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An overview of dental caries-preventive approaches for children

ABSTRACT

Dental caries is biofilm-induced acid demineralization of enamel and dentin, which is mediated by saliva. Given time, the interaction of cariogenic microorganisms and fermentable carbohydrates on the tooth surface may induce demineralization and progress to loss of tooth structure and cavitations. Despite the implementation of community water fluoridation and the widespread use of fluoride toothpastes, dental caries remains a significant problem in Hong Kong preschool children. Of great concern, dental caries is unequally distributed among the population and heavily concentrated in socially disadvantaged children, who are least likely to have adequate access to dental care. Dental caries in children is a preventable and reversible infectious disease process. In children, prevention improves their overall quality of life, reduces the cost of restorative treatment, and promotes a positive attitude towards oral health. The objective of the paper was to provide an overview of the effectiveness of various caries-preventive agents which can be applied to the teeth of children in Hong Kong. These include the use of chlorhexidine, xylitol, fluorides, fissure sealant, and remineralizing products. Increased emphasis on caries prevention by the dental profession could bring about more favorable oral health outcomes for children in Hong Kong.

Key words: Child; Chlorhexidine; Dental caries/prevention and control; Fluorides; Pit and fissure sealants; Xylitol

Introduction

Dental caries

Fundamentally, dental caries is biofilm (dental plaque)-induced acid demineralization of enamel and dentin, which is mediated by saliva. Given time, the interaction of cariogenic microorganisms (mutans streptococcus and lactobacilli) and fermentable carbohydrates on the tooth surface may induce demineralization and progress to loss of tooth structure and cavitation. Early childhood caries (ECC) encompasses all dental caries that occurs in the primary dentition of young children. It has been defined as the presence of one or more decayed (noncavitated or cavitated), missing (due to caries) or filled tooth surfaces in any primary tooth in a child aged 71 months or younger [1]. In children younger than 3 years, any sign of smooth surface caries is indicative of severe ECC (S-ECC). During the age period 3 to 5 years, one or more cavitated, missing (due to caries), or filled smooth surfaces in the primary maxillary anterior teeth or a decayed, missing, or filled score of ≥4 (in a 3-year-old), ≥5 (in a 4-year-old), or ≥6 (in a 5-year-old) surfaces constitutes S-ECC [2].

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Epidemiology of caries in Hong Kong children

Despite the implementation of community water fluoridation and the widespread use of fluoride toothpastes, dental caries remains a significant problem for many Hong Kong preschool children. According to the oral health survey in 2001 [3], 51% of the 5-year-old Hong Kong children had ECC, with a mean decayed, missing or filled teeth (dmft) score of 2.3. Over 90% of the decayed teeth were untreated. Of great concern was the distribution of decayed teeth among 5-year-old children because it was highly polarized; almost one quarter (23.6%) of the 5-year-olds had four or more teeth with caries experience. Conversely, in a recent survey of dental health status of 3- to 5-year-old Hong Kong preschool children, the proportion of children with caries experience was found to have increased from 31% among the 3-year-olds to 42% among the 5-year-olds [4]. Similarly, dental caries is unequally distributed among the population and heavily concentrated in socially disadvantaged children, who are least likely to have adequate access to dental care [4]. For the younger age-group, S-ECC was found in 7.6% of the 1- to 3-year-old preschool children [5]. However, dental caries was not a problem among the 12-year-olds, as almost 80% of the students participated and received oral health care from the School Dental Care Service every year [3]. Around one third (38%) of the 12-year-olds had experienced caries in their permanent teeth, with a mean DMFT score of 0.8. Most of the decay experience (i.e. DMFT) was the filled component; while the proportion of untreated decay was relatively low.

Impact of early childhood caries

Early childhood caries in primary teeth is a preventable and reversible infectious disease process. The consequences of ECC are numerous and affect the child's overall quality of life. Untreated caries will progress quickly to involve the pulp and give rise to spontaneous pain, which may in turn disturb the child's sleep at night and affect academic performance at school. A child with multiple carious teeth may develop a poor appetite and weight loss, and chewing becomes painful or difficult. The longer that carious primary teeth remain untreated and the disease is allowed to advance, the more likely it is that treatment will be complicated, unpleasant, time-consuming, and expensive for the parents. Loss of space due to interproximal caries and early extraction can lead to malocclusion because the natural shedding sequence is disrupted and inadequate space remains for the permanent teeth. This will increase the need and complexity of subsequent orthodontic treatment.

Caries risk assessment

Early identification of children falling into the high caries risk group is essential for improving oral health in a cost-effective manner. Caries risk assessment depends on the likely incidence of caries during a certain time period. As dental caries is a dynamic process that can progress, reverse or remain inactive depending on the balance of factors that promote demineralization and remineralization, the goal of caries risk assessment is to screen out low-risk patients, and to identify high-risk patients and prevent caries initiation before the first sign of disease, as well as to monitor changes in disease status in caries-active patients. The caries risk assessment forms for dental providers (Tables 1 and 2), developed by the American Academy of Pediatric Dentistry, are used to assess the level of risk for caries development in infants, children and adolescents based on a set of clinical, environmental and general health factors [6]. Such assessment is recommended to be a routine component of new and periodic examinations by oral health providers.

Caries-preventive approaches

Caries is typically described as a multifactorial process, involving specific oral microflora, diet and a susceptible host. Based on the level of caries risk, different preventive approaches can be employed. These approaches can be classified into three distinct categories: (i) reducing cariogenic microbes in the oral cavity; (ii) reducing the exposure of these microbes to cariogenic substrates; and (iii) increasing the caries resistance of the tooth. The objective of this paper is to provide an overview of the effectiveness of various caries-preventive agents, which can be applied to the teeth of children in Hong Kong.

Reducing cariogenic microbes in the oral cavity

Chlorhexidine

Due to its highly cationic (positive) charge, chlorhexidine (CHX) reduces the number of mutans streptococci (MS).

However, it does not seem to be effective against lactobacilli. Chlorhexidine is available in a variety of formulations and vehicles, such as mouthrinses, gels, toothpastes, and varnish. A review of studies on the MS-inhibiting efficacy of various formulations of CHX has shown that the most effective reduction in MS was achieved by CHX varnishes, followed by gels and mouthwashes [7].

An early meta-analysis of eight clinical trials conducted between 1978 and 1991 on the caries-inhibiting effect of CHX therapy (rinse, gel and toothpaste) reported a prevented caries fraction of 46% [8]. A subsequent systematic review of trials published between 1995 and 2003 rated the evidence for the effectiveness of CHX varnish as inconclusive for

Table 1 **Caries risk assessment form for 0- to 5-year-olds [6]**

Factors *	High risk	Moderate risk	Protective
Biological			
Mother/primary caregiver has active caries	Yes		
Parent/caregiver has low socio-economic status	Yes		
Child has more than three between-meal sugar-containing snacks or beverages per day	Yes		
Child is put to bed with a bottle containing natural or added sugar	Yes		
Child has special health care needs		Yes	
Child is a recent immigrant		Yes	
Protective			
Child receives optimally fluoridated drinking water or fluoride supplements			Yes
Child has teeth brushed daily with fluoridated toothpaste			Yes
Child receives topical fluoride from health professional			Yes
Child has dental home/regular dental care			Yes
Clinical findings			
Child has >1 decayed/missing/filled surfaces (dmfs)	Yes		
Child has active white spot lesions or enamel defects	Yes		
Child has elevated mutans streptococci level	Yes		
Child has plaque on teeth		Yes	

* Circling those conditions that apply to a specific patient helps the practitioner and parent understand the factors that contribute to or protect from caries. Risk assessment categorization of low, moderate, or high is based on preponderance of factors for the individual. However, clinical judgment may justify the use of one factor (e.g. frequent exposure to sugar-containing snacks or beverages, more than one dmfs) in determining overall risk

Table 2 **Caries risk assessment form for above 6-year-olds [6]**

Factors *	High risk	Moderate risk	Protective
Biological			
Patient is of low socio-economic status	Yes		
Patient has more than three between-meal sugar-containing snacks or beverages per day	Yes		
Patient has special health care needs		Yes	
Patient is a recent immigrant		Yes	
Protective			
Patient receives optimally fluoridated drinking water			Yes
Patient brushes teeth daily with fluoridated toothpaste			Yes
Patient receives topical fluoride from health professional			Yes
Additional home measure (e.g. xylitol, MI paste, antimicrobial)			Yes
Patient has dental home/regular dental care			Yes
Clinical findings			
Patient has ≥1 interproximal lesions	Yes		
Patient has active white spot lesions or enamel defects	Yes		
Patient has low salivary flow rate	Yes		
Patient has defective restorations		Yes	
Patient is wearing an intraoral appliance		Yes	

* Circling those conditions that apply to a specific patient helps the practitioner and parent understand the factors that contribute to or protect from caries. Risk assessment categorization of low, moderate, or high is based on preponderance of factors for the individual. However, clinical judgment may justify the use of one factor (e.g. frequent exposure to sugar-containing snacks or beverages, more than one decayed/missing/filled surfaces) in determining overall risk

caries-active schoolchildren and adolescents who had daily exposure to fluoride [9].

A recent systematic review of 10 placebo-controlled clinical trials published during the period 1995 to 2006 on the caries-inhibiting effect of CHX varnishes on the permanent dentition of children, adolescents and young adults that did not receive any preventive treatment [10] concluded that CHX varnish has a moderate caries-inhibiting effect when applied every 3 to 4 months. This effect seems to diminish approximately 2 years after the last application. The evidence for the effectiveness of CHX varnish for preventing caries in primary teeth is judged to be insufficient [11]. Hence, due to a lack of clinical evidence, the routine use of CHX for caries prevention in children is not currently recommended.

Reducing the exposure of microbes to cariogenic substrates

Xylitol

Sugar alcohols, such as xylitol, sorbitol, mannitol and maltitol have been shown to be non-cariogenic [12]. Xylitol can be found as an additive in chewing gums, chewable tablets, lozenges, toothpastes, mouthwashes, and cough mixtures. Xylitol-containing gum appears to be more effective than sorbitol or combinations of xylitol and sorbitol in chewing gum [13]. Xylitol is not fermented by cariogenic plaque bacteria and thus does not lower the pH of plaque. As pH is not reduced, enamel demineralization is prevented and remineralization is enhanced. Xylitol reduces plaque accumulation on the surface of a tooth [14]. It accumulates intracellularly in MS and inhibits bacterial growth. Long-term, habitual consumption of xylitol appears to have a selective effect on MS, resulting in certain populations becoming less adherent to tooth surfaces [15]. These colonies are shed more easily from plaque into saliva. This effect may also hamper the transmission and subsequent colonization from mother to child.

In a recent systematic review to assess the impact of polyol-containing chewing gum on dental caries, it was concluded that compared with no use of chewing gum, the mean prevented fraction was 59% for xylitol, 53% for xylitol-sorbitol blend, and 20% for sorbitol [16]. For long-term caries-preventive effects to be maximized, habitual xylitol gum-chewing should be started at least 1 year before the permanent teeth erupt [17]. Although xylitol-containing gums have demonstrated great success in reducing caries, very young children may have difficulty in using chewing gum and may have a tendency to swallow it. High single doses may induce intestinal discomfort and osmotic diarrhea in susceptible individuals [13]. Maternal xylitol consumption has been shown to reduce bacteria in the oral cavity as well as transmission of MS from mother to child [18].

In summary, considerable evidence is available to support the use of xylitol chewing gum as part of a normal oral hygiene regimen for mothers and older children, in order to prevent dental caries.

Dietary control

There is no question that caries risk is greatest if sugars and fermentable carbohydrates are consumed at high frequency and in a form that remains in the mouth for longer periods. In a systematic study of sugar consumption and caries risk, the authors concluded that the relationship between sugar consumption and caries is much weaker in this modern age of fluoride exposure than in the prefluoride era [19]. However, there is evidence that frequent bottle feeding at night, breast-feeding *ad libitum*, extended and repetitive use of a no-spill training cups are associated, but not consistently implicated in ECC [20]. Frequent consumption of refined carbohydrates and acid-containing beverages place children and adolescents at increased risk of caries [21-23]. Restriction of sugar consumption still has an important role in caries prevention. Dietary counseling should begin with the mother before birth, and continue through infancy, childhood, and adolescence.

Increasing the caries resistance of the tooth

Fluoride

The mechanisms of action of fluoride are both systemic (pre-eruptive) and topical (post-eruptive). However, current evidence suggests that the actions of fluoride are primarily topical for both adults and children [24]. The pre-eruptive incorporation of fluoride ions into the developing enamel structure is considered to result in the formation of fluoroapatite. The post-eruptive effect acts in two ways, fluoride concentrated in plaque and saliva reduces enamel dissolution and encourages remineralization. As cariogenic bacteria metabolize carbohydrates and produce acid, fluoride is released from dental plaque in response to the low pH at the tooth-plaque interface. The released fluoride ions in saliva are taken up along with calcium and phosphate by demineralized enamel to establish an improved enamel structure. Low levels of fluoride may inhibit the glycolytic pathway of cariogenic bacteria, by reducing the conversion of sugars into acids and interfering with bacterial production of adhesive polysaccharides [25]. High levels of fluoride may also have bactericidal effects.

Fluoride gel

Professionally applied fluoride gels and foams are available with 1.23% acidulated phosphate fluoride formulations (12,300 ppmF) and as 2% neutral sodium fluoride containing 9,000 ppm. A meta-analysis of data from 17 studies concluded that fluoride gel applications reduced the caries increment in the permanent dentition by 22% [26]. A 2002 Cochrane systematic review involving 14 placebo-controlled trials reported a pooled prevented fraction of 21% in the permanent dentition with the active treatment as compared to placebo or no treatment [27]. There is insufficient evidence to address whether or not there is a difference in the efficacy of sodium fluoride versus applied topical fluoride (APF) gels [28]. However, APF gel should not be used on patients with composite, glass ionomer and porcelain restorations, because the acidic gel can etch and damage the surface morphology of such restorations. Little information is available concerning primary dentition [27]. However, with poor acceptance of tray applications in young children and the risk from swallowing excessive amounts of fluoride gel, fluoride varnish is nevertheless preferred for children under the age of 6 years.

There are considerable data on caries reduction for professionally APF gel treatments lasting 4 minutes or more [27]. Conversely, no clinical data are available on the efficacy of 1-minute applications; therefore, 1-minute applications of fluoride gels are not recommended. Fluoride foam was marketed in the early 90's because it had the advantage of requiring only a small amount for each application, thereby reducing the risk associated with inadvertent ingestion. Although laboratory data showed similar levels of fluoride release from foam and gel [29], only two clinical trials have been published evaluating the effectiveness of fluoride foam [30,31], for which further studies in children are still required.

Fluoride varnish

Varnishes are available as sodium fluoride (2.26% [22,600 ppm] fluoride) or difluorsilane (0.1% [1,000 ppm] fluoride) preparations. Varnishes consist of organic or synthetic resin materials with fluoride incorporated. The fluoride varnish often comes in individual packets with a disposable brush. It is painted directly onto dry teeth by an oral health care professional. The varnish hardens with moisture contact. Parents have been instructed to give their child a soft diet and avoid toothbrushing for the next 12 hours [32].

Application should target the enamel surfaces along the gingival margins and interproximal surfaces below the contact points. Fluoride varnish also helps to prevent caries on the occlusal surface of partially erupted molars. Applying a thin layer of fluoride varnish to the pits and fissures of partially erupted molars, especially the surface that is covered by the operculum, protects the immature enamel until the tooth erupts sufficiently so that a fissure sealant placement can be performed successfully [33,34].

A Cochrane systematic review of seven trials on the effectiveness of fluoride varnish for preventing caries reported a pooled prevented fraction of 46% for permanent teeth and 33% for primary teeth [35]. This was based on a comparison of the use of varnish 2 or 4 times a year with a placebo or no treatment. In comparison with fluoride gel, the advantages of varnish include adherence to the tooth surface, decreased likelihood of ingestion at one time, and increased contact time between the fluoride and tooth surface allowing slow release of fluoride over time. Furthermore, fluoride varnish creates less patient discomfort and hence achieves greater patient acceptability than does fluoride gel, especially in preschool children.

Fluoride toothpaste

The extensive use of fluoridated toothpastes has probably been one of the major reasons for the dramatic reduction in dental caries over the past 30 years. A recent Cochrane review of 66 studies on the effectiveness and safety of fluoride toothpastes in the prevention of caries in children concluded that such use is associated with a pooled prevented fraction of 23% in the mixed and permanent dentitions of children and adolescents, when comparing 1000-to-1250 ppmF toothpaste with a non-fluoride toothpaste [36]. In another systematic review [37], daily use of fluoride toothpaste had a significant caries-preventive effect with a prevented fraction of 24% in children when compared with placebo toothpastes.

The anticaries effect significantly improved with supervised toothbrushing, increased brushing frequency to twice daily, as well as use of a toothpaste with a concentration of 1,500 ppmF [37]. However, both reviews noted that there was little information regarding the effectiveness of fluoridated toothpaste in primary dentition.

The effectiveness of fluoride toothpaste is concentration dependent. Systematic reviews [36,38] comparing the anticaries efficacy of children's toothpastes concluded that toothpastes with fluoride concentrations of 1000 ppm and above are effective in the prevention of caries in the permanent dentition. Low-concentration fluoride toothpastes were introduced specifically for young children. Evidence on the effectiveness of these low-fluoride toothpastes (<600 ppmF) for preventing caries in primary teeth is not robust [38].

One problem with young children's use of toothpaste is that they may swallow considerable amounts, thus posing a subsequent risk for dental fluorosis [39]. Dental fluorosis is a developmental disturbance of enamel, resulting from an increase in the fluoride concentration within the micro-environment of the ameloblasts during enamel formation. It occurs as a result of excessive fluoride ingestion during tooth development. It is characterized by increased subsurface hypomineralization of enamel, causing the enamel to appear opaque. The very mild and mild forms of enamel fluorosis appear as chalky white, lacy striations across the enamel surface. In the moderate form of fluorosis, more than 50% of the enamel surface is rendered opaque white. With severe fluorosis, the enamel becomes pitted and brittle and may develop areas of brown staining [40].

The occurrence of dental fluorosis is reported to be most strongly related to cumulative fluoride intake during enamel development, but the severity of the condition depends on the dose, duration of exposure, and timing of fluoride use [41]. Inappropriate use of fluoride toothpastes and fluoride supplements in young children are two major factors associated with increased risk of developing fluorosis [42]. The maturation stage of enamel development is most sensitive to chronic exposure to low levels of fluoride [43]. The maxillary central incisors are reportedly most susceptible to fluorosis from 15 to 24 months of age for males, and 21 to 30 months of age for females [44]. After 8 years of age, the enamel of the incisors is no longer susceptible to enamel fluorosis.

For children less than 6 years old, the best balance between risk and efficacy might be achieved by using only small amounts of high-fluoride toothpaste under close parental supervision. Parents should obtain professional advice with regard to the use of fluoride toothpaste when children are perceived to have high risk of dental caries. A 'smear' of fluoridated toothpaste for children younger than 2 years may decrease the risk of fluorosis when brushing with a toothpaste containing at least 1,000 ppmF. A 'pea-sized' amount of toothpaste is said to be appropriate for children aged 2 to 5 years [45].

Parents should dispense the toothpaste onto a soft, age-appropriate–sized toothbrush and perform or assist with toothbrushing until at least 7 years of age. Because many children at this age have not learned to successfully control the swallowing reflex, parents should encourage the child to spit excess toothpaste into the sink. To maximize the beneficial effect of fluoride in the toothpaste, rinsing after brushing should be kept to a minimum or preferably be eliminated [46]. Therefore, older patients should be advised to spit out excess toothpaste and not to rinse after toothbrushing. However, for younger children, a balance needs to be achieved. Flossing should be initiated by the mother on a daily basis when adjacent tooth surfaces cannot be cleansed by a toothbrush to help dislodge food and bacterial plaque levels.

Fluoride mouthrinse

Fluoride mouthrinse is a concentrated solution intended for daily or weekly use. The most common fluoride compound used in mouthrinses is sodium fluoride. Over-the-counter solutions of 0.05% sodium fluoride (230 ppmF) for daily rinsing are available for use by persons older than 6 years. Solutions of 0.20% sodium fluoride (920 ppmF) are used in supervised, school-based weekly rinsing programs. The fluoride from a mouthrinse is retained in dental plaque and saliva to help prevent caries. Children younger than 6 years should not use a fluoride mouthrinse without consultation with a dentist, because enamel fluorosis may ensue if repeatedly swallowed.

A Cochrane systematic review of 34 studies on the effectiveness of fluoride mouthrinse for preventing caries reported a prevented fraction of 26% on the permanent dentition, when compared to placebo or no treatment [47]. There was no significant association between the mouthrinse's effectiveness and the baseline caries, background exposure to other sources of fluoride, rinsing frequency and the mouthrinse's fluoride concentration. Another systematic review on the caries-preventive effect of sodium fluoride mouthrinses concluded that sodium fluoride mouthrinses may have an anticaries effect in children with limited background of fluoride exposure, while the additive effect in those using fluoride toothpaste daily was questionable [48]. As fluoride mouthrinse results in only a limited reduction in caries among schoolchildren, and especially as their exposure to other sources of fluoride has increased, its use should be targeted at individuals, or groups that are at high risk for caries. The latter include: patients undergoing orthodontic treatment, children with reduced salivary flow from medications or radiation therapy, and those wearing intraoral prostheses [49].

Fluoride supplements

Fluoride supplements were introduced to provide anticaries benefits to populations that resided in areas where optimally fluoridated water was unavailable, or where the primary source of drinking water had a low fluoride concentration. The recommended daily dose is based on a child's age and on the concentration of fluoride in drinking water. Tablets, lozenges, or liquids (including fluoride-vitamin preparations) are also available. Most supplements contain sodium fluoride as the active ingredient. Tablets and lozenges are manufactured with 1.0, 0.5, or 0.25 mg fluoride. To maximize the topical effect of fluoride, tablets and lozenges are intended to be chewed or sucked for 1 to 2 minutes before being swallowed [49]. Before supplements are prescribed, it is essential to review all dietary sources of fluoride (drinking water, consumed beverages, prepared food, toothpaste) to determine a child's true fluoride exposure [50].

In a systematic review of the effectiveness of fluoride supplements in preventing caries and their association with dental fluorosis, the authors concluded that the inappropriate use of supplements increases the risk factor for mild-to-moderate fluorosis, especially in young children during the first 6 years of life [51]. Fluoride supplements should not be prescribed to Hong Kong children as the public water supply is optimally fluoridated at 0.5 ppm. Some parents purchase bottled water for their children to drink instead of tap water; however, most bottled waters lack fluoride or the actual quantity is unclear. Prescribing the correct dosage of fluoride supplements for these children is difficult as they also spend considerable time in kindergartens and day-care centers consuming food and drinks that may be processed with fluoridated water; hence, in these children the use of fluoride supplements is not recommended too.

Silver diamine fluoride

A 38% silver diamine fluoride (SDF) solution is commonly used for preventing and arresting caries in children [52,53]. Silver diamine fluoride is postulated to prevent or arrest caries by three mechanisms. Firstly, through the action of fluoride; secondly, via the reaction of silver with bacterial amino acids and nucleic acids, which prevents metabolism and renders them bactericidal; and finally by precipitation of a layer of insoluble silver apatite [54]. The advantages of using SDF are immediate caries arrest, control of pain and infection, affordability, simplicity, and minimal need for follow-up [55]. Although the main disadvantages of using SDF to arrest caries are black staining and gingival sensitivity, the problems appear preventable with the use of potassium iodide, which reacts with the free silver ions to form a creamy white silver iodide [56]. A recent systematic review reported that SDF's lowest prevented fractions for caries arrest and caries prevention were 96% and 70%, respectively; whereas, for fluoride varnish, the corresponding highest prevented fractions were 21% and 56% [57]. These promising results suggest that SDF is more effective than fluoride varnish, and may be a valuable caries-preventive intervention for children with special needs, or to arrest caries progression among children in developing countries [55].

Fissure sealants

Fissure sealants are applied onto the pits and fissures of a caries-susceptible tooth, where they form a micro-mechanically bonded layer on the tooth surface and an oral environment, which can protect it from the environment and so prevent caries initiation and progression. A Cochrane systematic review of 16 trials found that when compared with unsealed molars, first permanent molar teeth sealed with resin-based sealant had a 78% reduction in caries on the occlusal surfaces after 2 years, and a 60% reduction after 4 to 4.5 years [58].

A meta-analysis of six studies, which examined the effectiveness of sealants in preventing caries progression in permanent teeth, showed that the median annual percentage of non-cavitated lesions progressing was 2.6% for sealed and 12.6% for unsealed carious teeth [59]. Moreover, there were no findings of significant increases in bacteria under sealants. Sealing caries was associated with a 100-fold reduction in the number of viable bacteria and reduced the number of lesions with viable bacteria by 50%, as long as the sealant remained intact [60]. Even, sealing non-cavitated caries in permanent teeth is effective in reducing caries progression.

Two types of available fissure sealants are predominant, namely resin-based and glass ionomers. Resin-based sealants can be polymerized by autopolymerization or photopolymerization using visible light or both. There are also two types of glass ionomer sealants: conventional and resin-modified. Glass ionomer sealants do not require additional acid-etching of enamel surface and are therefore easier to apply than those that are resin-based. Based on systematic reviews on caries-preventive effects of glass ionomer and resin-based fissure sealants on permanent teeth [61], it has been concluded that there is no difference in the caries-preventive effect of the glass ionomer and resin-based types over 2 to 3 years. In clinical situations where moisture control may be ineffective, the less technique-sensitive glass ionomer sealant may be used as an effective alternative sealant material.

A systematic review of 31 studies on the retention of resin-based pit and fissure sealants revealed no difference in the retention rate of autopolymerized, or light-cured resin-based sealant, whatever the follow-up time; at 48 months however, fluoride-containing light-cured resin-based sealant had a significantly lower retention rate than light-cured resin-based sealants without fluoride [62]. An etch-and-rinse adhesive, which contains both an adhesive and a primer, may be used between the previously acid-etched enamel surface and the sealant material to enhance sealant retention in the clinical situation [63]. However, the use of a self-etching adhesive, which does not involve a separate etching step, may provide less retention than the standard acid-etching technique and is thus not recommended [64].

Recently, a Cochrane review of four studies was conducted to compare the effectiveness of pit and fissure sealants with fluoride varnishes for the prevention of caries on occlusal surfaces [65]. The follow-up times for the four studies were 1 year [66], 2 years [67,68], and 9 years (4 years of active caries-preventive programme plus 5 years of discontinuation of the active programme [69]). Resin-modified glass ionomer sealant was used in one study [66]; while resin-based sealants were used in the other three studies [67-69]. The fluoride varnish used was Duraphat (Colgate Oral Pharmaceuticals) in all four studies. For the prevention of occlusal caries, some evidence indicated the superiority of pit and fissure sealants over fluoride varnish [65]. Teeth with fully or partially lost sealants were not at higher risk of developing caries than teeth that had never been sealed [70].

In summary, fissure sealants should be placed on all permanent molar teeth without evidence of cavitation as soon after eruption as isolation can be achieved.

Remineralizing products

Recent developments in the area of remineralization include casein phosphopeptide-amorphous calcium phosphate (CPP-ACP). The milk protein, CPP, stabilizes high concentrations of calcium phosphate ions in ACP solutions. The CPP-ACP is taken up by dental biofilms and localizes to the enamel surface as nanoparticles. Calcium, phosphate and fluoride from CPP-ACP, which are released during acidogenic challenge, help to maintain the supersaturated state of these ions in the biofilm and so promote remineralization over demineralization [71]. A systematic review of 12 studies examining the clinical efficacy of casein derivatives concluded that the quantity and quality of clinical trial evidence are currently insufficient to draw conclusions regarding the long-term effectiveness of casein derivatives. Specifically, this review made the same inference about CPP-ACP, as a means of preventing caries in vivo and treating dentine hypersensitivity or dry mouth [72].

A recent meta-analysis on caries-preventive effect of CPP-ACP concluded that the in-situ clinical trials support their short-term remineralization effect when added to chewing gum, mouthrinse, lozenges, and milk [73]. Furthermore, the in-vivo randomized clinical trials provide promising results for the long-term use of CPP-ACP chewing gum for caries prevention [73].

Most of the anticaries effect of CPP-ACP come from in-situ model studies, mainly by one research group at the

University of Melbourne, which concluded that the current level of clinical evidence is inadequate to support its use as an alternative remineralization strategy to topically applied fluorides [74].

A summary of the various caries-preventive approaches for 0- to 5-year-olds and 6- to 12-year-olds based on caries risk assessment is shown in Tables 3 and 4.

Conclusions

Although dental caries in children is a preventable and reversible infectious disease process, achieving such outcomes is difficult and long-term risks still remain. Despite fluoride exposure, rapid progression of caries into dentin has been reported in second primary molars and first permanent molars of 6- to 12-year-old children, once the carious lesion has reached the inner half of the enamel as judged radiographically [75]. Early identification of children falling into the high-risk caries group is essential for improving dental health in a cost-effective manner. The effectiveness of CHX varnish in caries prevention for children remains inconclusive. Recent research supports the use of polyol-containing chewing gum to prevent dental caries in their young children, specifically in the form of maternal xylitol consumption as part of normal oral hygiene. Routine home care with fluoridated toothpaste is associated with reductions in caries increments. Semi-annual application of fluoride varnish is recommended for preschool children with high caries risk. Currently, CPP-ACP cannot be recommended as an alternative remineralization strategy to topically applied fluoride, due to limited clinical evidence. Fissure sealant remains the mainstay for the prevention of dental caries on occlusal surfaces. Based on assessment of caries risk, sealants should be placed on all permanent molar teeth without cavitation, as soon after their eruption as isolation can be achieved. Following the guidelines of the American Academy of Pediatric Dentistry, parents or caregivers are encouraged to establish a dental home for infants by 12 months of age. This could allow

Table 3 Dental caries-preventive approaches for 0-5 years old

	Low risk	Moderate risk	High risk
Chlorhexidine	Insufficient evidence	Insufficient evidence	Insufficient evidence
Toothbrushing with fluoride toothpaste	• Twice daily • Use 'smear' of fluoride toothpaste in those <2 years old • Use a small 'pea-sized' fluoride toothpaste in 2-5 years old	• Twice daily • Use 'smear' of fluoride toothpaste in those <2 years old • Use a small 'pea-sized' fluoride toothpaste in 2-5 years old	• Twice daily • Use 'smear' of fluoride toothpaste in those <2 years old • Use a small 'pea-sized' fluoride toothpaste in 2-5 years old
Fluoride varnish	No	At least every 6 months	Every 3 months
Fluoride mouthrinse	No	No	No
Fluoride supplements	Not recommended	Not recommended	Not recommended
Diet counseling	Yes	Yes	Yes
Recall	Every 6-12 months	Every 6 months	Every 3 months

Table 4 Dental caries-preventive approaches for 6-12 years old

	Low risk	Moderate risk	High risk
Chlorhexidine	Insufficient evidence	Insufficient evidence	Insufficient evidence
Toothbrushing with fluoride toothpaste	Twice daily	Twice daily	Twice daily
Fluoride varnish	No	At least every 6 months	Every 3 months
Fluoride mouthrinse	No	No	Yes
Fluoride supplements	Not recommended	Not recommended	Not recommended
Fissure sealants*	Yes	Yes	Yes
Diet counseling	Yes	Yes	Yes
Xylitol	No	No	Yes
Remineralizing products	Insufficient evidence	Insufficient evidence	Insufficient evidence
Recall	Every 6-12 months	Every 6 months	Every 3 months

* Indicated for teeth with deep fissure or developmental defects

institution of a caries risk assessment and provision of anticipatory guidance for prevention of oral diseases [76]. Increased emphasis on caries prevention by daily use of fluoride toothpaste, proper dietary control, and regular professional care could bring about a more favorable oral health outcome for children in Hong Kong.

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