oral Health. 2015;15:108.

88. Masumo R, Bardsen A, Mashoto K, Astrom AN. Feeding practice among 6-36 months old in Tanzania and Uganda: reliability and relationship with early childhood caries, ECC. Acta Odontol Scand. 2013;71 (5):1309-18.

89. Ghazal T, Levy SM, Childers NK, Broffitt B, Cutter GR, Wiener HW, et al. Factors associated with early childhood caries incidence among high caries-risk children. Community Dent Oral Epidemiol. 2015;43 (4):366-74.

90. Lim S, Tellez M, Ismail AI. Dental caries development among African American children: results from a 4-year longitudinal study. Community Dent Oral Epidemiol. 2015;43(3):200-7.

91. Wigen TI, Wang NJ. Does early establishment of favorable oral health behavior influence caries experience at age 5 years? Acta Odontol Scand. 2015;73(3):182-7.

92. Meurman PK, Pienihakkinen K. Factors associated with caries increment: a longitudinal study from 18 months to 5 years of age. Caries Res. 2010;44 (6):519-24.

93. Ohlund I, Holgerson PL, Backman B, Lind T, Hernell O, Johansson I. Diet intake and caries prevalence in four-year-old children living in a low-prevalence country. Caries Res. 2007;41(1):26-33.

94. Hong L, Levy SM, Warren JJ, Broffitt B. Infant breast-feeding and childhood caries: a nine-year study. Pediatr Dent. 2014;36(4):342-7.

95. Warren JJ, Weber-Gasparoni K, Marshall TA, Drake DR, Dehkordi-Vakil F, Dawson DV, et al. A longitudinal study of dental caries risk among very young low SES children. Community Dent Oral Epidemiol. 2009;37(2):116-22.

96. Maruyama S, Teramoto S, Miyazawa H. Epidemiological study of dental disease factors among young Japanese children. Pediatric Dental Journal. 2008;18 (2):156-66.

97. Palmer CA, Kent R, Jr., Loo CY, Hughes CV, Stutius E, Pradhan N, et al. Diet and caries-associated bacteria in severe early childhood caries. J Dent Res. 2010;89 (11):1224-9.

98. Zaki NA, Dowidar KM, Abdelaziz WE. Assessment of the Healthy Eating Index-2005 as a predictor of early childhood caries. Int J Paediatr Dent. 2015;25 (6):436-43.

99. Li Y, Zhang Y, Yang R, Zhang Q, Zou J, Kang D. Associations of social and behavioural factors with early childhood caries in Xiamen city in China. Int J Paediatr Dent. 2011;21(2):103-11.

100. Kolker JL, Yuan Y, Burt BA, Sandretto AM, Sohn W, Lang SW, et al. Dental caries and dietary patterns in low-income African American children. Pediatr Dent. 2007;29(6):457-64.

101. Abdelaziz WE, Dowidar KM, El Tantawi MM. Association of healthy eating, juice consumption, and bacterial counts with Early Childhood Caries. Pediatr Dent. 2015;37(5):462-7.

102. Vargas CM, Dye BA, Kolasny CR, Buckman DW, McNeel TS, Tinanoff N, et al. Early childhood caries and intake of 100 percent fruit juice: Data from NHANES, 1999-2004. J Am Dent Assoc. 2014;145 (12):1254-61.

103. Wulaerhan J, Abudureyimu A, Bao XL, Zhao J. Risk determinants associated with early childhood caries in Uygur children: a preschool-based cross - sectional study. BMC Oral Health. 2014;14:136.

104. Stecksen-Blicks C, Holm AK. Between-meal eating, toothbrushing frequency and dental caries in 4-year-old children in the north of Sweden. Int J Paediatr Dent. 1995;5(2):67-72.

105. Congiu G, Campus G, Sale S, Spano G, Cagetti MG, Luglie PF. Early childhood caries and associated determinants: a cross-sectional study on Italian preschool children. J Public Health Dent. 2014;74 (2):147-52.

106. Kumarihamy SL, Subasinghe LD, Jayasekara P, Kularatna SM, Palipana PD. The prevalence of Early Childhood Caries in 1-2 yrs olds in a semi-urban area of Sri Lanka. BMC Res Notes. 2011;4:336.

107. Kiwanuka SN, Astrom AN, Trovik TA. Dental caries experience and its relationship to social and behavioural factors among 3-5-year-old children in Uganda. Int J Paediatr Dent. 2004;14(5):336-46.

108. Khanh LN, Ivey SL, Sokal-Gutierrez K, Barkan H, Ngo KM, Hoang HT, et al. Early Childhood Caries, mouth pain, and nutritional threats in Vietnam. Am J Public Health. 2015;105(12):2510-7.
109. Seow WK. Environmental, maternal, and child factors which contribute to early childhood caries: a unifying conceptual model. Int J Paediatr Dent. 2012;22(3):157-68.
110. Baggio S, Abarca M, Bodenmann P, Gehri M, Madrid C. Early childhood caries in Switzerland: a marker of social inequalities. BMC Oral Health. 2015;15:82.
111. Stecksén -Blicks C, Hasslof P, Kieri C, Widman K. Caries and background factors in Swedish 4-year-old children with special reference to immigrant status. Acta Odontol Scand. 2014;72(8):852-8.
112. Putnam SP, Gartstein MA, Rothbert MK. Measurement of fine-grained aspects of toddler temperament: Early Childhood Behavior questionnaire. Infant behav Dev. 2006;29:386-401.
113. Williamson R, Oueis H, Casamassimo PS, Thikkurissy S. Association between early childhood caries and behavior as measured by the Child Behavior Checklist. Pediatr Dent. 2008;30(6):505-9.
114. Shantinath SD, Breiger D, Williams BJ, Hasazi JE. The relationship of sleep problems and sleep - associated feeding to nursing caries. Pediatr Dent. 1996;18(5):375-8.
115. Menon I, Nagarajappa R, Ramesh G, Tak M. Parental stress as a predictor of early childhood caries among preschool children in India. Int J Paediatr Dent. 2013;23(3):160-5.
116. Seow WK, Clifford H, Battistutta D, Morawska A, Holcombe T. Case-control study of early childhood caries in Australia. Caries Res. 2009;43(1):25-35.
117. Finlayson TL, Siefert K, Ismail AI, Sohn W. Psychosocial factors and early childhood caries among low-income African-American children in Detroit. Community Dent Oral Epidemiol. 2007;35 (6):439-48.
118. Tang C, Quinonez RB, Hallett K, Lee JY, Whitt JK. Examining the association between parenting stress and the development of early childhood caries. Community Dent Oral Epidemiol. 2005;33(6):454-60.
119. Duijster D, Verrips GH, van Loveren C. The role of family functioning in childhood dental caries. Community Dent Oral Epidemiol. 2014;42(3):193-205.
120. Ismail AI, Lim S, Sohn W, Willem JM. Determinants of early childhood caries in low - income African American young children. Pediatr Dent. 2008;30 (4):289-96.
121. de Souza PM, Mello Proenca MA, Franco MM, Rodrigues VP, Costa JF, Costa EL. Association between early childhood caries and maternal caries status: A cross-section study in Sao Luis, Maranhao, Brazil. Eur J Dent. 2015;9(1):122-6.
122. Camacho MEI, Pérez LS, Pérez ÁG, Zepeda MAZ. Relationship between Severe Early Childhood Caries, mother's oral health and mutans streptococci in a low-income group: changes from 1996 to 2007. J Clin Pediatr Dent. 2009;33(3):241-6.
123. Tsai AI, Johnsen DC, Lin YH, Hsu KH. A study of risk factors associated with nursing caries in Taiwanese children aged 24-48 months. Int J Paediatr Dent. 2001;11(2):147-9.
124. Nakayama Y, Mori M. Association of environmental tobacco smoke and snacking habits with the risk of early childhood caries among 3-year-old Japanese children. J Public Health Dent. 2015;75 (2):157-62.
125. Iida H, Auinger P, Billings RJ, Weitzman M. Association between infant breastfeeding and early childhood caries in the United States. Pediatrics. 2007;120(4):e944-52.
126. Birungi N, Fadnes LT, Okullo I, Kasangaki A, Nankabirwa V, Ndeezi G, et al. Effect of breastfeeding promotion on Early Childhood Caries and breastfeeding duration among 5 year old children in eastern Uganda: a cluster randomized trial. PLoS One. 2015;10 (5):e0125352.

127. Correa-Faria P, Paixao-Goncalves S, Paiva SM, Pordeus IA, Marques LS, Ramos-Jorge ML. Association between developmental defects of enameland early childhood caries: a cross - sectional study. Int J Paediatr Dent. 2015;25(2):103-9.
128. Folayan MO, Kolawole KA, Oziegbe EO, Oyedele T, Oshomoji OV, Chukwumah NM, et al.Prevalence, and early childhood caries risk indicators in preschool children in suburban Nigeria. BMC Oral Health. 2015;15:72.
129. Kato T, Yorifuji T, Yamakawa M, Inoue S, Saito K, Doi H, et al. Association of breast feeding with early childhood dental caries: Japanese population-based study. BMJ Open. 2015;5(3):e006982.
130. Liang CY, Liu YC, Shieh TY, Lin JR, Tseng YC, Teng AY. Experience of Early Childhood Caries may positively correlate with psychomotor development. Oral Health Prev Dent. 2015;13(4):365-75.
131. Nakayama Y, Mori M. Association between nocturnal breastfeeding and snacking habits and the risk of early childhood caries in 18- to 23-month-old Japanese children. J Epidemiol. 2015;25(2):142-7.
132. Paglia L. Does breastfeeding increase risk of early childhood caries? Eur J Paediatr Dent. 2015;16(3):173.
133. Albino J, Tiwari T, Henderson WG, Thomas J, Bryant LL, Batliner TS, et al. Learning from caries- free children in a high-caries American Indian population. J Public Health Dent. 2014;74(4):293-300.
134. Batliner T, Wilson AR, Tiwari T, Glueck D, Henderson W, Thomas J, et al. Oral health status in Navajo Nation Head Start children. J Public Health Dent. 2014;74(4):317-25.
135. Chaffee BW, Feldens CA, Vitolo MR. Association of long-duration breastfeeding and dental caries estimated with marginal structural models. Ann Epidemiol. 2014;24(6):448-54.
136. Congiu G, Campus G, Luglie PF. Early Childhood Caries (ECC) prevalence and background factors: a review. Oral Health Prev Dent. 2014;12(1):71-6.
137. Gao X, Hsu CY, Loh T, Hwarng B, Koh D. Role of microbiological factors in predicting early childhood caries. Pediatr Dent. 2014;36(4):348-54.
138. Gilbert K, Joseph R, Vo A, Patel T, Chaudhry S, Nguyen U, et al. Children with severe early childhood caries: streptococci genetic strains within carious and white spot lesions. J Oral Microbiol. 2014;6:25805.
139. Han DH, Kim DH, Kim MJ, Kim JB, Jung - Choi K, Bae KH. Regular dental checkup and snack-soda drink consumption of preschool children are associated with early childhood caries in Korean caregiver/ preschool children dyads. Community Dent Oral Epidemiol. 2014;42(1):70-8.
140. Jabin Z, Chaudhary S. Association of child temperament with early childhood caries. J Clin Diagn Res. 2014;8(12):ZC21-4.
141. Koo H, Bowen WH. Candida albicans and Streptococcus mutans: a potential synergistic alliance to cause virulent tooth decay in children. Future Microbiol. 2014;9(12):1295-7.
142. Krisdapong S, Somkotra T, Kueakulpipat W. Disparities in early childhood caries and its impact on oral health-related quality of life of preschool children. Asia Pac J Public Health. 2014;26(3):285-94.
143. Li W, Yu D, Gao S, Lin J, Chen Z, Zhao W. Role of Candida albicans - secreted aspartyl proteinases (Saps) in severe early childhood caries. Int J Mol Sci. 2014;15(6):10766-79.
144. Masumo R, Birungi N, Bardsen A, Fadnes LT, Astrom AN. Impact of low birthweight on early childhood caries in 6-36 months old infants in Uganda: A cross-sectional study. Acta Odontol Scand. 2014;72(4):312-20.
145. Peng SM, Wong HM, King NM, McGrath C. Is dental caries experience associated with adiposity status in preschool children? Int J Paediatr Dent. 2014;24(2):122-30.

146. Piovesan C, Tomazoni F, Del Fabro J, Buzzati BC, Mendes FM, Antunes JL, et al. Inequality in dental caries distribution at noncavitated and cavitated thresholds in preschool children. J Public Health Dent. 2014;74(2):120-6.
147. Reyes-Perez E, Borrell LN, Katz RV, Gebrian BJ, Prophete S, Psoter WJ. Effect of early childhood protein - energy malnutrition on permanent dentition dental caries. J Public Health Dent. 2014;74(3):181-7.
148. Schroth RJ, Lavelle C, Tate R, Bruce S, Billings RJ, Moffatt ME. Prenatal vitamin D and dental caries in infants. Pediatrics. 2014;133(5):e1277-84.
149. Torriani DD, Ferro RL, Bonow ML, Santos IS, Matijasevich A, Barros AJ, et al. Dental caries is associated with dental fear in childhood: findings from a birth cohort study. Caries Res. 2014;48(4):263-70.
150. Xu H, Hao W, Zhou Q, Wang W, Xia Z, Liu C, et al. Plaque bacterial microbiome diversity in children younger than 30 months with or without caries prior to eruption of second primary molars. PLoS One. 2014;9(2):e89269.
151. American Academy of Pediatric Dentistry. Council on Clinical Affairs. Policy on early childhood caries (ECC): classifications and consequences, and preventive strategies. Oral Health Policies. 2013/14;35 (6):50 - 2.
152. American Academy of Pediatric Dentistry. Council on Clinical Affairs. Policy on early childhood caries (ECC): unique challenges and treatment options. Oral Health Policies. 2013/14;35(6):53 - 5.
153. Alanzi A, Minah G, Romberg E, Catalanotto F, Bartoshuk L, Tinanoff N. Mothers' taste perceptions and their preschool children's dental caries experiences. Pediatr Dent. 2013;35(7):510-4.
154. Feldens CA, Rodrigues PH, Rauber F, Chaffee BW, Vitolo MR. Food expenditures, cariogenic dietary practices and childhood dental caries in southern Brazil. Caries Res. 2013;47(5):373-81.
155. Naidu R, Nunn J, Kelly A. Socio - behavioural factors and early childhood caries: a cross-sectional study of preschool children in central Trinidad. BMC Oral Health. 2013;13:30.
156. O'Keefe E. Early childhood caries. Evid Based Dent. 2013;14(2):40-1.
157. Pani SC, Abuthuraya D, AlShammery HM, AlShammery D, AlShehri H. Salivary cortisol as a biomarker to explore the role of maternal stress in early childhood caries. Int J Dent. 2013;2013:565102.
158. Smith GA, Riedford K. Epidemiology of early childhood caries: clinical application. J Pediatr Nurs. 2013;28(4):369-73.
159. Whitney-Evans EW, Hayes C, Palmer CA, Bermudez OI, Cohen SA, Must A. Dietary intake and severe early childhood caries in low - income, young children. J Acad Nutr Diet. 2013;113(8):1057-61.
160. Hughes CV, Dahlan M, Papadopolou E, Loo CY, Pradhan NS, Lu SC, et al. Aciduric microbiota and mutans streptococci in severe and recurrent severe early childhood caries. Pediatr Dent. 2012;34(2):e16-23.
161. Masumo R, Bardsen A, Mashoto K, Astrom AN. Prevalence and socio-behavioral influence of early childhood caries, ECC, and feeding habits among 6-36 months old children in Uganda and Tanzania. BMC Oral Health. 2012;12:24.
162. Nunes AM, Alves CM, Borba de Araujo F, Ortiz TM, Ribeiro MR, Silva AA, et al. Association between prolonged breast-feeding and early childhood caries: a hierarchical approach. Community Dent Oral Epidemiol. 2012;40(6):542-9.
163. Plutzer K, Keirse MJ. Influence of first-time mothers' early employment on severe early childhood caries in their child. Int J Pediatr. 2012;2012:820680.
164. Qadri G, Nourallah A, Splieth CH. Early childhood caries and feeding practices in kindergarten children. Quintessence Int. 2012;43(6):503-10.
165. Yang XQ, Zhang Q, Lu LY, Yang R, Liu Y, Zou J. Genotypic distribution of Candida albicans in dental biofilm of Chinese children associated with severe early childhood caries. Arch Oral Biol. 2012;57 (8):1048-53.

166. Zhang XH, Zhou Y, Zhi QH, Tao Y, Lin HC. Genetic polymorphisms of the sortase A gene and early childhood caries in two - year - old children. Arch Oral Biol. 2012;57(7):948-53.
167. Agarwal V, Nagarajappa R, Keshavappa SB, Lingesha RT. Association of maternal risk factors with early childhood caries in schoolchildren of Moradabad, India. Int J Paediatr Dent. 2011;21(5):382-8.
168. Duran-Contreras GL, Torre-Martinez HH, de la Rosa EI, Hernandez RM, de la Garza Ramos M. spaP gene of Streptococcus mutans in dental plaque and its relationship with early childhood caries. Eur J Paediatr Dent. 2011;12(4):220-4.
169. Hart TC, Corby PM, Hauskrecht M, Hee Ryu O, Pelikan R, Valko M, et al. Identification of microbial and proteomic biomarkers in early childhood caries. Int J Dent. 2011;2011:196721.
170. Kawashita Y, Kitamura M, Saito T. Early childhood caries. Int J Dent. 2011;2011:725320.
171. Lindemeyer RG, Satpute NS, Katz SH. Evaluation of bronchial asthma as risk factor for early childhood caries. N Y State Dent J. 2011;77(6):18-21.
172. Mathur A, Mathur A, Jain M, Bhandari S, Choudhary S, Prabu D, et al. Influence of feeding habits on early childhood caries(ECC) with in primary dentition in India. Pediatric Dent J. 2011;21(2):101-6.
173. Zhou Y, Lin HC, Lo EC, Wong MC. Risk indicators for early childhood caries in 2-year-old children in southern China. Aust Dent J. 2011;56(1):33-9.
174. Zhou Q, Qin X, Qin MAN, Ge L. Genotypic diversity of Streptococcus mutans and Streptococcus sobrinus in 3–4-year-old children with severe caries or without caries. Int J Paediatr Dent. 2011;21(6):422-31.
175. Elfrink ME, Schuller AA, Veerkamp JS, Poorterman JH, Moll HA, ten Cate BJ. Factors increasing the caries risk of second primary molars in 5-year-old Dutch children. Int J Paediatr Dent. 2010;20(2):151-7.
176. Johansson I, Holgerson PL, Kressin NR, Nunn ME, Tanner AC. Snacking habits and caries in young children. Caries Res. 2010;44(5):421-30.
177. Kanasi E, Dewhirst FE, Chalmers NI, Kent R, Jr., Moore A, Hughes CV, et al. Clonal analysis of the microbiota of severe early childhood caries. Caries Res. 2010;44(5):485-97.
178. Parisotto TM, Steiner-Oliveira C, Duque C, Peres RC, Rodrigues LK, Nobre-dos-Santos M. Relationship among microbiological composition and presence of dental plaque, sugar exposure, social factors and different stages of early childhood caries. Arch Oral Biol. 2010;55(5):365-73.
179. Petti S. Why guidelines for early childhood caries prevention could be ineffective amongst children at high risk. J Dent. 2010;38(12):946-55.
180. Tuli A, Singh A. Early childhood caries and oral rehabilitation: a treatment quandary. Eur J Paediatr Dent. 2010;11(4):181-4.
181. Adeniyi AA, Ogunbodede EO, Jeboda SO, Folayan MO. Do maternal factors influence the dental health status of Nigerian pre - school children? Int J Paediatr Dent. 2009;19(6):448-54.
182. Alaki SM, Burt BA, Garetz SL. The association between antibiotics usage in early childhood and early childhood caries. Pediatr Dent. 2009;31(1):31-7.
183. Irigoyen-Camacho ME, Sanchez-Perez L, Garcia-Perez A, Zepeda-Zepeda MA. Relationship between severe early childhood caries, mother's oral health and mutans streptococci in a low-income group: changes from 1996 to 2007. J Clin Pediatr Dent. 2009;33(3):241-6.
184. Choi EJ, Lee SH, Kim YJ. Quantitative real - time polymerase chain reaction for Streptococcus mutans and Streptococcus sobrinus in dental plaque samples and its association with early childhood caries. Int J Paediatr Dent. 2009;19(2):141-7.
185. Jigjid B, Ueno M, Shinada K, Kawaguchi Y. Early childhood caries and related risk factors in Mongolian children. Community Dent Health. 2009;26(2):121-8.
186. Nunn ME, Braunstein NS, Krall Kaye EA, Dietrich T, Garcia RI, Henshaw MM. Healthy eating index is a predictor of early childhood caries. J Dent Res. 2009;88(4):361-6.

187. Nunn ME, Dietrich T, Singh HK, Henshaw MM, Kressin NR. Prevalence of early childhood caries among very young urban Boston children compared with US children. J Public Health Dent. 2009;69 (3):156-62.
188. Uribe S. Early childhood caries - risk factors. Evid Based Dent. 2009;10(2):37-8.
189. Cogulu D, Ersin NK, Uzel A, Eronat N, Aksit S. A long-term effect of caries-related factors in initially caries-free children. Int J Paediatr Dent. 2008;18 (5):361-7.
190. Alaki SM, Burt BA, Garetz SL. Middle ear and respiratory infections in early childhood and their association with early childhood caries. Pediatr Dent. 2008;30(2):105-10.
191. Declerck D, Leroy R, Martens L, Lesaffre E, Garcia - Zattera MJ, Vanden Broucke S, et al. Factors associated with prevalence and severity of caries experience in preschool children. Community Dent Oral Epidemiol. 2008;36(2):168-78.
192. Mohebbi SZ, Virtanen JI, Vahid-Golpayegani M, Vehkalahti MM. Feeding habits as determinants of early childhood caries in a population where prolonged breastfeeding is the norm. Community Dent Oral Epidemiol. 2008;36(4):363-9.
193. Warren JJ, Weber-Gasparoni K, Marshall TA, Drake DR, Dehkordi-Vakil F, Kolker JL, et al. Factors associated with dental caries experience in 1-year-old children. J Publ Health Dent. 2008;68(2):70-5.
194. Du M, Luo Y, Zeng X, Alkhatib N, Bedi R. Caries in preschool children and its risk factors in 2 provinces in China. Quintessence Int. 2007;38(2):143-51.
195. Ferreira SH, Beria JU, Kramer PF, Feldens EG, Feldens CA. Dental caries in 0- to 5-year-old Brazilian children: prevalence, severity, and associated factors. Int J Paediatr Dent. 2007;17(4):289-96.
196. Kramer MS, Vanilovich I, Matush L, Bogdanovich N, Zhang X, Shishko G, et al. The effect of prolonged and exclusive breast-feeding on dental caries in early school-age children: new evidence from a large randomized trial. Caries Res. 2007; 4 1 (6):484-8.
197. Olak J, Mandar R, Karjalainen S, Soderling E, Saag M. Dental health and oral mutans streptococci in 2-4-year-old Estonian children. Int J Paediatr Dent. 2007;17(2):92-7.
198. Schroth RJ, Cheba V. Determining the prevalence and risk factors for early childhood caries in a community dental health clinic. Pediatr Dent. 2007;29(5):387-96.
199. Tiberia MJ, Milnes AR, Feigal RJ, Morley KR, Richardson DS, Croft WG, et al. Risk factors for early childhood caries in Canadian preschool children seeking care. Pediatr Dent. 2007;29(3):201-8.
200. de Carvalho FG, Silva DS, Hebling J, Spolidorio LC, Spolidorio DM. Presence of mutans streptococci and Candida spp. in dental plaque/dentine of carious teeth and early childhood caries. Arch Oral Biol. 2006;51(11):1024-8.
201. Hallett KB, O'Rourke PK. Pattern and severity of early childhood caries. Community Dent Oral Epidemiol. 2006;34(1):25-35.
202. Law V, Seow WK. A longitudinal controlled study of factors associated with mutans streptococci infection and caries lesion initiation in children 21 to 72 months old. Pediatr Dent. 2006;28(1):58-65.
203. Psoter WJ, Pendrys DG, Morse DE, Zhang H, Mayne ST. Associations of ethnicity/race and socioeconomic status with early childhood caries patterns. J Public Health Dent. 2006;66(1):23-9.
204. Tsai AI, Chen CY, Li LA, Hsiang CL, Hsu KH. Risk indicators for early childhood caries in Taiwan. Community Dent Oral Epidemiol. 2006;34(6):437-45.
205. Nomura Y, Tsuge S, Hayashi M, Sasaki M, Yamauchi T, Ueda N, et al. A survey on the risk factors for the prevalence of dental caries among preschool children in Japan. Pediatr Dent J. 2004;14(1):79-85.
206. Rosenblatt A, Zarzar P. Breast-feeding and early childhood caries: an assessment among Brazilian infants. Int J Paediatr Dent. 2004;14(6):439-45.
207. Stevens A, Freeman R. The role of the mother-child interaction as a factor in nursing caries (ECC): a preliminary communication. Eur J Paediatr Dent. 2004;5(2):81-5.

208. Vachirarojpisan T, Shinada K, Kawaguchi Y, Laungwechakan P, Somkote T, Detsomboonrat P. Early childhood caries in children aged 6-19 months. Community Dent Oral Epidemiol. 2004;32 (2):133-42.

209. Ismail AI. Determinants of health in children and the problem of early childhood caries. Pediatr Dent. 2003;25(4):328-33.

210. Jin BH, Ma DS, Moon HS, Paik DI, Hahn SH, Horowitz AM. Early childhood caries: prevalence and risk factors in Seoul, Korea. J Public Health Dent. 2003;63(3):183-8.

211. Jose B, King NM. Early childhood caries lesions in preschool children in Kerala, India. Pediatr Dent. 2003;25(6):594-600.

212. Chan SC, Tsai JS, King NM. Feeding and oral hygiene habits of preschool children in Hong Kong and their caregivers' dental knowledge and attitudes. Int J Paediatr Dent. 2002;12(5):322-31.

213. Rosenblatt A, Zarzar P. The prevalence of early childhood caries in 12- to 36-month-old children in Recife, Brazil. J Dent Child. 2002;69(3):319-24, 236.

214. Tinanoff N, Kanellis MJ, Vargas CM. Current understanding of the epidemiology mechanisms, and prevention of dental caries in preschool children. Pediatr Dent. 2002;24(6):543-51.

215. Maciel SM, Marcenes W, Sheiham A. The relationship between sweetness preference, levels of salivary mutans streptococci and caries experience in Brazilian pre-school children. Int J Paediatr Dent. 2001;11(2):123-30.

216. Ansai T, Tahara A, Ikeda M, Katoh Y, Miyazaki H, Takehara T. Influence of colonization with mutans streptococci on caries risk in Japanese preschool children: 24 month survival analysis. Pediatr Dent. 2000;22(5):377-80.

217. Rodrigues CS, Sheiham A. The relationships between dietary guidelines, sugar intake and caries in primary teeth in low income Brazilian 3-year-olds: a longitudinal study. Int J Paediatr Dent. 2000;10 (1):47-55.

218. Tinanoff N, Palmer CA. Dietary determinants of dental caries and dietary recommendations for preschool children. J Public Health Dent. 2000;60 (3):197-206; discussion 7-9.

219. Oulis CJ, Berdouses ED, Vadiakas G, Lygidakis NA. Feeding practices of Greek children with and without nursing caries. Pediatr Dent. 1999;21(7):409-16.

220. Bowen WH. Response to Seow: biological mechanisms of early childhood caries. Community Dent Oral Epidemiol. 1998;26(1 Suppl):28-31.

221. Davies GN. Early childhood caries — a synopsis. Community Dent Oral Epidemiol. 1998;26(Suppl1):106-16.

222. Reisine S, Douglass JM. Psychosocial and behavioral issues in early childhood caries. Community Dent Oral Epidemiol. 1998;26(Suppl1):32-44.

223. Tinanoff N. Introduction to the Early Childhood Caries Conference: initial description and current understanding. Community Dent Oral Epidemiol. 1998;26(Suppl1):5-7.

224. Del Valle LL, Velazquez - Quintana Y, Weinstein P, Domoto P, Leroux B. Early childhood caries and risk factors in rural Puerto Rican children. J Dent Child. 1998;65(2):132-5.

225. Peretz B, Kafka I. Baby bottle tooth decay and complications during pregnancy and delivery. Pediatr Dent. 1997;19(1):34-6.

226. Tinanoff N, O'Sullivan DM. Early childhood caries: overview and recent findings. Pediatr Dent. 1997;19 (1):12-6.

227. Todd RV, Durward CS, Chot C, So PK, Im P. The dental caries experience, oral hygiene and dietary practices of preschool children of factory workers in Phnom Penh, Cambodia. Int J Paediatr Dent. 1994;4 (3):173-8.

Oral health promotion and prevention of Early Childhood Caries

Chantana Ungchusak[1]

[1]Department of Health, Ministry of Public Health, Thailand

Abstract

Dental caries is a common childhood chronic disease which affects not only oral health of children but also their quality of life and their families. This paper reviewed the effectiveness of various preventive measures, categorized as primary, secondary and tertiary prevention. Primary prevention includes oral health education, tooth-brushing with fluoridated toothpaste, water fluoridation, fluoridated milk, and dietary control. Systematic reviews showed that effectiveness of simple health education for the prevention of ECC is limited. However, health education in conjunction with motivational intervention, active hands-on training, regular home visit, or with professional preventive programmes showed some promise results. Educational programmes that integrated with other health issues were also found more effective than simple oral health education alone. For fluoride strategies, water fluoridation is accepted as a high cost-effectiveness measure and most equitable method in dental health across social classes. Fluoridated milk, when provide before the age of 4 years, showed caries preventive effect on primary teeth. There is also evidence from systematic reviews and meta-analysis that tooth brushing with fluoridated toothpaste at least 1,000 ppm fluoride concentration, as home care intervention or school programs, is a cost effective way in reducing dental caries for young children. Sugar is a common risk to a number of other non-communicable diseases. The 'common risk approach', by multidisciplinary collaboration, as well as food policy development to reduce sugar consumption, is necessary. Fluoride varnish, as secondary prevention, can decrease caries incidence in early childhood. 10% providone iodine has been shown to provide some benefit to control of microbial colonization after treatment for severe ECC but for a limited period of time. Filling decayed teeth can be considered as tertiary prevention. The benefits of restoration not only help delay the new colonization of microorganism, but also enhance the healthy ecology of mouth and good nutrition of children.

Keywords

Early childhood caries, tooth decay in young children, dental caries in young children, prevention of Early Childhood Caries, Oral health promotion of early childhood caries

Introduction

Dental caries is a preventable disease and can be stopped or reversed during the early stages of caries development. Although dental caries in permanent teeth of school children and adults can be controlled to some extent, many reviews have shown that the prevalence of early childhood caries (ECC) in young children is generally high. Most young children do not have access to dental care, so that many decayed teeth are left untreated. This problem of ECC can impact on both oral health and the general health of children, such as their nutrition, their growth and development, their quality of life and adversely affect the cost of general health system.

This literature review is aimed to gather and update knowledge on the effectiveness of various measures to control and prevent tooth decay in young children. The review includes papers published during the years 1998 to 2015, and these are divided into three categories - primary, secondary and tertiary prevention - corresponding to different phases in the development and control of the disease.

Method

Literature to inform this review of aspects of Early Childhood Caries was obtained in several ways. First, an electronic internet search was made through PubMed and ScienceDirect databases. The primary search term was 'early childhood caries'. Other keywords included tooth decay in young children, dental caries in young children, nursing caries. Other associated terms used in the search included: diagnosis, criteria, epidemiology, prevalence, aetiology, risk factor, prevention, treatment and oral health related quality of life. Eligible studies were included when they met the following criteria: (1) articles in English providing relevant information within the time period 1990 to 2015; (2) presenting evidence relevant to ECC according to the defined themes: epidemiology, aetiology, prevention and treatment; (3) considers dental caries or sequelae in early childhood. Concerning the exclusion criteria, studies were excluded from the review if they focused on either: (1) concerned with other age-groups or other diseases, (2) studies published in languages other than English. A total of 417 articles were identified through database searching; duplicates and references irrelevant to ECC were removed, reducing this list by about one third. Two conference books relevant to the situation in Asian countries were also included.

Second, nine journals were searched by hand: International Journal of Paediatric Dentistry, European Journal of Paediatric Dentistry, Pediatric Dentistry, Journal of Dentistry for Children, Journal Clinical Pediatric Dentistry, Community Dentistry Oral Epidemiology, Community Dental Health, Caries Research, Journal of Public Health Dentistry. How far back the hand-searches were made, depended on the journal: for most journals it covered 2000 to 2015, while for International Journal of Paediatric Dentistry, the search extended back to 1990.

Third, some back-tracking from the reference lists attached to publications so far discovered was carried out to identify any remaining key articles. This resulted in a database of 380 references on all aspects of ECC, covering the years 1993 to 2016. Out of this database, 71 publications were relevant to this review of oral health promotion and the prevention of ECC.

Results and discussion

Primary prevention

The aim of primary prevention is to keep healthy children with healthy teeth. The incidence of ECC is controlled by targeting specific causes and risk factors. These measures include oral health education, tooth-brushing with fluoridated toothpaste, fluoridation as a community-based intervention, and dietary control. These will be considered in turn.

Oral health education

The oral health of young children depends on their parents' or caregivers' knowledge, attitudes, behavior, and the family lifestyle. For example, parents' beliefs influence the likelihood of their children brushing their teeth twice a day,[1] and parents' dental health habits also influence their children's oral health.[2]

The goal for health education is to increase the knowledge and healthy practices of parents or care givers about tooth-brushing, and also to improve dietary habits so as to improve their own oral health and their performance in looking after the health of their children. However, the effectiveness of health education for the prevention of ECC is limited,[3,4] according to this review of literature, and it can be concluded that education has a modest impact on improvement of dietary habits, and suggested that education should be provided in conjunction with early screening and professional preventive programmes. Castilho *et al.,*[2] in a systematic review, also confirmed the important of health education but suggested that oral health education programmes should pay attention, not only to the child's oral health, but also to their quality of life. The programmes should involve the entire family - their lifestyles and their oral health habits.

Many studies have tried to improve the effectiveness of programmes designed to educate parents and to change their attitudes and practices for the oral care of their young children. These have included either: the 'motivational intervention technique,[5,6] the 'autonomy-supportive psycho-educational technique,[7,8] tailored educational intervention,[9] a participatory dental health education programme,[10] or the free distribution of toothpaste and toothbrush together with an oral health education programme.[11] The varied nature of these interventions is shown in the studies listed in Table 1. From these several studies, some common results emerge:

(1) Health education with a neutral message (delivered for example by brochures) cannot make any positive change;

(2) Health education using the motivational intervention technique showed promising results in knowledge and behavioral change, but with an inconsistent effect for dental caries.

(3) Health education together with regular motivation or regular home visits can reduce dental caries and caries risk factors in children significantly.

(4) Multiple interventions, such as health education plus free distribution of toothpaste and toothbrushes, health education plus hands-on tooth-brushing practice, showed promising positive results in preventing Early Childhood Caries.

Many studies have indicated that to make oral preventive practices, such as tooth-brushing, sustainable for young children, families and communities, follow-ups are necessary and messages should be reinforced regularly. Home visits by dental personnel showed very good results in terms of monitoring, counseling, providing guidance, and even can provide some preventive dental services such as fluoride varnish application. In addition, dental personnel can learn and understand the social context of children and families.[12,13] Analysis of results of a preventive programme in Thailand, where health education was provided with active training by a 'hands-on' technique and regular home visits every 4 months, showed a significant reduction in dental caries when compared with the control group within one year ($P<0.001$).[14]

However, a programme of home visits is a heavy load for dental personnel in terms of cost and time, and telephone contact may be another choice with compatible effectiveness.[15]

Table 1 Summary of health education intervention

Authors, with year	Methods / content of the intervention	Main findings
Harrison *et al*.[5] Model Motivational Interviewing	240 children 6 to 18 months old were randomly assigned to either the study (MI + pamphlet +video +2 counseling sessions + 4 follow up telephone call) or control group (traditional health education; pamphlet+ video). Children had a dental exam, and their mothers completed questionnaires at baseline and 1, 2 years post intervention.	The MI group had about a 46% lower rate of dmfs at 2 years than did control children. Similar treatment effects were obtained from models that included white spot carious lesions.
Ismail *et al*.[9] Model Motivational Interviewing with tailored educational intervention	This randomized longitudinal study included 1,021 children (0–5 years) and their caregivers. The families were examined at baseline in 2002–2004, 2004–2005 and 2007. The families were randomized into two educational groups, intervention (MI + DVD + dialogue + booster telephone call within 6 months), and control group (DVD-only). Both caregivers and the children were interviewed and examined after 2 years of intervention (Wave III: 2007).	After 6-month of follow-up, caregivers receiving MI + DVD were more likely to report checking the child for 'pre-cavities' and making sure the child brushes at bedtime. Evaluation of the 2 years final outcomes found that MI intervention may change some reported oral health behaviours, but failed to reduce the number of new untreated carious lesions.
Borrelli *et al*. Model Motivational Interviewing	This paper presents a meta-analysis of parent-involved MI to improve paediatric health behaviour and health outcomes. Twenty-five studies (with 5,130 participants) were included. Three studies included oral health.	MI was associated with significant improvements in health behaviours (oral health, diet, physical activity, reduced screen time, smoking cessation, second hand smoke) and reduction in body mass index. Results suggest that MI may also outperform comparison groups in terms of dental caries, but more studies are needed.
Naidu R *et al*. Model Motivational Interviewing	This study included a cluster randomized controlled trial and semi-structured focus groups. Parents and caregivers in the test-group (n = 25) received a talk on dental health using MI approach + two telephone call follow-ups, and the control-group (n = 54) received a talk using traditional DHE. Both groups received written dental health information. Participants in the test group were also invited to take part in a focus group to share their views on the dental health talk.	At four month follow-up, knowledge items increased in both the test (DHE + MI) and control (DHE) groups (($p < 0.05$). In the test groups there were increases in mean child tooth-brushing frequency and a reduction in oral health fatalism ($p < 0.05$). Findings from focus groups suggested that MI talk and telephone follow-up were well accepted and helpful in supporting parent and caregiver efforts to improve oral health practices for their children.

Table 1 Summary of health education intervention (Continued)

Authors, with year	Methods / content of the intervention	Main findings
Weber-Gasparoni K *et al.* (Part 1)[7] Model Self-determination theory : Psycho-educational intervention	415, 12- to 49-month-old children and their mothers were included in the study. 283 in the intervention group received videotaped message, and were motivated for their autonomy feeling, their internalization of video, and their own expected outcome. 132 in control group received same content of message via brochure. Mothers completed questionnaires at baseline and after 6 months follow up regarding their child's dietary/oral hygiene habits.	Relative to their baseline scores, the intervention group showed a greater increase in knowledge and behavioural intentions than the control group, both at one-month (P=.002) and six-month follow-ups (P<.001). However, knowledge and behavioural intention levels at six-month follow-up did not differ significantly from those at one-month follow-up.
Weber-Gasparoni K *et al.* (Part 2)[8]		Significantly more positive changes were observed for dietary/oral knowledge and hygiene behaviours among the intervention group at one- and six-month follow-ups than for the controls.
Plutzer and Spencer Model Anticipatory guidance during pregnancy	A randomized controlled trial provided anticipatory guidance to expectant mothers during their pregnancy period, and later when the child reached 6 and 12 months of age.	Oral examination of the children at 20±2.5 months found that the incidence of severe-ECC in the test group was 1.7%, significantly lower (P < 0.001) compared with the control group of 9.6%.
Plutzer *et al*. Model Home visit	The evaluation of the above study was repeated when the children were 6-7 years old.	Caries prevalence was still significantly different - 33% in the study group and 42% in the control group. They concluded that providing new mothers with guidance on caries prevention can help to reduce ECC and the effect can be sustained up to school age.
Kowash *et al.*[12] Model Home visit	A randomly selected cohort of 228 children were divided into 5 groups: the 4 study groups (A to D) received different topics of dental health education through regular home visits every 3 months for the first 2 years and twice a year in the third year of the study. The control group (E) received no DHE and were never visited but examined. All children and mothers were examined for caries and oral hygiene at 3 years.	It was found that the differences in caries levels and caries risk factors between study and control groups were statistically significant (P < 0.001). Mothers in the study group also showed an improvement in their own levels of gingivitis, debris and calculus scores by the second and third examinations (P < 0.001).

Table 1 Summary of health education intervention (Continued)

Authors, with year	Methods / content of the intervention	Main findings
Feldens *et al*.[13] Model Home visit	A randomized field trial: intervention group received home visits for advising mothers about breast-feeding and weaning 10 days after the child's birth, monthly up to 6 months, at 8, 10 and 12 months, based on the 'Ten Steps for Healthy Feeding'. Feeding behaviours and dental caries of the children in both groups were collected at 6 and 12 months.	The results showed that 10.2% of the children in the intervention group had caries compared with 18.3% in the control. The intervention group had significantly longer duration of exclusive breast-feeding, and later introduction of sugary food and drink. It was concluded that home visits for dietary advice appear to help in reducing dental caries in infants.
Thanakanjanaphakdee and Trairatvorakul[14] Model 'Hands on' training with home visit	Health education was provided to care givers of 9-18 months old children, together with active training by a 'hands on' technique, and regular home visits every 4 months by local health volunteers	One year follow-up showed that this programme reduced the incidence of dental caries 2.5 times compared with the control group within the one year. The parents in the experimental group improved their brushing behaviour for children (P<0.05), while other behaviours, such as feeding habits, were not changed. The percent caries-free young children in the control group was 6.5% compared with 64.3% in the experiment group (P<0.001)
Plonka *et al*.[15] Model Home visit and Telephone contact	A longitudinal study of 325 children, mean age of 42 days, were randomly assigned to receive either home visit or telephone call, 3 contacts at 6 monthly, compared to control group.. At 24 months, all groups were orally examined for ECC and colonization of mutans streptococci and lactobacilli.	The caries prevalence in the HV, TC and control groups were 1.5%, 6.8% and 22.5%, respectively. (P= 0.5 to < 0.001). The colonization of mutans streptococcus was also different between the three groups (P = 0.02). The authors concluded that home visits and telephone contacts conducted 6 monthly from birth are effective in reducing ECC prevalence at the age of 24 months.
Vachirarojpisan *et al*.[10] Model Participatory dental health education	A one-year intervention programme among 520 mothers/ caregivers of 6-19 month-old children. Intervention included small group discussion with active involvement in the intervention group, and the national teaching dental health education programme in the control group.	Percent of subjects using a toothbrush and brushing with fluoride toothpaste was 93% and 87% respectively, in the intervention group, significantly higher (p<0.01) than the control group (73% and 58%). Eating behaviours appeared the same in both groups. The net cavity increment was 3.5 (±3.4) teeth in the intervention and 3.2 (±3.5) in the control group (NS).

Table 1 Summary of health education intervention (Continued)

Authors, with year	Methods / content of the intervention	Main findings
Azevedo *et al*. Model Pamphlet and verbal explanation	To evaluate the impact of an early educational intervention on ECC prevention, the study group (SG) comprised 271 children aged 0-12 months and their mothers, received oral health instructions from a pamphlet and by verbal explanation, while the control (CG; n = 251) received oral health instructions from a pamphlet only. The children were examined for caries status (cavity and/or white spot lesion) of maxillary anterior teeth, labial surface, after a one-year intervention.	The prevalence of caries was 12.9% in the SG and 17.9% in the CG. The odds of caries was 80% higher in the CG than in the SG (p = 0.037).
Azevedo *et al*. Model Pamphlet and verbal explanation	To evaluate the impact of an early educational intervention on ECC prevention, the study group (SG) comprised 271 children aged 0-12 months and their mothers, received oral health instructions from a pamphlet and by verbal explanation, while the control (CG; n = 251) received oral health instructions from a pamphlet only. The children were examined for caries status (cavity and/or white spot lesion) of maxillary anterior teeth, labial surface, after a one-year intervention.	The prevalence of caries was 12.9% in the SG and 17.9% in the CG. The odds of caries was 80% higher in the CG than in the SG (p = 0.037).

Tooth-brushing with fluoridated toothpaste

The most important way that family members can help to control plaque in infants and young children is tooth-brushing with fluoridated toothpaste twice daily at home. The lack of tooth-brushing, or brushing inefficiently, has been shown to be related to rampant caries development in the primary teeth,[16] while regularly brushing the teeth from birth to 5 years of age, reduced the occurrence of dental caries.[17] It is recommended that using of fluoride toothpaste should begin with the eruption of the first tooth.[18] A systematic review in 2014,[19] which included 17 studies, found that for children younger than 6 years, brushing under supervision with 1,000 to 1,500 ppm fluoride concentration toothpaste is effective in caries control when measured by dmfs and dmft. For the studies in which participants used toothpastes with less than 1,000 ppm fluoride, the findings were less consistent compared with those in control groups not using fluoride toothpastes. A systematic review to determine the efficacy of manual tooth-brushing in permanent teeth found that brushing led to a 42% reduction in plaque score, on average.[20] Sub-analysis of brushing duration revealed that 1 and 2 minutes brushing resulted in a mean reduction of 27% and 41%, respectively.

Tooth-brushing programmes may be organized effectively in a community formal setting, such as day - care centres or kindergarten schools. Schwarz *et al*.[21] demonstrated the long-term effects of daily tooth-brushing with fluoride toothpaste in 3-6 years old Chinese children attending kindergartens (test group) (control group). In the test group, teacher-supervised

compared with children of the same age who had no organized preventive programme tooth-brushing with 1,000 ppm MFP toothpaste in addition to oral health education activities. At baseline, the mean dmfs was 4.8 in the test group and 6.5 in the control group (NS). After three years, the caries increment was 6.2 and 8.4 in the test and control groups, respectively (P<0.05). It was concluded that a daily tooth-brushing with limited involvement of professional staff was feasible in a Chinese kinder-garten and that caries development was significantly slowed in the test children. Curnow *et al* [22] compared the rate of dental caries in 5 year-old children, where the study group brushed their teeth with fluoridated toothpaste every day at school under the supervision of volunteer mothers. The control group received only dental check - ups every six months. After two years of implementation, it was found that the study group had significantly lower dmft (0.81) compared with 1.19 dmft in the control group.

Brushing twice daily with fluoridated toothpaste is the most important primary prevention for ECC as part of self-care. A systematic review in 2003 [23] reported results of investigations into the caries preventive effect of fluoride toothpastes in primary dentition and young permanent dentition, with 2.25 to 7 years follow-up studies. The results revealed strong evidence (level 1) (i) for the caries preventive effect of daily use of fluoride toothpaste compared with a placebo in the young permanent dentition (Preventive Fraction 25%), (ii) that toothpastes with 1,500 ppm of fluoride had a superior preventive effect compared with standard dentifrices with 1,000 ppm F in the young permanent dentition (PF 10%), and (iii) that higher caries reductions were recorded in studies with supervised tooth-brushing compared with non-supervised tooth brushing (PF 23%). However, incomplete evidence (level 4) was found regarding the effect of fluoride toothpaste in the primary dentition. A review of 75 studies of interventions for caries prevention in children and adolescents with age 16 years or less found that, when compared with placebo, toothpaste with fluoride concentrations of 1,000 to 1,500 ppmF can provided 22% caries reduction compared with 36% for toothpastes containing 2,400 to 2,800 ppmF. The effectiveness of toothpastes containing 250 to 550 ppmF was not statistically significantly different from toothpastes without fluoride.[24]

According to AAPD recommendations, all children should have twice-daily brushing with fluoridated toothpaste from the time of eruption of the first teeth. To prevent any undesirable effects from swallowing dentifrice containing a high concentration of fluoride by young children, AAPD has recommended that: "A 'smear' or 'rice-size' amount of fluoridated toothpaste (approximately 0.1 mg fluoride) should be used for children less than three years of age. A 'pea-size' amount of fluoridated toothpaste (approximately 0.25 mg fluoride) is appropriate for children aged three to six".[25,26]

Water fluoridation

The first water fluoridation programme was instituted in United States of America in 1945 and this public health measure is now implemented widely in many countries. Evaluations have shown that caries levels were 21 percent lower in the primary dentition and 25 percent lower in the permanent dentition in fluoridated communities than in nonfluoridated communities[27] A Cochrane review in 2015[28] found that using water fluoridation resulted in children having 35% fewer dmft (primary teeth) and 26% fewer DMFT in the permanent dentition. The review also showed a 15% increase in children

[A] The Workshop on 'Effective use of Fluoride in Asia' was held in Thailand during March 22-24, 2011, under the co-organized by The Dental Association of Thailand and Faculty of Dentistry, Thammasat University. The co-sponsored were WHO, FDI, and IADR.

children with a caries-free permanent dentition. Petersen *et al*.[29] summarized a key conclusion from the 'Workshop on effective use of fluoride in Asia'[A] that water fluoridation is a most effective and equitable strategy for prevention of dental caries. However, currently there is a wide variety of other fluoride delivery methods, which may be useful if some groups of the population are more concerned about possible undesirable health impacts from fluoride. Thus, before implementing a water fluoridation programme, countries need to prepare a systematic management programme which would include a feasibility study, an epidemiological surveillance system, and community education, strengthen the health system research and arrange for technical support.

Milk fluoridation

The fluoridation of milk is another kind of public health measure for caries prevention. Currently milk fluoridation programmes exist in several countries including Thailand, Chile, the Russian Federation, and the UK. This method is appropriate in the schools, kindergartens or day-care centres that already have a system of providing milk regularly to the children. Bánóczy *et al*.[30] reviewed the effectiveness of milk fluoridation: from the 20 reports of 15 studies carried out in 10 countries, eight studies showed a caries preventive effect in primary teeth and ten studies in permanent teeth. Two studies in United Kingdom showed no effect in either dentition. There is also evidence that beginning to drink fluoridated milk at an early age (before the age of 4 years) was essential to obtain a caries preventive effect in primary teeth .[31,32] A Cochrane review in 2015[33] confirmed that fluoridated milk may be beneficial to 3-year-old school children, substantially reducing the formation of caries cavities in primary teeth. Petersen *et al.*[34] evaluated the clinical effectiveness of a 5 year community milk fluoridation programme in Bulgaria. The result showed that, for primary teeth, caries increments were 46% ($p<0.001$) and 30% ($p<0.01$) lower in the fluoridated milk group compared with two non-fluoridated milk reference groups, respectively. For permanent teeth those reductions were 61% and 53% ($p<0.001$).

Dietary control

Many research reports have shown clear evidence that sugar consumption is one of the main aetiological factors for dental caries, both in terms of the amount and the frequency of sugars consumed. For young children, the use of a baby bottle filled with sweetened milk or beverages has been found to be associated with high dental caries experience.[16,17] In a review of literature, Rugg-Gunn and Woodward[35] concluded that milk and milk products, if unsweetened by added sugars, are safe and possibly beneficial for teeth. For young children, the risk of dental caries from sugar consumption increases with certain feeding habits, such as a feeding bottle with added sugars used for night-feeding, or feeding at will.

WHO and most national organizations recommend exclusive breast-feeding (EBF) for at least 6 months. To assess the impact of EBF on early childhood caries, a cluster randomized trial was done to compare dental caries of an EBF group and a control group at 5 years of age. The study showed no impact of EBF on early childhood caries when compared with the control group.[36] A systematic review and meta-analysis also confirmed that breast-fed children were significantly less affected by dental caries than bottle-fed children. The researchers concluded that breast-feeding can protect against early childhood caries.[37]

Health education alone seems unlikely to lead to behavioral change in mothers and children regarding dietary habits. In addition, more and more research shows the association between high sugar consumption and non-communicable diseases (NCDs), particularly overweight/obesity and diabetes. Thus, high sugars consumption is clearly with caries-free primary teeth and 14% increase in identified as a 'common risk factor', and the 'common risk approach',

by multidisciplinary collaboration is recommended. Sugar consumption is strongly linked to 'lifestyle' that is influenced by an unhealthy environment, which includes strong marketing of foods/drinks, easy access for all to food/drink with high sugar content, food marketing for children in schools, etc. This environment strongly influences people's behaviour. Thus, health education alone may not be enough to strengthen self-esteem and change people's behaviour - food policy development to reduce sugar consumption, particularly relevant for infants and young children, is also necessary.[38] However, more evidence-based research is required to evaluate the effectiveness of those approaches in terms of oral health outcomes.

To control the increasing trend of NCDs and dental caries, WHO recommends that free (added) sugars should remain below 10% of energy intake, and consumption of foods/drinks containing free sugars should be limited to a maximum of four times per day.[39] In 2015, this recommendation has been emphasized as a "STRONG" recommendation, while the new conditional recommendation suggests a further reduction to less than 5% of total daily energy intake.[40]

In some countries/communities, there are proposals for the introduction of healthy policies to the government and public. For example, in Thailand, the Ministerial Regulation (MR) number 286, since 2004 inhibits the addition of sugar to 'follow-on' formula milk for young children, and the MR number 305 which concerns labeling of the sugar, fat, sodium and energy content in certain kinds of Ready-to-Eat Foods, since 2007. Many countries have proposed school policies to control the sale and consumption of high sugar soft drinks and high calorie foods/snacks sold in school.

Secondary prevention

Secondary prevention aims to reduce or stop the disease at early stage through early diagnosis and preventive measure application. This level of prevention includes early detection, fluoride varnish and chemical control of microbial colonization by 10% providone iodine.

Early detection

The purpose of early detection is to screen for oral hygiene status as well as to detect white spot carious lesions in young children in order to provide early preventive intervention. Dental caries in infants often starts with the accumulation of plaque on the teeth and white lesions in the labial cervical areas of the maxillary anterior primary teeth. This is a strong predictor of future caries development. Therefore, the technique of "Lift the lip" to examine for visible plaque accumulation, any white lesions or frank dental caries on the four upper front teeth is recommended for dental caries screening.

To make the early detection activities appropriate to the health system, it is recommended that this oral screening process should be integrated with the 'well-child care clinic'. The AAPD Guideline on Infant Oral Health Care[26] stated that: 'Every infant should receive an oral health risk assessment from his/her primary health care provider or qualified health care professional by six months of age', and 'Parents should establish a dental home [B] for infants by 12 months of age' for oral examination, tooth-brushing demonstration, and prophylaxis and fluoride varnish treatment if indicated.

[B] Establishing a Dental Home means that a child's oral health care is managed in a comprehensive, continuously accessible, coordinated and family-centered way by a licensed dentist. *(http://www.aapd.org/assets/1/7/DentalHomeNeverTooEarly.pdf)*

Fluoride varnish

Fluoride varnish is a product containing a high concentration of fluoride (5% sodium fluoride) that is applied professionally to the surfaces of teeth, including primary teeth. The purpose of applying fluoride varnish is to arrest and reverse the process of demineralization. Currently, the use of fluoride varnishes to prevent tooth decay in young children is worldwide. Zimmer *et al*.[41] conducted a two-year longitudinal randomized clinical study to evaluate the efficacy of 0.1% fluoride varnishes four times per year, in addition to tooth-brushing and oral hygiene instruction, in the high risk school children. The results showed that the experimental group had 4.0 ± 4.97 increased rates of initial caries while control group had 6.5 ± 5.71 (P<0.001). However, no difference was found when the 'cavitated caries index' was used for evaluation.

The following study, although conducted in older children, illustrates the effect of frequency of application of fluoride varnish. In 2005, Skold *et al*.[42] reported a 3-year randomized controlled trial in school students aged 13-16 years, to evaluate different regimes of applying 5% fluoride varnish to control dental caries in proximal surfaces of teeth. Fluoride varnish applied monthly prevented 76% of caries development, whilst the 6-monthly application of varnish prevented 57% of carious surfaces across all of the populations. In areas with a high risk of dental caries, fluoride varnish of any form showed significantly greater percentage caries reductions compared with a no-varnish group.

Marinho *et al*.[43], in a systematic review of fluoride varnishes together with a meta analysis, found a mean of 33% fewer surfaces with caries in the primary dentition and 46% fewer carious surfaces in the permanent dentition in the children treated with fluoride varnishes compared with those who had received no treatment. They concluded that regular fluoride varnish application 2 to 4 times per year in the primary and permanent dentitions prevents caries development in children. Weintraub *et al*.[44] studied the 2-year effectiveness of fluoride varnishes (5% NaF) two times per year, in addition to counseling, to prevent dental caries in 6 and 44 months-old high-risk children. The study started when the 376 children were cavity-free. They found that fluoride varnishes prevented the incidence of new dental caries 3.8 times (95% CI 1.88-7.58) in the study group compared with the control. This study was undertaken in San Francisco where drinking water is fluoridated. Other studies [45-47] also found positive results after fluoride varnish application in their studies. Fluoride varnish also has been accepted well by parents, compared with other measures.

A cohort study in Thailand [48] compared the application of fluoride varnish four times every six months (when the children were aged 9-12, 18, 24 and 30 months) together with oral hygiene instruction, with a control group who received oral hygiene instruction alone. The 2-year evaluation found that 34% of the study group had dental caries, compared with 48% in control group children (P=0.002). The protective effect of fluoride varnish in caries incidence was 30%. Another two studies, in 2013 and 2015, found that the number of non-cavitated carious lesions was significantly lower in the fluoride varnish group,[49] and a decrease in mean dmft in the fluoride varnish group compared with the non - fluoride varnish group.[50] However, some clinical evaluations of fluoride varnishes found no positive effect or found that the effect of fluoride varnish was no different from brushing with fluoride toothpaste alone.[51-53]

Chemical control of microbial colonization with 10% Povidone Iodine

Early childhood caries (ECC) is closely related to the high number of mutans streptococci, lactobacilli and Candida albicans. The reduction of oral colonization is one of the goals for preventing ECC.

10% Povidone Iodine (PI) consist of 90% aqueous (water), 8.5% polyvinyl pyrrolidone and 1% Iodine. Polyvinyl pyrrolidone acts as a carrier of iodine to cell membranes of bacteria, and also helps to reduce the irritation and staining from iodine. Iodine reacts with the cytoplasm and cytoplasmic membrane of bacteria, providing a bacteriocidal effect within seconds. Through this property, PI is used as a post-operative treatment for severe-ECC after dental surgery to prevent recurrence of new caries.There has been some research to explore the effect of 10% povidone iodine as a chemical control of microbial colonization after treatment of ECC. Simratvir *et al*.[54] compared the effects of application of 10% PI in the reduction of mutans streptococci (MS) and reduction of new carious lesions. PI was applied every three months, for a period of 12 months, to 4 year-old children with severe early childhood caries, after their dental treatment. The results showed that application of 10% PI caused a significant reduction in the rise of MS levels from the baseline after 12 months of treatment and also decreased the relapse of caries in these children compared with the control group. Berkowitz *et al*.[55] *assessed the effect of a single application of 10%* PI *on the number of salivary MS after dental surgery treatment. The samples were 2-5 year-old children with severe early childhood caries. It was found that* the percentages of subjects with at least a 50% reduction in MS level were 85%, 83% and 84% at 30, 60 and 90 days post dental surgery, when compared with baseline *(P < 0.0001).* No new cavitated caries lesion occurred during the first 90 days post dental surgery. *However, at the 12 months follow up examination,* 39% of children had new cavitated caries lesion(s) that required restoration.[56]

In a clinical trial among 2-7 year-old children with severe ECC and treated under general anesthesia, children received topical PI three times every two months during the first 4 months of the study, while the control group did not receive PI. At 6 months post dental surgery, both group had significantly decreased MS counts (P=0.003). At 1 year, 5 out of 8 children in the control group had new caries compared with 2 out of 11 children in the experimental group (P=0.06).[57]

There were two reports regarding the use of 10% povidone iodine in high risk children. Lopez *et al*.[58] reported a study in 12-19 month-old children with high risk of ECC. The experimental group had 10% povidone iodine every 2 months, while the control group had placebo applied to their dentition. The evaluation at 155 days found that 5 of the 16 control subjects and 0 of the 15 experimental subjects had white spot lesion on their four maxillary anterior teeth (P=0.04). Lopez *et al*.[59] also reported a 12-month follow-up trial in 12 to 19 month-old infants; 37 infants in the study group and 44 in the control group. The experimental group had 10% povidone iodine applied every 2 months. They found that 91% of experimental group and 54% of control group were disease-free (no white spot lesion). They concluded that 10% PI every 2 months as a topical antimicrobial therapy, reduced risk for the development of ECC in 12-19 month-old high-risk children.

However, studies have found that povidone iodine may not result in long-term effectiveness. Zhang *et al*.[60] *assessed the effects of a single application of 10%* povidone iodine together with 1.23% acidulated phosphate fluoride *gel application as an adjunct to clinical treatment of children with* severe *early childhood caries. It was found that MS and lactobacilli levels in the* povidone iodine *group were significantly reduced relative to baseline at one hour, three weeks and three months but, after one year, at least 60% of subjects had new caries lesions in each group, and there was no significant difference in caries increment between the two groups.*

In conclusion, use of *10%* povidone iodine has been demonstrated to be effective in reducing bacteria in the mouth. However, most studies are limited in short term of approximately one year.

Tertiary prevention

Filling carious cavities in teeth can be considered tertiary preventive care. The benefits of restoration are not only preventing the progress of disease, but also to enhance healthy ecology of mouth and ensure the good nutrition of the children.

Preventive restorative procedures

Many studies have indicated that most of dental caries in young children is left untreated. Restoration of a cavity can help to reduce accumulation of microorganisms, resulting in good oral health, and enhancing the quality of life of the children. Peretz *et al.*[61] evaluated the microbial flora immediately after treatment for ECC in 44 children. It was found that dental treatment resulted in significantly lower MS counts. Palmer *et al.*[62] reported that the amount of microorganisms was reduced significantly after restorative treatment: the evaluation of mutans streptococci strains before, and six months after this treatment, showed that MS strains fell from 3-7 to 1-2 strains. Another prospective clinical study[63] monitored the oral health of 50 children after comprehensive treatment under general anesthesia. The 12 months follow-up found that plaque and the numbers of mutans streptococci, lactobacilli and yeasts were significantly reduced as a result of treatment (P<0.0001). Never-theless, this effect was not permanent - the number of bacteria and yeasts increased linearly over time (P<0.01) with an odds ratio of 2.2 per year. One third (34%) of the children developed new dentinal lesions within 1 year post-operatively.

The restoration of carious teeth may also improve the nutrition and growth of children. Acs *et al.*[64] compared the percentile weight and percentile growth velocity of children with severe early childhood caries after dental treatment (test subjects) with the caries free children. Prior to dental rehabilitation, test subjects' percentile weight categories were significantly less than the caries free group (P<.001). After comprehensive dental treatment, it was found that the ECC children exhibited significantly increased growth velocities through the follow-up period (P<.001). At the end of the follow-up period (1.58 years for ECC group and 1.36 years for caries free group) there were no statistically significant differences noted in the percentile weight categories of the test and comparison groups.

Currently, the use of glass ionomer restorative material by the 'atraumatic restorative treatment' technique (ART/SMART) may be another choice for restoring primary teeth. This material is a fluoride-releasing material and this may provide an additional benefit in preventing dental caries. A systematic investigation, plus meta-analysis, into survival of ART sealants and restorations, using high-viscosity glass ionomer, reported 2-year survival rates of 93% for single-surface and 62 % for multiple-surface restorations in primary teeth[65]. A randomized control trial was reported which compared atraumatic restorative treatment procedures (ART: Test) against the standard care approach (Control) to treat early childhood caries in 273 children of mean age 3.8 years, in a primary care setting. At the 11.4 month follow-up, it was found that more teeth were filled in the ART group (2.9 ± 2.48) than in the control group (1.5 ± 2.20) (P < 0.0001). The control group also showed a higher risk of referral for specialist care than the ART group (OR 33, 95% CI 10.8–98.4, P < 0.0001). The researchers concluded that the ART approach reduced significantly the likelihood of referral for specialist care, and more children and teeth were provided with treatment[66].

Conclusions

This literature to review the effectiveness of various preventive measures was searched through PubMed, ScienceDirect databases, and searched by hand for the years 1998 to 2015. This review has examined the 71 publications concerned with the prevention of ECC. From these several studies, we found that:

1. The effectiveness of simple health education for the prevention of ECC is limited. However, health education in conjunction with motivational intervention, active hands-on training, regular home visit, educational programmes that integrated with other health issues, or with professional preventive programmes, showed some promise results.

2. Water fluoridation is accepted as a high cost-effectiveness measure and most equitable method in dental health across social classes. Fluoridated milk, when provide before the age of 4 years, showed caries preventive effect on primary teeth. Tooth brushing with fluoridated toothpaste at least 1,000 ppm fluoride concentration, is a cost effective way in reducing dental caries for young children

3. To reduce sugar consumption, the 'common risk approach', by multidisciplinary collaboration, as well as food policy development is necessary.

4 . Fluoride varnish can decrease caries incidence in early childhood particularly in high risk children. 10% providone iodine has been shown to provide some benefit to control of microbial colonization but for a limited period of time.

Filling decayed teeth, considered as tertiary prevention, may help delay the new colonization of microorganism and also enhance the healthy ecology of mouth and good nutrition of children.

References

1. Pine CM, McGoldrick PM, Burnside G, Curnow MM, Chesters RK, Nicholson J, Huntington E. An intervention programme to establish regular toothbrushing: understanding parents' beliefs and motivating children. Int Dent J. 2000;Suppl Creating A Successful:312-23.

2. Castilho AR, Mialhe FL, Barbosa Tde S, Puppin-Rontani RM. Influence of family environment on children's oral health: a systematic review. J Pediatr (Rio J). 2013 Mar-Apr;89(2):116-23. (abstract)

3. Ammari JB, Baqain ZH, Ashley PF. Effects of programs for prevention of early childhood caries. A systematic review. Med Princ Pract. 2007;16(6):437-42.

4. Ismail AI. Prevention of early childhood caries. Community Dent Oral Epidemiol. 1998;26(1 Suppl):49-61

5. Harrison R, Benton T et al. Effect of motivational interviewing on rates of early childhood caries: a randomized trial. Pediatr Dent 2007; 29: 16-2

6. Cascaes AM, Bielemann RM, Clark VL, Barros AJ. Effectiveness of motivational interviewing at improving oral health: a systematic review. Rev Saude Publica. 2014 Feb;48(1):142-53.

7. Weber-Gasparoni K, Reeve J et al. An effective psychoeducational intervention for early childhood caries prevention: part 1. Ped Dent 2013; 35: 241-246.

8. Weber-Gasparoni K, Warren JJ, Reeve J, Drake DR, Kramer KW, Marshall TA, Dawson DV. An effective psychoeducational intervention for early childhood caries prevention: part II. Pediatr Dent. 2013 May-Jun; 3 5 (3):247-51

9. Ismail AI, Ondersma S et al. Evaluation of a brief tailored motivational intervention to prevent early childhood caries. Community Dent Oral Epidemiol. 2011 Oct;39(5):433 – 438

10. Vachirarojpisan T, Shinada K, Kawaguchi Y. The process and outcome of a programme for preventing early childhood caries in Thailand. Community Dent Health. 2005; 22(4): 253 – 259.

11. Sgan-Cohen HD, Mansbach IK, Haver D, Gofin R. Community-oriented oral health promotion for infants in Jerusalem: evaluation of a program trial. J Public Health Dent. 2001 Spring;61(2):107-13.

12. Kowash MB, Pinfield A, Smith J, Curzon ME. Effectiveness on oral health of a long-term health education programme for mothers with young children. Br Dent J. 2000 Feb 26;188(4):201-5.

13. Feldens CA, Vitolo MR, Drachler ML. A randomized trial of the effectiveness of home visits in preventing early childhood caries. Community Dent Oral Epidemiol 2007; 35: 215-223.

14. Thanakanjanaphakdee W and Trairatvorakul C. Effectiveness of Parental Toothbrushing Instruction toward The 1-Year Incremental DMF Rate of 9-18 Month Old Children. J Dent Assoc Thai 2010; 60 (2):82-91

15. Plonka KA, Pukallus ML et al. A controlled, longitudinal study of home visits compared to telephone contacts to prevent early childhood caries. Int J Paediatr Dent. 2013 Jan;23(1):23-31.

16. Petti S, Cairella G. Rampant Early Childhood Dental Decay: an Example from Italy. Journal of Public Health Dentistry 2000;60:3,159-166.

17. Levy S.M., Warren J.J., Broffitt B., Hillis S.L., Kanellis M.J. Fluoride, Beverages and Dental Caries in the Primary Dentition. Caries Res 2003;37:157–165

18. Clark MB, Slayton RL. Fluoride Use in Caries Prevention in the Primary Care Setting. www.pediatrics.org/cgi/doi/10.1542/peds.2014-1699 doi:10.1542/peds.2014-1699 Accepted for publication Jun 9, 2014

19. Wright JT, Hanson N, Ristic H, Whall CW, Estrich CG, Zentz RR, Fluoride toothpaste efficacy and safety in children younger than 6 years. A systematic review. JADA 145(2) http://jada.ada.org February 2014

20. Slot DE, Wiggelinkhuizen L, Rosema NAM,Van der Weijden GA. The efficacy of manual toothbrushes following a brushing exercise: a systematic review. Int J Dent Hygiene 10, 2012; 187–197

21.Schwarz E, Lo ECM, Wong MCM. Prevention of Early Childhood Caries- Results of Fluoride Toothpaste Demonstration Trial on Chinese Preschool Children after Three years. Int J Paed Dent 1998; 58(1): 12-18

22. Curnow M.M.T., Pine C.M., Burnside G. A Randomised Controlled Trial of the Efficacy of Supervised Toothbrushing in High-Caries-Risk Children. Caries Res 2002;36:294-300

23. Twetman S, Axelsson S, Dahlgren H, Holm A-K, Kallestal C, Lagerlof F, Lingstrom P, Mejare I, Nordenram G, Norlund A, Petersson LG, Soder B. Caries-preventive effect of fluoride toothpaste: a systemic review. Acta Odontol Scand 2003;61:347-355.

24. Wong M.C.M, Clarkson J, Glenny AM, Lo E.C.M, Marinho V.C.C, Tsang B.W.K, Walsh T, and Worthington H.V. Cochrane Reviews on the benefits/ risks of fluoride toothpastes.J Dent Res 90(5)2011; 573-579

25. AAPD 2014, Classifications, Consequences, and Preventive Strategies. AMERICAN ACADEMY OF PEDIATRIC DENTISTRY. REFERENCE MANUAL V 37 / NO 615 / 16. Available from: http://www.aapd.org/media/policies_guidelines/p_eccclassifications.pdf

26.AAPD 2014, Guideline on Infant Oral Health Care REFERENCE MANUAL V 37 / NO 6 15 / 16. http://www.aapd.org/media/policies_guidelines/g_infantoralhealthcare.pdf

27. Gillcrist J.A., Brumley D.E. Blackford J.U. Community fluoridation status and caries experience in children. J Public Health Dent 2001;61(3):168-71

28. Iheozor-Ejiofor Z, Worthington HV, Walsh T, O'Malley L, Clarkson JE, Macey R, Alam R, Tugwell P, Welch V, Glenny A. Water fluoridation for the prevention of dental caries (Review) A reprint of Cochrane review, prepared and maintained by The Cochrane Collabolation and published in The Cochrane Library 2015, Issue 6.
http://www.thecochranelibrary.com

29. Petersen P.E., Baez R.J., and Lennon M.A. Community-oriented administration of fluoride for the prevention of dental caries: A summary of the current situation in Asia. Adv Dent Res 24(1):5-10, 2012.

30. Bánóczy J, Petersen JE, Rugg-Gunn AJ. Milk fluoridation for the prevention of dental caries. [Last accessed on 2015 November 10]. Available from: http://www.who.int/oral_health/publications/milk_fluoridation_2009_en.pdf

31. Mariño, R., Villa, A. and Guerrero, S. A community trial of fluoridated powdered milk in Chile. Community Dentistry and Oral Epidemiology, 2001, 29: 435–442.

32.Bian, J. Y., Wang, W. H., Wang, W. J., Rong, W. S. and Lo, E. C. M. (2003), Effect of fluoridated milk on caries in primary teeth: 21-month results. Community Dentistry Oral Epidemiology, 31: 241–245.
Health (2015) 32, 199–203

33. Yeung CA,Chong LY and Glenny AM. Fluoridated milk for preventing dental caries. . Fluoridated milk for preventing dental caries (Review) A reprint of Cochrane review, prepared and maintained by The Cochrane Collabolation and published in The Cochrane Library 2015, Issue 5.
http://www.thecochranelibrary.com
34. Petersen P.E., Kwan S. and Ogawa H. Long term evaluation of the clinical effectiveness of community milk fluoridation in Bulgaria Community Dental Health (2015) 32, 199–203
35. Rugg-Gunn A, and Woodward M. Milk and oral health. [Last accessed on 2015 November 10]. Available from: http://www.borrowfoundation.org/assets/uploads/milk-and-oral-health.pdf.
36. Birungi N, Fadnes LT, Okullo I, Kasangaki A, Nankabirwa V, Ndeezi G, Tumwine JK, Tylleskär T, Lie SA, Aström AN. Effect of breastfeeding promotion on early childhood caries and breastfeeding duration among 5 year old children in Eastern Uganda: a cluster randomized trial. PLoS ONE 2015; 10: e125352.
37. Avila WM, Pordeus IA, Paiva SM, Martins CC. Breast and bottle feeding as risk factors for dental caries: a systematic review and meta-analysis. PLoS ONE 2015; 10: e142922.
38. Sheiham A and Watt RG. The common risk factor approach: a rational basis for promoting oral health.Community Dent Oral Epidemiol. 2000 Dec;28 (6):399-406.
39. WHO-FAO, 2003. Diet, nutrition and the prevention of chronic diseases. http://apps.who.int/iris/bitstream/10665/42665/1/WHO_TRS_916.pdf
40. World Health Organization. Guideline: Sugars intake for adults and children. Geneva: World Health Organization; 2015. [Last accessed on 2015 November 10]. Available from: http://www.who.int/nutrition/publications/guidelines/sugars_intake/en/
41. Zimmer S Zimmer, M Bizhang, R Seemann, S Witzke... The effect of a preventive program, including the application of low-concentration fluoride varnish, on caries control in high-risk children. Clin Oral Invest (2001) 5:40-44
42. Skold UM, Petersson LG, Lith A, Birkhead D. 2005. Effect of School-Based Fluoride Varnish Programmes on Approximal Caries in Adolescents from Different Caries Risk Areas. Caries Research 39, pp. 273-279.
43. Marinho VCC, Higgins JPT, Logan S, Sheiham A. Fluoride varnishes for preventing dental caries in children and adolescents. Cochrane Database of Systematic Reviews 2002, Issue 1.
44. Weintraub J.A., Ramos-Gomez F, Jue B, Shain S, Hoover C.I0, Featherstone J.D.B., and Gansky S.A. Fluoride Varnish Efficacy in Preventing Early Childhood Caries. J Dent Res. 2006 Feb; 85(2): 172–176
45. Lawrence HP, Binguis D et al. A 2-year community-randomized controlled trial of fluoride varnish to prevent early childhood caries in Aboriginal children. Community Dent Oral Epidemiol 2008; 36: 503-516.
46. Adams SH, Hyde S, Gansky SA. Caregiver acceptability and references for early childhood caries preventive treatments for Hispanic children. J Publ Health Dent 2009; 69: 217-224.
47. Milgrom P, Tut OK. Evaluation of Pacific Islands early childhood caries prevention project: Republic of the Marshall Islands. J Publ Health Dent 2009; 69: 201- 203.
48. Leelasithorn S, Ungchusak C, Promma S,Bunmee S. Effect of Fluoride Varnish on Caries Prevention in 0-3 Year-old Children. THAILAND JOURNAL OF HEALTH PROMOTION AND ENVIRONMENTAL HEALTH 2009;32(2):62-71
49. Pitchika V, Kokel C, Andreeva J, Crispin A, Hickel R, Kűhnisch J, Heinrich-Weltzien R. Effectiveness of a new fluoride varnish for caries prevention in pre-school children. J Clin Pediatr Dent 2013; 38: 7-12.
50.Mohammadi TM, Hajizamani A, Hajizamani HR, Abolghasemi B. Fluoride varnish effect on preventing dental caries in a sample of 3-6 years old children. J Int Oral Health 2015; 7: 30-35.

51. Oliveira BH, Salazar M, Carvalho DM, Falcão A, Campos K, Nadanovsky P. Biannual fluoride varnish applications and caries incidence in preschoolers: a 24-month follow-up randomized placebo-controlled clinical trial. Caries Res. 2014;48(3):228-36. Epub 2014 Jan 29.

52. Agouropoulos A, Twetman S, Pandis N, Kavvadia K, Papagiannoulis L. Caries-preventive effectiveness of fluoride varnish as adjunct to oral health promotion and supervised tooth brushing in preschool children: a double-blind randomized controlled trial. J Dent. 2014 Oct;42(10):1277-83.

53. Jiang EM, Lo ECM, Chu CH, Wong MCM. Prevention of early childhood caries (ECC) through parental toothbrushing training and fluoride varnish application: a 24-month randomized controlled trial. J Dent 2014; 42: 1543-1550.

54. Simratvir M, Singh N et al. Efficacy of 10% Povidone Iodine in Children Affected with Early Childhood Caries: An In vivo Study. J Clin Paediatr Dent 2010; 34(3): 233 – 238.

55. Berkowitz RJ, Koo H et al. Adjunctive chemotherapeutic suppression of mutans Streptococci in the setting of severe early childhood caries: an exploratory study. J Publ Health Dent 2009; 69: 163-167.

56. Berkowitz R.J., Amante A, Dorota T. Kopycka-Kedzierawski, Billings R.J., Feng C, Dental caries recurrence following clinical treatment for severe early childhood caries. Pediatr Dent. 2011 Nov-Dec;33 (7):510-4

57. Amin MS, Harrison RL, Benton TS, Roberts M, Weinstein P.Effect of Povidone-iodine on Streptococcus Mutans in Children With Extensive Dental Caries. Pediatr Dent. 2004;26:5-10

58. Lopez L, Berkowitz R, Zlotnik H, Moss M, Weinstein P. Topical antimicrobial therapy in the prevention of early childhood caries. Pediatr Dent. 1999 Jan-Feb;21(1):9-11

59. Lopez L, Berkowitz R , Spiekerman C, Weinstein P. Topical antimicrobial therapy in the prevention of early childhood caries: a follow-up report. Pediatr Dent 24:204-206, 2002.

60. Zhang L, Featherstone JDB et al. Antibacterial treatment needed for severe early childhood caries. J Publ Health Dent 2006; 66: 174-179.

61. Peretz B, Sarit F et al. Mutans Streptococcus counts following treatment for early childhood caries. J Dent Child 2003; 70: 111-114.

62. Palmer EA, Nielsen T et al. Children with severe early childhood caries: pilot study examining mutans streptococci genotypic strains after full-mouth caries restorative therapy. Pediatr Dent. 2012 Mar-Apr;34(2):e1 – 10.

63. Klinke T, Urban M et al. Changes in Candida spp., Mutans Streptococci and Lactobacilli following treatment of early childhood caries: A 1-Year follow-up. Caries Res 2014: 48: 24 – 31.

64. Acs G, Shulman R et al. The effect of dental rehabilitation on the body weight of children with early childhood caries. Pediatr Dent 1999; 21: 109-113.

65. de Amorim RG1, Leal SC, Frencken JE. Survival of atraumatic restorative treatment (ART) sealants and restorations: a meta-analysis.Clin Oral Investig. 2012 Apr;16(2):429-41. doi: 10.1007/s00784-011-0513-3. Epub 2011 Jan 28.

66. Arrow P, Klobas E. Minimum intervention dentistry approach to managing early childhood caries: a randomized control trial. Community Dent Oral Epidemiol 2015; 43: 511-520.

67. Borrelli, Belinda1; Tooley, Erin M.2; Scott-Sheldon, Lori A.J.Motivational Interviewing for Parent-child Health Interventions: A Systematic Review and Meta -Analysis Pediatric Dentistry, Volume 37, Number 3, May/June 2015, pp.254-265(12)

caries. Braz Oral Res 2015; 29: 1-8.

68. Naidu R, Nunn J, Irwin JD. The effect of motivational interviewing on oral healthcare knowledge, attitudes and behaviour of parents and caregivers of preschool children: an exploratory cluster randomised controlled study. BMC Oral Health 2015; 15: 101.

69. Plutzer K, Spencer AJ. Efficacy of an oral health promotion intervention in the prevention of early childhood caries. Community Dent Oral Epidemiol 2008; 36: 335-346.

70. Plutzer K, Spencer AJ, Keirse MJNC. Reassessment at 6 – 7 years of age years of randomized controlled trial initiated before birth to prevent early childhood caries. Community Dent Oral Epidemiol. 2012; 40 (2):116 – 124.

71. Azevedo MS, Romano AR, Correa MB, dos Santos IS, Cenci MS. Evaluation of a feasible educational intervention in preventing early childhood caries. Braz Oral Res 2015; 29: 1-8.

Management of Early Childhood Caries – a comparison of different approaches

Bathsheba J Turton[1]
Callum S Durward[2]

[1]Lecturer Department of Dentistry University of Puthisastra
[2]Dean Faculty of Health Sciences University of Puthisastra

Abstract

Early childhood caries (ECC) is a major problem in the South East Asian (SEA) region. The management of ECC in preschool children is multi-faceted and can be challenging for the child, the dental team, and the family. There is only limited evidence for the use of specific techniques in the management of ECC. The objective of this paper is to review different treatment approaches in the management of ECC. Method: a critical review of the literature was conducted in order to examine evidence for the best techniques to manage ECC. Results: three treatment approaches were examined (1) the 'no treatment' approach, (2) the 'minimally invasive dentistry' (MID) approach, and (3) the 'conventional' approach. Treatment of carious lesions in the primary dentition is well-justified and results in improvements in Quality-of-Life. Recommendations for conventional treatment techniques vary widely and often require general anaesthetic to be predictable for preschool children who may have difficulty accepting treatment. The minimally invasive approach appears to be promising and centres around the use of Atraumatic Restorative Technique (ART), Arrest of Caries Treatment (ACT) with silver diamine fluoride, and the Hall crown technique. Early intervention to treat early lesions and prevent caries is very important. It can be concluded that the Minimally Invasive Dentistry (MID) approach to managing ECC appears to be the most appropriate public health approach for managing ECC in the SEA region. It would be beneficial to build more evidence around this approach in order to inform the practice of caries management in preschool children.

Keywords

Early childhood caries, ECC, Primary dentition, Management of Early Childhood Caries, Review of Early Childhood Caries

Introduction

Early Childhood Caries (ECC) is highly prevalent in many South East Asian countries. Just as the presentation and socio-behavioural aspects of ECC differ somewhat from caries found in older children, the management of ECC can also differ. This is partly related to the child's stage of cognitive, physical, psychosocial and dental development.[1] When treating young children, their stage of development, the context of their families, and the social environment are of utmost importance.[1-3] Behaviour management can be a considerable challenge.[1] In addition, the restorative and endodontic techniques used in the adult dentition may not always be appropriate in primary teeth, which are anatomically different and in the mouth for a limited period of time. Primary teeth are smaller, have thinner enamel and dentine, have a more bulbous crown shape, and often have complicated root canal systems.[4]

These factors may have contributed to some ambiguity in terms of defining the ideal dental treatment in preschool children.[5] In addition to this, there is some ambiguity in defining the management of dental caries which may be broadly categorised into primary prevention which addresses the control of risk factors, secondary prevention which addresses the non-cavitated lesions by preventing their progression to cavitation, and tertiary prevention which addresses cavitated lesions thereby preventing pulp problems and risk of need for extraction. Primary prevention is dealt with in another paper within this supplement and so this paper is mainly focused on secondary and tertiary prevention.[6] Around the latter two phases of caries management, there is a lack of robust research about the best techniques to use for preschool children, and some hesitation about how dentists should manage preschool children in the dental clinic.[7] The aim of this article is to describe three different approaches to the management of ECC: the 'No Treatment' approach, the 'Minimally Invasive Dentistry' (MID) approach, and the 'Conventional' approach.

Method

Literature to inform this review of aspects of Early Childhood Caries was obtained in several ways. First, an electronic internet search was made through PubMed and ScienceDirect databases. The primary search term was 'early childhood caries'. Other keywords included tooth decay in young children, dental caries in young children, nursing caries. Other associated terms used in the search included: diagnosis, criteria, epidemiology, prevalence, aetiology, risk factor, prevention, treatment and oral health related quality of life. Eligible studies were included when they met the following criteria: (1) articles in English providing relevant information within the time period 1990 to 2015; (2) presenting evidence relevant to ECC according to the defined themes: epidemiology, aetiology, prevention and treatment; (3) considers dental caries or sequelae in early childhood. Concerning the exclusion criteria, studies were excluded from the review if they focused on either: (1) concerned with other age-groups or other diseases, (2) studies published in languages other than English. A total of 417 articles were identified through database searching; duplicates and references irrelevant to ECC were removed, reducing this list by about one third. Two conference books relevant to the situation in Asian countries were also included.

Second, nine journals were searched by hand: International Journal of Paediatric Dentistry, European Journal of Paediatric Dentistry, Pediatric Dentistry, Journal of Dentistry for Children, Journal Clinical Pediatric Dentistry, Community Dentistry Oral Epidemiology, Community Dental Health, Caries Research, Journal of Public Health Dentistry. How far back the hand-searches were made, depended on the journal: for most journals it covered 2000 to 2015,

while for International Journal of Paediatric Dentistry, the search extended back to 1990.

Third, some back-tracking from the reference lists attached to publications so far discovered was carried out to identify any remaining key articles. This resulted in a database of 380 references on all aspects of ECC, covering the years 1993 to 2016. Out of this database, 89 publications were relevant to this review of the management of ECC.

The 'No Treatment' approach

Some researchers have argued that most young children do not actually experience much pain from decayed primary teeth and that "less intervention is better".[7] These authors argue that carious primary teeth often exfoliate without pain, and that there is a lack of robust research justifying conventional treatment modalities.[8] From the perspective of reducing exposure of children to upsetting dental interventions, and saving resources, the idea of not having to treat primary teeth is an attractive one. In resource-poor communities and in developing countries, this approach to dental caries in the primary teeth has considerable appeal, as it would eliminate the burden of treatment costs borne by the parents or the public health system. Even in wealthier countries, the high cost of treating many of these young children (especially those who are treated under general anaesthesia) is a growing concern.[9-11]

The argument for "no treatment of primary teeth" assumes (i) that pain is the only measured outcome validating treatment of deciduous teeth, and (ii) that pain is expressed the same way in young children as it is in adults. However, studies have shown that pain frequently is present in children with ECC.[11,13] For a young child with a severe burden of dental caries, pain can be a daily experience and accepted as "normal"; their experience of pain may not be articulated in words but rather by changes in behaviour, including changes in eating patterns.[14] For many children, the diagnosis of ECC is only made when they articulate their experience of pain, at which stage extraction or pulp treatment may be required.[15] The carious teeth most likely to cause symptoms are the primary molars with pulpal symptoms by the age of 3 years.[16]

The suggestion that primary teeth do not need treatment also fails to take into account several studies suggesting that Severe Early Childhood Caries (sECC) of primary teeth may be associated with dietary changes leading to a lower weight gain.[12, 17-19] In addition, approximal lesions and the premature loss of decayed primary teeth due to extraction, may result in space loss and subsequent crowding in the permanent dentition.[19-20] There may also be social consequences for the child who has an aesthetically-poor appearance due to dental caries.[17, 19, 21] Other researchers have pointed to the importance of primary teeth for speech development, oral function (eating), and normal growth and development.[14] Based on this rationale, active management of carious lesions in preschool children is warranted. The justifications for active management of carious lesions are presented in Table 1.

Minimally invasive approaches

Mejàre et al.[8] suggested that standard treatment guidelines for this unique group (preschoolers) need to be modified to give dentists more confidence when treating young children and to achieve better management of the caries process. Recent research has begun to build evidence for such an approach in preschool children.[22]The concept of Minimally Invasive Dentistry (MID) has been promoted for both adults and children in recent decades. Whereas treatment of dental caries has traditionally focused on the management of cavitated lesions, the MID approach seeks to manage cavitated lesions but, in addition, promotes the management of early lesions, which present in preschool children as white spots.

Table 1 – Justifications for the management of ECC

Prevention and management of pain and infection
Improved growth and development
Aesthetics and social well-being
Avoidance of space loss
Oral function and speech development
Reducing negative impacts on children, families, dental providers and the public health system

The focus of MID is to manage the caries process, rather than just the lesion. When considering the caries process, it is important to place treatment in the context of the 'caries balance' between protective and pathological factors. Protective factors include sufficient saliva, fluoride, sealants, antibacterials, a healthy diet, and good oral hygiene. The pathological factors include high sugar diets, cariogenic bacteria and absence of saliva.[22,24] Clinicians must recognize and manage early non-cavitated lesions, and tip the balance towards the protective factors, while reducing exposure to the pathological factors.

The MID approach for non-cavitated lesions

The management of non-cavitated lesions is considered to be non-invasive treatment which aims to constrain the disease process by arresting demineralisation and facilitating remineralisation. It involves enhancing exposure to protective factors on the one hand and minimising exposure to risk factors on the other. If the competing exposures can be modified to favour protective factors then existing lesions will not progress, net remineralisation will occur, and no new lesions will develop. This management entails a combination of 'clinic-based' interventions, and 'home-based' interventions to be conducted by the patient or in the present context, the caregivers. MID management of the caries process is presented in Table 2.

Home-based management of non-cavitated lesions

A key part of the management of non-cavitated lesions involves behaviours over which the clinician has little control; these behaviours primarily involve sugar consumption and oral hygiene behaviours. Providing diet counselling (especially related to sugar consumption) and oral hygiene instruction (especially related to the optimal use of fluoride toothpaste) can have positive results.[25] Evidence is growing that motivational interviewing techniques and other social-behavioural techniques can be successful in achieving behaviour change. Reductions in ECC after such interventions have been reported.[26]

Clinic-based management of non-cavitated lesions

Fluoride-based therapies remain the gold standard for the management of non-cavitated lesions and this was reflected in the US Surgeon General's report on reducing caries risk. That report called for supervised tooth-brushing with a fluoride toothpaste, systemic fluoride supplementation, and the use of fluoride varnishes and gels.[27, 28] The most common chairside intervention for the management of non-cavitated lesions in children is the use of 5% sodium fluoride varnish, applied ideally three times per year[29] although some other caries management frameworks recommend 3-monthly follow-ups for high risk children[6]. Two other interventions growing in popularity are the use of agents to enhance remineralisation and the use of 'fissure protection'

(using GIC) for primary molars. There are some studies showing favourable retention of GIC sealants in primary molars[30-32] but further research is needed to examine the applicability of these results.[33,34] There is some limited evidence promoting the use of bio-available calcium and phosphate substrates such as CPP-ACP for managing the caries process in preschool children.[35,36] Unfortunately, most of the literature on CPP-ACP is based on *in vitro* studies[37] or on permanent dentitions of adolescents post-orthodontic treatment.[38,39] The key tools for management of non-cavitated lesions are included in Table 2.

Table 2 – MID (minimally invasive dentistry) approach to the management of non-cavited and cavitated lesions in preschool children

Clinic based care	Home based care
Sodium fluoride varnish CCP-ACP	Regular oral hygiene with a fluoride toothpaste
Pit and fissure sealants on primary molars	Dietary sugar reduction
Atraumatic Restorative Treatment (ART) Arrest of Caries (ACT) with Silver Diamine Fluoride 'Hall'stainless steel crowns	Oral health education – including dietary counselling, oral hygiene instruction, and motivational interviewing techniques

The MID approach to the management of cavitated lesions

Along with promoting home-based management of caries, the MID approach to the treatment of cavities at tooth level is focused on remineralisation and biofilm management. That is to say, treatment involves either creating an environment which is hostile to a cariogenic biofilm (e.g. by using silver diamine fluoride), or by sealing the underlying lesion from access to the surface biofilm through Atraumatic Restorative Treatment (ART), or Hall crowns. These techniques will successfully retain the primary tooth and preserve tooth structure, while at the same time minimize the possibility of upsetting the child.[22,40-42] When this treatment approach is applied to preschool children, it can also help to reduce the need for management under a General Anaesthetic (GA).[22, 41] ACT, ART and Hall crowns are further discussed below.

Arrest of Caries Treatment (ACT)

Arrest of a carious lesion through the application of silver diamine fluoride (SDF) is thought to occur by a combination of the antibacterial effect of silver in combination with the well-known anti-cariogenic effects of fluoride.[43] A single application of SDF has been shown to arrest half of previously active lesions and bi-annual applications can arrest three quarters of such lesions.[43-45] There is also some evidence that a combination of silver nitrate with fluoride varnish can also achieve arrest of caries active lesions,[46] whereas fluoride varnish alone does not appear to be effective at arresting open, cavitated lesions.[43]

ACT has been shown to be effective in pre-school children; however, the arrest rates tend to be less favourable than in older children, perhaps due to the higher chance of saliva contamination during placement in a smaller mouth. The lower rate of arrest in preschool children can be compensated for by additional applications.[47] Chu et al.[48] compared the ability of SDF solution and NaF varnish to arrest caries in preschool children, and found the SDF was far more successful. The other advantage of ACT is that it does not rule out the possibility of conventional restoration in the future. It has been shown that glass ionomer cement (GIC) restorations and composite restorations can be placed after SDF treatment without compromising bonding.[49, 50]

The use of SDF is generally accepted as safe for young children, and there are no reports in the literature of serious side-effects. The most common minor side-effect occurs as a result of the solution coming into contact with the gingival soft tissues. In this situation, a minor chemical burn and a localized whitening of the gingiva may occur. This is not associated with discomfort and it will disappear within a few days without intervention. The other common side effect is the delayed dark staining of the carious lesion after SDF application and, for that reason, caregivers should be informed of this discolouration prior to application. A temporary dark stain can also occur on the facial soft tissues (including the lips), fingers or skin if the application is not well controlled.[43] One author explored the theoretical chance of fluorosis due ingestion of the fluoride; however, this logic has not been validated and the consensus is that the risk is extremely low.[51] The fluoride concentration in a 38% SDF solution is 49,000 ppm; this equates to 1ml (more than 10 drops) of solution before potential fluorosis could occur. In contrast, it is estimated that one drop (0.05 – 0.1ml) of SDF can treat up to 6 teeth, so the amount used is safe.[52]

Differences in arrest rates appear to be related primarily to the concentration of the solution, the frequency of application of SDF, and the need to clean and dry prior to application.[45] Most protocols recommend a bi-annual application with 38% SDF, and all recommend cleaning and drying the lesion first.[44, 52] Among the tertiary prevention techniques for preschool children in the MID approach, SDF is perhaps the least costly, least invasive, and easiest to implement.[53]

Atraumatic Restorative Technique (ART)

The key goal of placing an ART restoration is the minimal removal of sound tooth tissue and the sealing of a lesion from the oral environment. Most of the literature around ART involves occlusal surfaces of the permanent dentition; however, there are some studies that examine the success in the primary dentition.[54,55] Another variation on ART is the Simplified-Modified Atraumatic Restorative Technique (SMART) which uses partial caries removal and capsulated Glass Ionomer Cements and this technique is growing in popularity across South East Asia.[56, 57] This present discussion will focus more on ART after taking into account the literature available in English language at the time of submission. One of the key advantages of the ART technique is that it does not require the use of local anaesthesia and dental 'drills' which can be difficult for a young child to cope with. It is now well accepted in the literature that leaving a small amount of carious dentine directly over the pulp (sometimes referred to as indirect pulp therapy or indirect pulp capping) is now the standard management of the deep carious lesion because the GIC restoration seals infected dentine from plaque and dietary sugar.[58]

In addition to conserving tooth structure, ART has also been associated with decreased levels of anxiety in children[59] and has been associated with a reduction in general anaesthesia waiting lists.[22] ART has been used by dentists and other dental providers in both conventional and community settings for

over 25 years, primarily for single and two-surface surface restorations. Success rates appear to be lower for two-surface ART restorations; single surface ART restorations in primary teeth have been shown to have comparable long-term success with conventional restorative techniques.[60-63] Part of the success of ART restorations may be related to fluoride release from GIC restorations,[64] and there is some evidence that GIC might also have preventive effects on adjacent teeth.[65] Additional studies are needed to confirm these findings and to examine success within very young children.

The Hall crown technique

The most successful restorative option for the management of large carious lesions in the primary dentition is the stainless steel crown; however, the traditional technique requires 'cutting down' the teeth and the use of local anaesthesia. In contrast, the Hall technique involves placing stainless steel crowns directly over decayed primary molars, which have not had prior tooth preparation. By sealing the lesion under the crown, the caries process arrests and usually no further treatment is required. To facilitate the placement of the crowns, a separating elastic module can be placed between the primary molars a few days prior to crown cementation. The procedure can be carried out without local anaesthesia. The technique is gaining international acceptance, as studies show success rates comparable to crowns placed following conventional tooth preparation.[42,66,67] Patients, caregivers, clinicians have been reported to have a clear preference for the Hall technique over conventional preparation techniques.[68]

The Conventional Treatment Approach for managing ECC

Conventional management of dental caries in the primary dentition includes the use of local anaesthesia, cavity preparation with rotary handpieces, restoration with a variety of filling materials, crowns, pulp treatments (pulpectomy and pulpotomy), and extractions - procedures which can be challenging for the young child, the family, and the dental team. It is important to note, however, that such treatment only eradicates individual lesions, it does not address the disease itself which requires management through primary prevention.[6] Conventional restorative materials including amalgam, composite, compomer, GIC, resin-modified GIC (RMGIC) and stainless steel crowns are used by dentists.[69] There appears to be wide variation among dentists and dental schools concerning recommendations about the best materials to use for primary teeth.[70-72]

Direct restorative materials

Many studies have shown that stainless steel crowns perform best, followed by amalgam.[69,73,74] The AAPD guidelines[89] also support the use of composites, compomers, and RMGICs for 1- and 2-surface primary tooth restorations; however, they do not endorse the use of GICs for Class II restorations. Chadwick and Evans (2007) concluded from their review of restorations in the primary teeth, that GIC restorations could not be recommended for Class II cavities. Despite this, GIC materials are the most popular material used by dentists in some countries.[71] Composites perform well, in terms of aesthetics and wear resistance; however, the occurrence of new lesions alongside composite restorations can be a significant problem. GIC and RMGIC restorations have the advantage of fluoride release into the surrounding tooth tissues, minimizing the chance of the development of new lesion initiation alongside restoration margins and rendering the tooth more resistant to decay should the restoration be lost.[75, 76]

Amalgam restorations have been shown in many studies to have greater longevity in primary teeth than tooth-coloured restorations (particularly GIC). However, some countries no longer recommend or permit the use of amalgam in young children (primarily for environmental reasons), and

there is a growing trend to reduce its use.[77, 78] Reliable up-to-date evidence about the clinical performance of the different tooth-coloured materials for primary teeth is lacking, especially for preschool children.[79-81] Yengopal[79] and Uribe[81] state that there is insufficient evidence to make any recommendations about which dental material should be used in the primary dentition.

Preformed restorations

Conventional stainless steel crowns are the most predictable way to restore primary molar teeth which have had pulp treatment or have extensive caries of the crown. They are also recommended for young high caries-risk children, because tooth-coloured or amalgam restorations may fail and the teeth may continue to decay.[69] However, crowns are a more costly form of treatment, and some parents object to their appearance.[42, 82, 83] In recent years, tooth-coloured crowns have become more popular for use on primary molar and incisor teeth; however, studies on their success are few, and their cost is much higher than a conventional stainless steel crown.[84,85]

Pulp treatment for primary teeth

Throughout this paper, the focus has been on restoring teeth that have cavitated lesions which are not pulpally involved. Unfortunately, this is not always the case and primary teeth may require some form of pulp treatment or extraction when the pulp becomes inflamed or loses vitality. In this situation, the clinician will need to consider a number of factors when choosing the appropriate treatment modality. These factors include the correct diagnosis of the pulpal condition, an overall assessment of the value of the tooth in relation to the child's overall development, the restorability of the tooth, alternatives to pulp therapy, the medical history, the age and cooperation of the child.[86]

Accurate diagnosis of the pulpal condition is one of the most important aspects of choosing an appropriate pulp treatment. If the pulp is irreversibly inflamed or necrosed then the options become limited to root canal therapy or extraction. In the case that a vital pulp is free from symptoms or reversibly inflamed, then therapies such as indirect pulp therapy (IPT), direct pulp capping or pulpotomy could be considered. IPT can be applied where the carious lesion is in close proximity to the pulp but the pulp is not inflamed, or where there are symptoms of reversible pulpitis. This involves removal of all the peripheral soft carious dentine except for a layer immediately over the pulp, so as to avoid exposing the pulp. A lining (e.g. with calcium hydroxide or GIC) arrests the lesion and a permanent restoration (preferably a crown) is then placed. Studies show this approach is very successful if the pulpal condition was accurately diagnosed.[87-89]

Direct pulp capping is generally recommended for traumatic pulp exposures rather than carious pulp exposures. The exposure is covered with a hard-setting calcium hydroxide or mineral trioxide aggregate (MTA). Unfortunately, the long-term success of pulp capping has been shown to be low, especially if used when there is a carious pulp exposure.[89]

Pulpotomies are indicated for carious pulp exposures where the pulp in the root(s) is still healthy. Formocresol was once the gold standard pulpotomy medicament; however, in recent years there have been growing concerns over its toxicity. Ferric sulphate and MTA have largely replaced formocresol, with similar success rates.[88,90-93] More recently, sodium hypochlorite has also been showing good success in some studies.[94, 95]

For primary teeth with pulp necrosis or an abscess, extraction is often recommended. If this occurs within a year of the normal eruption time of the successor tooth, there is usually no long-term problem for space maintenance.[89] However, if it is going to be a long time before the successor tooth erupts, space loss may occur, especially if the extracted tooth is a first or second primary molar. These considerations might indicate that root canal treatment and retention of the tooth is more desirable. For primary teeth requiring root canal treatment, a variety of resorbable root filling materials have been used with variable success. Plain zinc oxide eugenol is one of the oldest and is still widely used; however, medicaments such as Vitapex (a calcium hydroxide iodoform paste) or Kri paste (iodoform-based) have become popular in recent decades.[89, 96-98] For all types of pulp treatment, a restoration with a good biological seal to prevent microleakage is important for success.[89, 99]

Although pulp treatment of primary teeth can be very successful, it is also reliant on an effective restorative seal and stainless steel crowns are recommended for long-term survival.[8 9] It should also be noted that carrying out pulp and complex restorative treatments on a preschool child can be very challenging or not possible, and the outcome may be less than ideal[1]. Sometimes sedation or general anaesthesia may be required.

Behaviour management for conventional dental treatment

The success of any restoration or pulp treatment will depend on the cooperation of the child – and this can be unpredictable, especially in the preschool child. Factors affecting the cooperation of the child in the dental setting may include: the stage of cognitive development (influencing their ability to understand and communicate verbally); their close attachment to the parent; a fear of 'strangers'; their resistance to certain dental procedures in the mouth; anxiety related to the dental clinic environment, dental procedures and dental personnel; small mouths; and a limited attention span.[1, 100, 101] For these reasons, a number of strategies for behaviour management have been employed by dentists, ranging from simple behavioural techniques such as 'tell-show-do', to sedation and general anaesthesia.[1] A summary of techniques for behaviour guidance is presented in Table 3 including reference to a number of simple behavioural techniques. Sedation and general anaesthetics for dental treatment are discussed below.

Table 3 – Techniques for Behaviour Guidance[a]

Communication and communicative guidance	Positive reinforcement and descriptive praise
Positive pre-visit imagery	Distraction
Direct observation	Memory restructuring
Tell-Show-Do	Parental presence / absence
Ask-Tell-Ask	Protective stabilization
Voice control	Sedation
Non-verbal communication	General anaesthesia

[a]Adapted from the American Association of Pediatric Dentistry Guideline on guideline on behaviour guidance for the paediatric dental patient[86]

Sedation

Some dentists employ sedation to help manage young children who may be anxious or uncooperative. The most popular agents are nitrous oxide sedation and oral sedation (e.g. with midazolam).[34-69] Although helpful, sedation does not always improve child cooperation, and local anaesthesia is still required to carry out invasive treatment. Sometimes sedation is given along with the use of restraint/stabilization devices (such as the papoose board); however, parents in many countries are becoming more resistant to the use of restraint during dental treatment.[102, 103] The cost of sedation is also a barrier for some families. In addition, not all dentists can administer sedation which requires special training in order to perform it safely.[104-106] Given these challenges, often the preference is to provide treatment under GA.

General anaesthesia

In some countries general anaesthesia is commonly used to provide dental treatment to anxious, uncooperative, and special needs preschool children. In recent decades, use of general anaesthesia in many countries has increased despite the fact that general anaesthesia is very costly, has certain risks, and that there is a relatively high rate of re-treatment under GA, as many children develop new lesions within a year.[9, 107]

The advantages of dental treatment under GA include the fact that all treatment can be completed in one visit, the child is usually not traumatized by the procedure, and that high-quality treatment can be provided in a well-controlled environment.[9] The success of restorations placed under GA may be higher than those placed in a dental surgery.[108] Further to this, there are reports that treatment of children with ECC under general anaesthesia results in 'catch-up' growth[14] and improvements in Oral-Health-Related Quality-of-Life. These improvements in quality of life are not only observed by the individuals but also by their family members who are no-longer woken at night due to pain or burdened by dealing with challenging behaviour when they take the child to the dental clinic.[109-113]

Summary

The management of ECC in preschool children is multi-faceted, challenging and there are large gaps in the literature regarding which techniques and materials to use in the context of preschool children. This paper has reviewed three different approaches to treatment. The 'no treatment' approach may appear attractive; however, it is not accepted by the authors as the best option for most children. The conventional restorative approach is labour intensive, expensive, invasive, and often difficult for preschool children to accept without sedation or GA. Management of ECC under GA has many advantages, but is disproportionately expensive in contrast to the minimally invasive (MID) approach. The MID approach, including ART, ACT (SDF), Hall crowns, and management of early (non-cavitated) lesions, maybe the most appropriate approach for the majority of children in the South East Asian region, since access to GA is very limited. MID techniques are 'child-friendly' and can manage the disease in most children, without the need for costly general anaesthesia. MID techniques can be employed both for individual children visiting a dental clinic, and for large groups of children in a public health setting. It is recommended that further research be conducted on the MID approach for managing ECC in the SEA region. This would help to confirm the best approach for clinicians as well as public dental service providers as they endeavour to manage ECC in preschool children.

References

1. Wright GZ, Kupietzky A. Behavior management in dentistry for children. John Wiley & Sons; 2014.
2. Teng F, Yang F, Huang S, Bo C, Xu ZZ, Amir A, et al. Prediction of early childhood caries via spatial-temporal variations of oral microbiota. Cell Host Microbe. 2015;18(3):296–306.
3. Hallett KB, O'Rourke PK. Social and behavioural determinants of early childhood caries. Aust Dent J. 2003;48(1):27–33.
4. Pinkham JR, Casamassimo PS, Fields HW, McTigue DJ, Nowak A. Pediatric dentistry. Infancy Adolesc 4th Ed Phila WB Saunders Co [Internet]. 2005 [cited 2016 Aug 4]; Available from: http://www.just.edu.jo/FacultiesandDepartments/FacultyofDentistry/Departments/PreventiveDentistry/Lists/Courses/Attachments/93/565%20Course%202013-2014%20modified[1].doc
5. Ismail AI. Determinants of health in children and the problem of early childhood caries. Pediatr Dent. 2003;25(4):328–33.
6. Evans RW, Dennison PJ. The Caries Management System: an evidence-based preventive strategy for dental practitioners. Application for children and adolescents. Aust Dent J. 2009;54(4):381–9.
7. Milsom KM, Tickle M, King D. Does the dental profession know how to care for the primary dentition? Br Dent J. 2003;195(6):301–3.
8. Mejàre IA, Klingberg G, Mowafi FK, Stecksén-Blicks C, Twetman SHA, Tranæus SH. A systematic map of systematic reviews in pediatric dentistry—what do we really know? PLoS ONE [Internet]. 2015 Feb 23 [cited 2015 Jun 4];10(2). Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4338212/
9. Lingard GL, Drummond BK, Esson IA, Marshall DW, Durward CS, Wright FA. The provision of dental treatment for children under general anaesthesia. N Z Dent J. 2008;104(1):10–8.
10. Rashewsky S, Parameswaran A, Sloane C, Ferguson F, Epstein R. Time and cost analysis: pediatric dental rehabilitation with general anesthesia in the office and the hospital settings. Anesth Prog. 2012;59(4):147–53.
11. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft: the human and economic cost of early childhood caries. J Am Dent Assoc. 2009;140(6):650–7.
12. Khanh LN, Ivey SL, Sokal-Gutierrez K, Barkan H, Ngo KM, Hoang HT, et al. Early childhood caries, mouth pain, and nutritional threats in Vietnam. Am J Public Health. 2015 Oct 15;e1–8.
13. Slade GD. Epidemiology of dental pain and dental caries among children and adolescents. Community Dent Health. 2001;18(4):219–27.
14. Sheiham A. Dental caries affects body weight, growth and quality of life in pre-school children. Br Dent J. 2006;201(10):625–6.
15. Ferraz NKL, Nogueira LC, Pinheiro MLP, Marques LS, Ramos-Jorge ML, Ramos-Jorge J. Clinical consequences of untreated dental caries and toothache in preschool children. Pediatr Dent. 2014;36(5):389–92.
16. Levine RS, Pitts NB, Nugent ZJ. The fate of 1,587 unrestored carious deciduous teeth: a retrospective general dental practice based study from northern England. Br Dent J. 2002;193(2):99–103.
17. Oliveira LB, Sheiham A, Bönecker M. Exploring the association of dental caries with social factors and nutritional status in Brazilian preschool children. Eur J Oral Sci. 2008;116(1):37–43.
18. Malek Mohammadi T, Hossienian Z, Bakhteyar M. The association of body mass index with dental caries in an Iranian sample of children. J Oral Health Oral Epidemiol [Internet]. 2015 [cited 2016 Aug 4]; Available from: http://eprints.kmu.ac.ir/21468/
19. Finucane D. Rationale for restoration of carious primary teeth: a review. Eur Arch Paediatr Dent. 2012;13(6):281–92.
20. Laing E, Ashley P, Naini FB, Gill DS. Space maintenance. Int J Paediatr Dent. 2009;19(3):155–62.

21. Broder HL. Children's oral health-related quality of life. Community Dent Oral Epidemiol. 2007;35 (s1):5–7.
22. Arrow P, Klobas E. Minimum intervention dentistry approach to managing early childhood caries: a randomized control trial. Community Dent Oral Epidemiol. 2015; 43:511-20.
23. Featherstone JDB. Remineralization, the natural caries repair process—the need for new approaches. Adv Dent Res. 2009;21(1):4–7.
24. Featherstone JD. Caries prevention and reversal based on the caries balance. Pediatr Dent. 2006;28 (2):128–32.
25. Gao X, Lo ECM, Kot SCC, Chan KCW. Motivational interviewing in improving oral health: a systematic review of randomized controlled trials. J Periodontol. 2014;85(3):426–37.
26. Harrison R, Benton T, Everson-Stewart S, Weinstein P. Effect of motivational interviewing on rates of early childhood caries: a randomized trial. Pediatr Dent. 2007 Jan 1;29(1):16–22.
27. Allukian Jr M. The neglected epidemic and the surgeon general's report: a call to action for better oral health. Am J Public Health. 2000;90(6):843.
28. Tinanoff N, Reisine S. Update on Early Childhood Caries Since the Surgeon General's Report. Acad Pediatr. 2009 Nov 1;9(6):396–403.
29. Weintraub JA, Professor LH. Fluoride varnish for caries prevention: comparisons with other preventive agents and recommendations for a community-based protocol. Spec Care Dentist. 2003 Sep 1;23(5):180–6.
30. Ganesh M, Tandon S. Clinical evaluation of FUJI VII sealant material. J Clin Pediatr Dent. 2007;31 (1):52–7.
31. Hotuman E, Rølling I, Poulsen S. Fissure sealants in a group of 3-4-year-old children. Int J Paediatr Dent. 1998;8(2):159–60.
32. Hardison JR, Collier DR, Sprouse LW, Van Cleave ML, Hogan AD. Retention of pit and fissure sealant on the primary molars of 3-and 4-year-old children after 1 year. J Am Dent Assoc. 1987;114(5):613–5.
33. Beauchamp J, Caufield PW, Crall JJ, Donly K, Feigal R, Gooch B, et al. Evidence-based clinical recommendations for the use of pit-and-fissure sealants: a report of the American Dental Association Council on Scientific Affairs. J Am Dent Assoc. 2008;139(3):257–68.
34. Wright JT, Tampi MP, Graham L, Estrich C, Crall JJ, Fontana M, et al. Sealants for preventing and arresting pit-and-fissure occlusal caries in primary and permanent molars: a systematic review of randomized controlled trials—a report of the American Dental Association and the American Academy of Pediatric Dentistry. J Am Dent Assoc. 2016;147 (8):631–45.
35. Plonka KA, Pukallus ML, Holcombe TF, Barnett AG, Walsh LJ, Seow WK. A randomized controlled clinical trial comparing a remineralizing paste with an antibacterial gel to prevent early childhood caries. Pediatr Dent. 2013;35(1):e8–12.
36. Plonka KA, Pukallus ML, Barnett AG, Holcombe TF, Walsh LJ, Seow WK. A longitudinal case-control study of caries development from birth to 36 months. Caries Res. 2013;47(2):117–27.
37. Cochrane NJ, Reynolds EC. Calcium phosphopeptides—mechanisms of action and evidence for clinical efficacy. Adv Dent Res. 2012;24(2):41–7.
38. Bailey DL, Adams GG, Tsao CE, Hyslop A, Escobar K, Manton DJ, et al. Regression of post-orthodontic lesions by a remineralizing cream. J Dent Res. 2009;88(12):1148–53.
39. Sudjalim TR, Woods MG, Manton DJ. Prevention of white spot lesions in orthodontic practice: a contemporary review. Aust Dent J. 2006;51(4):284–9.
40. Walsh LJ, Brostek AM. Minimum intervention dentistry principles and objectives. Aust Dent J. 2013;58(s1):3–16.
41. Chan T. Atraumatic restorative treatment: an alternative for pre-cooperative children. J Mich Dent Assoc. 2007;89(1):42–4.

42. Innes NP, Stewart M. The hall technique, a simplified method for placing stainless steel crowns on primary molars, may be as successful as traditionally placed crowns. J Evid Based Dent Pract. 2015;15(2):70–2.
43. Rosenblatt A, Stamford TCM, Niederman R. Silver diamine fluoride: a caries "silver-fluoride bullet." J Dent Res. 2009;88(2):116–25.
44. Fung MHT, Wong MCM, Lo ECM, Chu CH. Arresting early childhood caries with silver diamine fluoride - a literature review. Oral Hyg Health. 2013;1:117. doi: 10.4172/2332-0702.1000117
45. Chu CH, Fung HTM, Duangthip D, Wong MCM, Lo ECM. Caries arresting effect using silver-diamine-fluoride with different concentration and periodicity. J Dent Res [Internet]. 2016 [cited 2016 Aug 4]; Available from: http://hub.hku.hk/handle/10722/227503
46. Peng J-Y, Botelho MG, Matinlinna JP. Silver compounds used in dentistry for caries management: a review. J Dent. 2012;40(7):531–41.
47. Duangthip D, Chu CH, Lo ECM. A randomized clinical trial on arresting dentine caries in preschool children by topical fluorides—18 month results. J Dent. 2016;44:57–63.
48. Chu CH, Lo EC, Lin HC. Effectiveness of silver diamine fluoride and sodium fluoride varnish in arresting dentin caries in Chinese pre-school children. J Dent Res. 2002;81(11):767-70.
49. Quock RL, Barros JA, Yang SW, Patel SA. Effect of silver diamine fluoride on microtensile bond strength to dentin. Oper Dent. 2012;37(6):610–6.
50. Knight GM, McIntyre JM, others. The effect of silver fluoride and potassium iodide on the bond strength of auto cure glass ionomer cement to dentine. Aust Dent J. 2006;51(1):42–5.
51. Gotjamanos T. Safety issues related to the use of silver fluoride in paediatric dentistry. Aust Dent J. 1997;42(3):166–8.
52. Horst JA, Ellenikiotis H, Milgrom PM, Committee USCA, others. UCSF protocol for caries arrest using silver diamine fluoride: rationale, indications, and consent. J Calif Dent Assoc. 2016;44(1):16.
53. Zhi QH, Lo ECM, Lin HC. Randomized clinical trial on effectiveness of silver diamine fluoride and glass ionomer in arresting dentine caries in preschool children. J Dent. 2012;40(11):962–7.
54. Smales RJ, Yip HK. The atraumatic restorative treatment (ART) approach for primary teeth: review of literature. 2000 [cited 2016 Aug 4]; Available from: http://hub.hku.hk/handle/10722/65856
55. Arrow P. Restorative outcomes of a minimally invasive restorative approach based on atraumatic restorative treatment to manage early childhood caries: a randomised controlled trial. Caries Res. 2015;50(1):1–8.
56. Phonghanyudh A, Phantumvanit P, Songpaisan Y, Petersen PE. Clinical evaluation of three caries removal approaches in primary teeth: A randomised controlled trial. Community Dent Health. 2011;20:1–6.
57. Phantumvanit P. SMART preventive restoration for primary dentition. Int J Oral Health. 2012;8.
58. Schwendicke F, Frencken JE, Bjørndal L, Maltz M, Manton DJ, Ricketts D, et al. Managing carious lesions: consensus recommendations on carious tissue removal. Adv Dent Res. 2016 May 1;28(2):58–67.
59. Leal SC, Abreu DM de M, Frencken JE. Dental anxiety and pain related to ART. J Appl Oral Sci. 2009;17(SPE):84–8.
60. Honkala E, Behbehani J, Ibricevic H, Kerosuo E, Al-Jame G. The atraumatic restorative treatment (ART) approach to restoring primary teeth in a standard dental clinic. Int J Paediatr Dent. 2003;13 (3):172–9.
61. Ersin NK, Candan U, Aykut A, Eronat C, Kose T, et al. A clinical evaluation of resin-based composite and glass ionomer cement restorations placed in primary teeth using the ART approach: results at 24 months. J Am Dent Assoc. 2006;137(11):1529–36.
62. Faccin ES, Ferreira SH, Kramer PF, Ardenghi TM, Feldens CA. Clinical performance of ART restorations in primary teeth: a survival analysis. J Clin Pediatr Dent. 2009;33(4):295–8.

63. Raggio DP, Hesse D, Lenzi TL, AB Guglielmi C, Braga MM. Is atraumatic restorative treatment an option for restoring occluso-proximal caries lesions in primary teeth? A systematic review and meta-analysis. Int J Paediatr Dent. 2013;23(6):435–43.
64. Forsten L. Fluoride release and uptake by glass-ionomers and related materials and its clinical effect. Biomaterials. 1998;19(6):503–8.
65. Cagetti MG, Carta G, Cocco F, Sale S, Congiu G, Mura A, et al. Effect of fluoridated sealants on adjacent tooth surfaces a 30-mo randomized clinical trial. J Dent Res. 2014; 93(7 Suppl):59S-65S.
66. Ludwig KH, Fontana M, Vinson LA, Platt JA, Dean JA. The success of stainless steel crowns placed with the Hall technique: A retrospective study. J Am Dent Assoc. 2014;145(12):1248–53.
67. Fontana M, Ludwig KH, Fontana M, Vinson LA, Platt JA. The success of stainless steel crowns placed with the Hall technique: a retrospective study. J Am Dent Assoc. 2014;145(12):1248-53.
68. Page LA, Boyd DH, Davidson SE, McKay SK, Thomson WM, Innes NP. Acceptability of the Hall Technique to parents and children. NZ Dent J. 2014;110(1):12–7.
69. American Association of Pediatric Dentistry. Guideline on Restorative Dentistry. In [cited 2016 Aug 4]. Available from: http://www.aapd.org/media/policies_guidelines/g_restorative.pdf
70. Buerkle V, Kuehnisch J, Guelmann M, Hickel R. Restoration materials for primary molars—results from a European survey. J Dent. 2005;33(4):275–81.
71. Tran LA, Messer LB. Clinicians choices of restorative materials for children. Aust Dent J. 2003;48 (4):221–32.
72. Guelmann M, Mjor IA, Jerrell GR. The teaching of Class I and II restorations in primary molars: a survey of North American dental schools. Pediatr Dent. 2001;23(5):410–4.
73. Qvist V, Laurberg L, Poulsen A, Teglers PT. Longevity and cariostatic effects of everyday conventional glass-ionomer and amalgam restorations in primary teeth: three-year results. J Dent Res. 1997;76 (7):1387–96.
74. Mjör IA, Dahl JE, Moorhead JE. Placement and replacement of restorations in primary teeth. Acta Odontol Scand. 2002;60(1):25–8.
75. Roberts JF, Attari N, Sherriff M. The survival of resin modified glass ionomer and stainless steel crown restorations in primary molars, placed in a specialist paediatric dental practice. Br Dent J. 2005;198(7):427–31.
76. Raggio DP, Tedesco TK, Calvo AFB, Braga MM. Do glass ionomer cements prevent caries lesions in margins of restorations in primary teeth?: A systematic review and meta-analysis. J Am Dent Assoc. 2016;147(3):177–85.
77. Burke FT. Amalgam to tooth-coloured materials—implications for clinical practice and dental education: governmental restrictions and amalgam-usage survey results. J Dent. 2004;32(5):343–50.
78. Fuks AB. The use of amalgam in pediatric dentistry: new insights and reappraising the tradition. Pediatr Dent. 2015;37(2):125–32.
79. Yengopal V, Harnekar SY, Patel N, Siegfried N. Dental fillings for the treatment of caries in the primary dentition. Cochrane Libr [Internet]. 2009 [cited 2016 Aug4];Available from: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD004483.pub2/full
80. Dhar V, Hsu KL, Coll JA, Ginsberg E, Ball BM, Chhibber S, et al. Evidence-based update of pediatric dental restorative procedures: dental materials. J Clin Pediatr Dent. 2015;39(4):303–10.
81. Uribe S. Which filling material is best in the primary dentition? Evid Based Dent. 2010;11(1):4–5.
82. Attari N, Roberts JF. Restoration of primary teeth with crowns: a systematic review of the literature. Eur Arch Paediatr Dent. 2006;1(2):58–62.
83. Bell SJ, Morgan AG, Marshman Z, Rodd HD. Child and parental acceptance of preformed metal crowns. Eur Arch Paediatr Dent. 2010;11(5):218–24.

84. Oueis H, Atwan S, Pajtas B, Casamassimo PS. Use of anterior veneered stainless steel crowns by pediatric dentists. Pediatr Dent. 2010;32(5):413–6.
85. Citron CI. Esthetics in pediatric dentistry. N Y State Dent J. 1995;61(2):30–3.
86. American Association of Pediatric Dentistry. Guideline on behavior guidance for the pediatric dental patient [Internet]. [cited 2016 Aug 9]. Available from: http://www.aapd.org/media/policies_guidelines/g_behavguide.pdf
87. Vij R, Coll JA, Shelton P, Farooq NS. Caries control and other variables associated with success of primary molar vital pulp therapy. Pediatr Dent. 2004;26 (3):214–20.
88. Fuks AB. Vital pulp therapy with new materials for primary teeth: new directions and treatment perspectives. J Endod. 2008;34(7):S18–24.
89. American Association of Pediatric Dentistry. Guideline on pulp therapy for primary and immature permanent teeth [Internet]. [cited 2016 Aug 9]. Available from:http://www.aapd.org/media/policies_guidelines/g_pulp.pdf
90. Vargas KG, Fuks AB, Peretz B. Pulpotomy Techniques: Cervical (Traditional) and Partial. In: Pediatric Endodontics [Internet]. Springer; 2016 [cited 2016 Aug 4]. p. 51–70. Available from: http://link.springer.com/chapter/10.1007/978-3-319-27553-6_5
91. Peng L, Ye L, Guo X, Tan H, Zhou X, Wang C, et al. Evaluation of formocresol versus ferric sulphate primary molar pulpotomy: a systematic review and meta-analysis. Int Endod J. 2007;40(10):751–7.
92. Fei A-L, Udin RD, Johnson R. A clinical study of ferric sulfate as a pulpotomy agent in primary teeth. Pediatr Dent. 1990;13(6):327–32.
93. Marghalani AA, Omar S, Chen J-W. Clinical and radiographic success of mineral trioxide aggregate compared with formocresol as a pulpotomy treatment in primary molars: a systematic review and meta-analysis. J Am Dent Assoc. 2014;145 (7):714–21.
94. Shabzendedar M, Mazhari F, Alami M, Talebi M. Sodium hypochlorite vs formocresol as pulpotomy medicaments in primary molars: 1-year follow-up. Pediatr Dent. 2013;35(4):329–32.
95. Ruby JD, Cox CF, Mitchell SC, Makhija S, Chompu-Inwai P, Jackson J. A randomized study of sodium hypochlorite versus formocresol pulpotomy in primary molar teeth. Int J Paediatr Dent. 2013;23 (2):145–52.
96. Holan G, Fuks AB. A comparison of pulpectomies using ZOE and KRI paste in primary molars: a retrospective study. Pediatr Dent. 1992;15(6):403–7.
97. Özalp N, Şaroğlu I, Sönme H. Evaluation of various root canal filling materials in primary molar pulpectomies: an *in vivo* study. American Journal of Dentistry. 2005;18(6):347-350.
98. Kubota K, Golden BE, Penugonda B. Root canal filling materials for primary teeth: a review of the literature. J Dent Child. 1991;59(3):225–7.
99. Coll J, Seale NS, Vargas K, Chi DL, Marghalani AA, Graham L. Protocol for a systematic review and meta-analysis of vital pulp therapy for children with deep caries in the primary dentition. Pediatr Dent. 2015;37(5):418–21.
100. Croll TP. Restorative dentistry for preschool children. Dent Clin North Am. 1995;39(4):737–70.
101. Ten Berge M. Dental fear in children: clinical consequences Suggested behaviour management strategies in treating children with dental fear. Eur Arch Paediatr Dent. 2008;9(1):41–6.
102. Eaton JJ, McTigue DJ, Fields HW, Beck FM. Attitudes of contemporary parents toward behavior management techniques used in pediatric dentistry. Pediatr Dent. 2005;27(2):107–13.
103. Peretz B, Kharouba J, Blumer S. Pattern of parental acceptance of management techniques used in pediatric dentistry. J Clin Pediatr Dent. 2013;38(1):27–30.

104. Lourenço-Matharu L, Ashley PF, Furness S. Sedation of children undergoing dental treatment. Cochrane Libr [Internet]. 2012 [cited 2016 Aug 4]; Available from: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD003877.pub4/pdf

105. Alcaino EA. Conscious sedation in paediatric dentistry: current philosophies and techniques. Ann R Australas Coll Dent Surg. 2000;15:206–10.

106. Webb MD, Moore PA. Sedation for pediatric dental patients. Dent Clin North Am. 2002;46(4):803–14.

107. Cantlay K, Williamson S, Hawkings J. Anaesthesia for dentistry. Contin Educ Anaesth Crit Care Pain. 2005;5(3):71–5.

108. Eshghi A, Samani MJ, Najafi NF, Hajiahmadi M. Evaluation of efficacy of restorative dental treatment provided under general anesthesia at hospitalized pediatric dental patients of Isfahan. Dent Res J. 2012;9(4):478.

109. Malden PE, Thomson WM, Jokovic A, Locker D. Changes in parent-assessed oral health-related quality of life among young children following dental treatment under general anaesthetic. Community Dent Oral Epidemiol. 2008;36(2):108–17.

110. Filstrup SL, Briskie D, Da Fonseca M, Lawrence L, Wandera A, Inglehart MR. Early childhood caries and quality of life: child and parent perspectives. Pediatr Dent. 2003;25(5):431–40.

111. Cantekin K, Yildirim MD, Cantekin I. Assessing change in quality of life and dental anxiety in young children following dental rehabilitation under general anaesthesia. Pediatr Dent. 2014 Jan 15;36 (1):12E – 17E.

112. Anderson HK, Drummond BK, Thomson WM. Changes in aspects of children's oral-health-related quality of life following dental treatment under general anaesthesia. Int J Paediatr Dent. 2004;14 (5):317–25.

113. Wong S, Anthonappa RP, Ekambaram M, McGrath C, King NM, Winters JC. Quality of life changes in children following emergency dental extractions under general anaesthesia. Int J Paediatr Dent. 2016 Jun 1; doi:10.1111/ipd12241.