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Review on role of Xylitol in the re-mineralization of dental caries:

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ABSTRACT: Natural demineralization of tooth at an early stage is reversed by saliva, which contains calcium ions, phosphate ions, buffering agents, fluoride, and other substances. The strategy for aided re-mineralisation is to have ions directly delivered to where and when they are needed the most.Xylitol promotes the remineralisation by the increasing of saliva rate and inhibition of bacteria growth by raising the pH of saliva, blocking the communication between saliva and bacteria to stop producing the polysaccharide. Sucrose forms complexes with calcium that allows precipitation of calcium out of saliva whilexylitol forms complexes with calcium that do not produce acid and maintain a supersaturated calcium level in saliva, which is important for remineralization of enamel. This is critical when teeth first erupt and are not completely mineralized. The ability of xylitol to maintain high salivary calcium levels as teeth erupt enhances final mineralization of these teeth. The ability of xylitol to bind with calcium is also evident in higher calcium levels measure in plaque when xylitol is present.Xylitol reduces the levels of mutans streptococci (MS) and Helicobacter pylori in plaque and saliva by disrupting their energy production processes, leading to futile energy cycle and cell death. It reduces the adhesion of these microorganisms to the teeth surface and also reduces their acid production potential (Tanzer et al., 2006). Xylitol in various vehicle was reported very effective in prevention of dental caries re-mineralization by several workers. The xylitol/chlorhexidine combination as mouth wash inhibited streptococci more when compared with xylitol or chlorhexidine being used alone.Xylitol gummy bear snacks consumption reported effective in reducing the cariogenic microorganisms in school-going children.Xylitol in syrup form can be indicated in young children with early childhood caries, as they are more likely to develop dental caries in permanent teeth than those without early childhood caries. This method of administration of xylitol is most acceptable and safe for toddlers and young children.Xylitol dentrifice in Toothpaste form led to a decrease in S. mutans colonies in saliva, the amount of secreted saliva, and the increase of pH value. It has a positive effect on the quality of the oral environment and it would be useful introducing it into prophylactic programmes.Xylitol and mother-child transmission of salivary S. mutanscan be prevented.Themothers who chew xylitol can decreaseS.mutans bacteria (responsible for dental caries in children) count in their mouth, can block vertical transmission from mother to child.

I. INTRODUCTION:

Xylitol is derived mainly from birch and other hardwood trees and discovered in 1890 by Fisher and Stahe in Germany as a sugar-alcohol, used as a natural sugar substitute during WWII in Finland (Bar, 1988). It is a natural polyol, used as saccharine re-placer and non-cariogenic edulcorant. It has been widely studied during the last 40 years for its effect on dental caries. It is found naturally in fruit, vegetables, and berries and is artificially manufactured from xylanrich plant materials such as birch and beechwood. The human body makes 5-10 grams of xylitol each day in the metabolism of carbohydrates. Xylitol's crystalline form looks and tastes like "table sugar," but contains only 2.4 calories per gram, providing 40 percent fewer calories than other carbohydrates having glycemic index 7, safer for diabetics patient.The most common source today is from fibers in corn cobs and corn stalks. It's digested as a fiber with no insulin released (Bar, 1988). On a commercial scale, xylitol can be produced by chemical and biotechnological processes mainly from birch trees or corn cobs (Rehman, 2015). Industrial xylitol production reproduces the same molecular structure of the natural one (Holgerson, 2007). Two main hypotheses explain the bacterial effect of xylitol on the caries processeither by a chewing movement (Mickenautsch, 2012) related to xylitol, producing saliva or as a sweetener substitute which is essentially not fermentable by the caries-inductive oral microflora (Trahan, 1995). Xylitol's principal mechanism is in its early action in the caries process and thereby, in the prevention of carious lesions (Trahan, 1995). Dental caries is a worldwide public health problem, affecting numerous urban and rural communities.The dental caries develops as a result of imbalance between de-mineralization and re-mineralisation process between tooth and dental biofilm. This process is regulated by various factors viz. dental biofilm's pH, Ca and PO4 levels, saliva buffering capacity, the use of fluoride and other anti-cariogenic agents, oral hygiene, diet and tooth anatomy. Xylitol promotes the re-mineralisation both by the increasing of saliva rate and inhibition of bacteria growth. Despite these anti-cariogenic properties, the proofs related to clinical effectiveness of xylitol are controversial. White-spot lesions (WSL) are the earliest macroscopic evidence of enamel caries. Typically, the enamel surface layer stays intact during subsurface de-mineralization, but, without treatment, will eventually collapse into a full cavity. Near-neutral pH of saliva is endowed with a natural buffering capacity. Turku, (1970) evaluated the effectiveness of xylitol on dental plaque reduction after that xylitol has been widely researched and globally accepted as a natural sweetener approved by the US Food and Drug Administration (FDA) and the American Academy of Pediatric Dentistry, 2010. The predominant modality for xylitol delivery recommended as a chewing gum. Chewing gum accelerates the processes of rinsing away acid and uptake of beneficial calcium phosphate molecules to re-mineralisetooth enamel. The recommended length of time for chewing after eating is approximately 20 minutes. Consumption of xylitol chewing gum for ≥3 weeks leads to both long-term and short-term reduction in salivary and plaque S. mutans levels (Deshpande and Jadad, 2008).

Mechanism of Xylitol action: Xylitol prevents caries in several ways. First, it interferes with the bacterial ability to produce acid. Second, it blocks communication between bacteria so they stop producing the polysaccharide slime that holds the biofilm together. Third, it raises the pH of the mouth. Cariogenic bacteria prefer living in a low pH environment and produce the acid that demineralizes enamel. In the presence of xylitol, the bacteria stop producing acid and the polysaccharide slime that holds the biofilm together, and they simply slide off the teeth. In the presence of sugar, bacteria thrive, produce acid and stick to the teeth. Bacterial numbers are significantly reduced in the presence of xylitol. Xylitol promotes an alkaline oral environment which is conducive to oral health.Sucrose forms complexes with calcium that allows precipitation of calcium out of saliva while xylitol forms complexes with calcium that do not produce acid and maintain a supersaturated calcium level in saliva, which is important for remineralization of enamel. This is critical when teeth first erupt and are not completely mineralized. The ability of xylitol to maintain high salivary calcium levels as teeth erupt enhances final mineralization of these teeth. The ability of xylitol to bind with calcium is also evident in higher calcium levels measure in plaque when xylitol is present.Xylitol reduces the levels of mutans streptococci (MS) in plaque and saliva by disrupting their energy production processes, leading to futile energy cycle and cell death. It reduces the adhesion of these microorganisms to the teeth surface and also reduces their acid production potential (Tanzer et al., 2006).Xylitol, like any other sweetener, promotes mineralization by increasing the salivary flow when used as chewing gum or large xylitol pastille. The uniqueness of xylitol is that it is practically nonfermentable by oral bacteria. Also, there is a decrease in levels of MS, as well as the amount of plaque, when there is habitual consumption of xylitol. Streptococcus mutans transports the sugar into the cell in an energy-consuming cycle that is responsible for growth inhibition. Xylitol is then converted to xylitol-5-phosphate via phosphoenolpyruvate: fructose phosphor-transferase system by S. mutans resulting in development of intracellular vacuoles and cell membrane degradation (Marttinen et al, 2012). unwittingly contributing to its own death, S. mutans then dephosphorylates xylitol-5-phosphate. The dephosphorylated molecule is then expelled from the cell. This expulsion occurs at an energy cost with no energy gained from xylitol metabolism. Thus, xylitol inhibits S. mutans growth essentially by starving the bacteria. Xylitol can inhibit the growth of harmful oral bacteria such as S. mutans, but its benefits do not stop in the oral cavity (Kontiokari et al; 1995). Xylitol alcohol has been shown to impact growth of nasopharyngeal bacteria such as S. pneumonia and S. mitis, and hence has a role to play in nasopharyngeal pneumonia.Tanzer et al (2006) Streptococcus mutans, the primary etiological agent of human dental caries, possesses at least two fructose phosphotransferase systems (PTSs), encoded by fru I and fru CD. fru I is also responsible for xylitol transport. They have hypothesized that fructose and xylitol transport systems do not affect virulence. Thus, colonization and cariogenicity of fru I− and fru CD−single and double mutants, their WT (UA159), and xylitol resistance (Xr) of S. mutans were studied in rats fed a high-sucrose diet.

Beneficial effects of Xylitol on dental caries prevention: Xylitol decreases the incidence of dental caries by increasing salivary flow and pH and reducing the number of cariogenic, S. mutans (MS) and periodontopathic (Helicobacter pylori) bacteria, plaque levels, xerostomia, gingival inflammation, and erosion of teeth (Nordblad et al; 1995).Xylitol is well tolerated by the human body as a sweetener, but its absorption rate in the small intestine is very slow. Excess xylitol is known to induce osmotic diarrhea, indicating there is an upper limit to its dosage that can be tolerated. Optimal inhibition of S. mutans growth by xylitol occurs with its total daily consumption of 5–6 g at a frequency of three or more times per day. The plaque samples of habitual xylitol users showed a significant reduction in plaque adhesiveness and insoluble extracellular polysaccharides produced by S. mutans when compared with those who did not consume xylitol at all (Kontiokari et al; 1995).Five FDA-approved non-nutritive sweeteners with intense sweetening power are acesulfame-K, aspartame, neotame, saccharin, and sucralose (Nordblad, 1995). Scientific evidence supports neither that intake of nutritive sweeteners by themselves increases the risk of obesity nor that nutritive or non-nutritive sweeteners cause behavioral disorders. However, nutritive sweeteners increase risk of dental caries. MS are the target organisms of xylitol, though several other bacterial species are also inhibited. Only certain strains of MS are inhibited by xylitol, and the degree of inhibition differs among the different strains (Vadeboncoeur et al; 1983).It has been observed that 80% of the total MS count was resistant to xylitol among the habitual xylitol consumers. However, the MS not inhibited by xylitol were found to be less virulent (Drucker et al; 1980).High concentrations of xylitol have been found to inhibit Lactococcus Lactis over time, but not S. salivarius and Lactobacillus casei. Xylitol prevents the adherence of pneumococcal and Haemophilus influenzae to nasopharyngeal cells due to fructose phosphotransferase system-mediated uptake and phosphorylation of xylitol in the cell. Xylitol reduces the levels of MS in plaque by various mechanisms. Firstly, plaque microorganisms cannot ferment xylitol. The ability of certain organisms to ferment xylitol is negated by inaction of other plaque organisms, which prevents the plaque pH from falling. Secondly, xylitol is incorporated into the cells of MS as xylitol-5-phosphate through the phosphoenolpyruvate phosphotransferase system. This results in inhibition of both growth and acid production. Thirdly, when exposed to xylitol, MS develop resistance to xylitol. These resistant strains are less virulent in an oral environment. Fourthly, xylitol increases the concentrations of ammonia and amino acids in plaque, thereby neutralizing plaque acids (Soderling et al; 1987).Remineralisation of initial caries lesions has been documented by various clinical and laboratory-based studies. However, remineralisation has been observed in all such experiments where non sugar sweeteners were used. The remineralisation occurs due to increased flow of saliva rich in calcium and phosphate and a shorter time interval of low plaque pH. The anticaries action of xylitol is mainly attributed to its effect on plaque and cariogenic microorganisms. Remineralisation in vivo is generally considered to be a slow process, and it is perhaps surprising that significant remineralisation occurs within 3 weeks. The stimulated saliva remineralizes enamel crystals damaged by initial caries attack more effectively than un-stimulated saliva because it has a higher concentration of ions that make up the lattice structure of hydroxyapatite (Ca^{2+}, $PO4^{3-}$, OH^{-}). Remineralisation of the enamel lesions was observed to be twice more with gum than without the gum (Bowen and Pearson, 1992).An anticaries effect of xylitol and sorbitol usage has been demonstrated and compared among primary and permanent teeth. The xylitol group had 27% fewer caries than the sorbitol group. This experiment also concluded that xylitol positively impacts permanent teeth. Recently, Murthykumar reported in (2013)that xylitol in milk demonstrated a beneficial anticaries effect and is well accepted by both children and adults. Induction of remineralization in deep layers of demineralized enamel using a remineralizing solution containing xylitol was studied. Demineralization at depths of 70–80 mm might be equivalent to the very early stages of natural caries progression. Our findings indicate the possibility of inducing remineralisation deep within enamel by utilizing the effect of xylitol. Concluding remarks include as morphologically the effect of xylitol on the remineralisation of artificially demineralized enamel were determined. Xylitol induces remineralisation of demineralized enamel in the deep and middle layers, but not in the surface layers.Kiet et al (2006) overviewed xylitol and other polyol sweeteners and their role in dental caries prevention in children and their applications for dental practice. Studies suggest polyols are noncariogenic and can decrease mutans

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streptococci levels in plaque and saliva.It can reduce dental caries in young children, mothers, and in children via their mothers. Food products containing xylitol are now available and have the potential to be widely accessible to consumers to help control rampant decay. Determining whether products contain adequate xylitol amounts for practical use towards prevention is challenging, however, because xylitol content is not clearly labeled. Sufficient evidence exists to support the use of xylitol to reduce caries.

Xylitol as a chewing gum: The predominant modality for xylitol delivery has been chewing gum. Chewing gum accelerates the processes of rinsing away acid and uptake of beneficial calcium phosphate molecules to remineralise tooth enamel. The recommended length of time for chewing after eating is approximately 20 minutes. Consumption of xylitol chewing gum for ≥3 weeks leads to both long-term and short-term reduction in salivary and plaque S. mutans levels (Deshpande and Jadad, 2008).A decrease in caries incidence has been reported among children exposed to the daily use of xylitol for 12–40 months. The long-term benefits have been observed up to 5 years after cessation of xylitol use. A prospective controlled, double-blind clinical trial confirmed that MS levels in plaque decreased as exposure to xylitol increased. However, a plateau effect was observed between 6.88 g/d and 10.32 g/d. The caries preventive effect was observed to be long term in relation to the teeth erupting during the period of xylitol use (Scheie and Fejerskov, 1998).A study among Montreal children showed that children who chewed xylitol gum had significantly lower caries progression after 24 months than those who did not use gum. These children exhibited a significantly higher number of reversals of carious lesions than the control group, suggesting that remineralization has occurred. In a long-term study it was confirmed that by using xylitol chewing gum, caries risk can be reduced by 59%, and the optimum time for introducing the chewing gum for caries prevention is at least 1 year prior to the eruption of permanent teeth (Hujoel et al., 1999).The effectiveness of various dosages of xylitol in the chewing gum was studied on S. mutans growth in adults. In a study by Milgrom et al. in 2006, a daily xylitol dose of 3.44 g/d, 6.88 g/d, and 10.32 g/d was given to the first, second, and third group, respectively. No xylitol gum was given to control group subjects. Saliva samples were obtained at the beginning of the study as well as after 5 weeks and 6 months of chewing gum with the indicated dosage of xylitol. S. mutans colonization in plaque and saliva was observed to decrease with increasing xylitol dosage. The S. mutans levels for subjects receiving 6.88 g and 10.32 g of xylitol per day were reduced over time compared with control subjects. There was no significant difference between subjects receiving 3.44 g/d and the control group; this indicated that xylitol levels of 3.44 g/d were insufficient to alter S. mutans levels in plaque and saliva. However, a plateau effect was evident between 6.88 g and 10.32 g when comparing the 5-week plaque and saliva samples and also in samples of 6 months of using chewing gum. This plateau effect showed no significant difference in the S. mutans plaque and saliva levels between the 6.88 g/d and 10.32 g/d samples in any time period; however, both groups showed a reduction in S. mutans levels in plaque and saliva compared with the control and 3.44 g/d samples in any time period. Chewing xylitol gum did not change colonization of the aerobic or facultative flora; this suggests that xylitol specifically impacts S. mutans without significantly altering the overall flora. The lack of difference of effect between 6.88 gm and 10.32 gm suggests that dosages >10.32 gm would not have any additional inhibitory effect on S. mutans (Jaana and Autio, 2002). Dental caries remains a significant problem for poor children in the United States. One strategy for treating dental caries is to suppress streptococcus mutans, the chief pathogen responsible for the disease. The aim of the present investigation was to evaluate the effect of xylitol chewing gum on mutans streptococci (MS) in saliva and dental plaque.Chewing 100% xylitol gum caused significant reductions on salivary MS scores ($p < 0.025$) which was little different from the 55% xylitol group. Jaana and Autio (2002)based on their study suggested that chewing xylitol gum may reduce salivary S. mutans levels. Xylitol chewing gum may provide a feasible caries prevention method for preschool children.The chewing of xylitol, sorbitol, and even sugar gum has been suggested to reduce caries rates. Campus et al (2009) evaluated the effect of daily high-dose xylitol chewing gum on plaque pH and salivary mutans streptococci (MS) in a sample of schoolchildren at high risk of caries. They suggested that the long-term use of high-dose non-sucrose chewing gums had beneficial effects on plaque pH, and that this effect was statistically greater when using xylitol chewing gums, both on plaque pH and MS salivary concentration. Ribelles et al (2010) studied the effects of chewing xylitol gum on mutans streptococci (MS) over short- and long-term periods in children; however, few studies have addressed long-term periods in adults. The

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objective of this investigation was to examine for 6 months the effects of chewing xylitol gum on MS in saliva and plaque in 127 adults (mean age 28.0 years). The study demonstrated that chewing xylitol gum for 6 months continued to inhibit the growth of mutans streptococci in adults. Mitali et al (2020) Comparatively evaluated the Stevia and Xylitol chewing gum on salivary streptococcus mutans count. Stevia is a natural sweetener which is used as sugar substitute. It has been suggested that stevia may be anticariogenic. However, there is limited research in this regard. Hence, the study was designed to assess reduction in S. mutans in stevia and xylitol chewing gums. The aim of this study is to evaluate the effectiveness of stevia and xylitol chewing gums on salivary Streptococcus mutans count. The reduction in S. mutans was seen from baseline to 1 hour in both stevia and xylitolgroups in trial and crossover design through intergroup comparison was not statistically significant. There was reduction seen from baseline to 15 minutes and 15 minutes to 1 hour in xylitol and stevia group both in trial and crossover design which was statistically significant. It was concluded that Stevia containing chewing gum is equally effective to Xylitol chewing gum in reducing salivary S. mutans counts. Sneha et al (2014) evaluated that Streptococcus mutans is one of the most common cariogenic microorganisms. Use of natural anticariogenic agents, such as Xylitol as well as Propolis chewing gum can also be used as an anticariogenic agent in children.

Xylitol gummy bear snacks: Milgrom et al. (2006) studied the effect of habitual consumption of xylitol gummy bear snacks (11.7 gm/day) in reducing cariogenic microorganisms in school-going children. There was a significant reduction in S. mutans and S. sobrinus. A plateau effect was observed at higher xylitol doses (>11.7 gm/day). Ly et al. (2008) reported that consumption of gummy bear snack containing xylitol (11.7 or 15.6 gm/day divided in three exposures) causes reductions in S. mutans/sobrinus levels.

Xylitol Syrups: Xylitol syrup is indicated in young children with early childhood caries, as they are more likely to develop dental caries in permanent teeth than those without early childhood caries. This method of administration of xylitol is most acceptable and safe for toddlers and young children. Twice-daily administration of xylitol oral syrup at a total daily dose of 8 g was observed to be effective in preventing caries (Milgrom et al; 2009).The studies confirm that the anti-caries effect is attributed to xylitol itself and not to chewing and digestion activities of products consumed. The syrup needs to be applied twice daily for effectiveness, thereby increasing the compliance as well as therapeutic effect. As xylitol syrup is not currently available in the retail market, commercially available products such as pudding jam and maple syrup may be used alternatively. The therapeutic dose of 4 g per serving can sometimes result in loose stools and diarrhea (Deshpande, 2008).Hence, a gradual increase in dose can acclimatize the patient to xylitol, thereby reducing potential gastrointestinal problems.

Xylitol mouth rinse: The effect of a combination of xylitol and chlorhexidine on the viability of S. sanguis or S. mutans during the early stages of biofilm development has been studied in comparison with xylitol and chlorhexidine alone (Decker et al., 2008).The xylitol/chlorhexidine combination inhibited streptococci more when compared with xylitol or chlorhexidine being used alone. This newly discovered synergistic action could be used for high-risk caries patients or for reducing MS transmission from mother to child. Chlorhexidine alone and xylitol/chlorhexidine solutions are effective against both S. mutans and S. sanguis. S. sanguis was most sensitive to the antiseptic effects of chlorhexidine alone, while S. mutans colonies were more sensitive to the xylitol/chlorhexidine solution.

Xylitol dentrifice: Toothpaste with xylitol led to a decrease in S. mutans colonies in saliva, the amount of secreted saliva, and the increase of pH value. It has a positive effect on the quality of the oral environment and it would be useful introducing it into prophylactic programmes. Low xylitol concentration in fluoride toothpastes has been shown to improve the cariostatic effects on tooth enamel. Synergistic use of xylitol with small doses of fluoride ions helps in caries control and avoiding contact of fluoride with tooth enamel during stages of mineralization (Petersson et al., 1991).

Xylitol and mother-child transmission of salivary S. mutans: An intriguing link between mothers who chew xylitol and a decrease in their children's caries development has been observed. Until the age of around 3 years, children's immune systems are underdeveloped, and hence newborns are extremely susceptible to bacterial colonization. These age group children frequently receive affectionate kisses from their parents/caretakers and also share utensils with them while eating. Due to these practices, parents transmit S. mutans from their mouths to their children's mouths. Regular use of xylitol is reported to reduce vertical transmission of dental caries from mother to child. The compliance of the patient is an important contributing factor that influences the efficacy of xylitol (Söderling et al., 2000).Pregnancy can be an appropriate time for reducing mother–child transmission of MS. Studies have reported that children using xylitol exhibited significantly more nondetectable, MS-negative levels on the tooth ridges or tongue and the gingival ridge at 9, 12, and 24 months. The xylitol group children were also significantly less likely to be MS positive than the control group children at and after 9 months of age. The children whose mothers did not chew xylitol gum acquired MS 8.8 months earlier than did those whose mothers did chew the gum (Nakai et al., 2010).Lynch and Milgrom (2003) overviewed of studies about xylitol and dental caries suggests potential clinical dental applications for xylitol. Xylitol is a naturally occurring, low-calorie sugar substitute with anticariogenic properties. Data from recent studies indicate that xylitol can reduce the occurrence of dental caries in young children, schoolchildren, and mothers, and in children via their mothers. Short-term consumption of xylitol is associated with decreased Streptococcus mutans levels in saliva and plaque. Aside from decreasing dental caries, xylitol may also decrease the transmission of S. mutans from mothers to children. Commercial xylitol-containing products may be used to help control rampant decay in primary dentition. Studies of schoolchildren in Belize and Estonia, along with data from the University of Washington, indicate that xylitol gum, candy, ice pops, cookies, puddings, etc., in combination with other dental therapies, are associated with the arrest of carious lesions. A prospective trial in Finland has demonstrated that children of mothers treated with xylitol had lower levels of S. mutans than children of mothers treated with chlorhexidine or fluoride varnish. Food products containing xylitol are available commercially and through specialized manufacturers, and have the potential to be widely use.

Xylitol chewing gum consumption among pregnant women with high salivary MS counts was compared with fluoride and chlorhexidine varnish treatments in a randomized controlled field study. The mothers were consuming 6–7 g of xylitol per day, whereas fluoride and chlorhexidine varnishes were applied biannually until the child was aged 2 years. The percentage colonization of MS was 10% in the xylitol group, 29% in the chlorhexidine group, and 49% in the fluoride varnish group at the children's age of 2 years. At the age of 5 years, the caries occurrence was observed to be 71% lower in the xylitol group as compared with the fluoride varnish group. After 10 years, the need for restoration was least in the xylitol group (Isokangas et al., 2000).Lynch and Peter Milgrom (2003) observed that xylitol can reduce the occurrence of dental caries in young children, schoolchildren, and mothers, and in children via their mothers.Short-term consumption of xylitol is associated with decreased Streptococcus mutans levels in saliva and plaque. Aside from decreasing dental caries, xylitol may also decrease the transmission of S. mutans from mothers to children. Commercial xylitol-containing products may be used to help control rampant decay in primary dentition. Studies of schoolchildren in Belize and Estonia indicate that xylitol gum, candy, ice pops, cookies, puddings, etc., in combination with other dental therapies, are associated with the arrest of carious lesions. A prospective trial in Finland has demonstrated that children of mothers treated with xylitol had lower levels of S. mutans than children of mothers treated with chlorhexidine or fluoride varnish. Food products containing xylitol are available commercially and through specialized manufacturers, and have the potential to be widely accessible to consumers.

Xylitol and oral hygiene: Xylitol consumption reduced MS counts in plaque but had no effect on the microbial composition of plaque or saliva in general. In a study, xylitol was compared with manuka honey and chlorhexidine mouthwash for its antiplaque efficacy. This study was performed among dental students aged between 21 and 25 years, and their plaque score was reduced to zero by performing the oral prophylaxis prior to the onset of the study. However, it was observed that chlorhexidine and manuka honey had significantly better antiplaque action than did xylitol. It has been confirmed by previous studies that chlorhexidine is more effective as an antiplaque agent when the oral hygiene status of the patient is reasonably good. At the same time, xylitol is recommended, especially in those children or individuals who lack manual dexterity and when their brushing cannot be supervised (Kovari et al., 2003).When used in mentally handicapped children, regular use of xylitol candies thrice daily effectively reduces plaque and gingival index scores, thereby supporting its role in oral hygiene routines in such children (Shyama et al., 2006).Limited studies are available in literature on the synergistic effects of xylitol and other oral health-promoting products like fluorides, chlorhexidine, and probiotics. Xylitol when combined with probiotics has been

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proved to beneficially influence the gut microflora. Probiotics like L. reuteri and L. rhamnosus GG are very effective in decreasing the counts of these oral pathogens and benefit from the presence of xylitol in them (Twetman et al; 2008).Makinen et al (2005) promoted several sugar alcohols (polyols) as a potential sugar substitutes in caries limitation. However, differences in the effects of simple alditol-type sugar alcohol homologues on dental plaque have not been compared in clinical tests. The effects of 6-month use of erythritol (a sugar alcohol of the tetritol type), xylitol (a pentitol) and D-glucitol (sorbitol, a hexitol) were investigated in a cohort of 136 teenage subjects assigned to the respective polyol groups or to an untreated control group (n = 30-36 per group). The daily use of the polyols was 7.0 g in the form of chewable tablets, supplemented by twice-a-day use of a dentifrice containing those polyols. The use of erythritol and xylitol was associated with a statistically significant reduction ($p < 0.001$ in most cases) in the plaque and saliva levels of mutans streptococci. The amount of dental plaque was also significantly reduced in subjects receiving erythritol and xylitol. Such effects were not observed in other experimental groups. Chemical analyses showed D-glucitol to be a normal finding in dental plaque while xylitol was less consistently detected. Erythritol was detected in measurable amounts only in the plaque of subjects receiving this polyol. Erythritol and xylitol may exert similar effects on some risk factors of dental caries, although the biochemical mechanism of the effects may differ. These in vivo studies were supported by cultivation experiments in which xylitol, and especially erythritol, inhibited the growth of several strains of mutans streptococci. Makinen et al (2001) The effect of 2-month usage of saliva-stimulating pastils containing either erythritol or xylitol was studied in a cohort of 30 subjects assigned to the respective polyol groups (n = 15). The daily consumption level of both polyols was 5.2 g, used in 5 daily chewing episodes. The mean weight of total plaque mass (collectable during a standard period of 3 min from all available tooth surfaces) was reduced significantly in the xylitol-group, while no such effect was observed in the erythritol-group. This reduction in plaque mass was accompanied by a significant reduction in the turbidity readings of aqueous plaque suspensions; no such effect was observed in the erythritol-group. However, plaque protein levels did not differ between baseline and endpoint in either polyol group. The plaque and salivary levels of Streptococcus mutans and plaque levels of total streptococci were reduced significantly in the xylitol-group, while no such effect was detected in the erythritol-group. However, either polyol regimen had no effect on plaque levels of S.sobrinus. The results suggest that systematic use of xylitol-containing saliva stimulants may be more effective in controlling some oral-hygiene-related and caries-associated parameters than similar use of erythritol-containing products. The results also speak for a special relationship between xylitol and S.mutans. However, owing to the great potential of erythritol as a caries-reducing agent based on the tetritol nature of erythritol. The present laboratory results should be considered preliminary and subject to verifying clinical studies. Runnel et al. (2013) observed that consumption of erythritol-containing candies by initially 7- to 8-year old children was associated with reduced plaque growth, lower levels of plaque acetic acid and propionic acid, and reduced oral counts of mutans streptococci compared with the consumption of xylitol or sorbitol candies. Falony et al (2016) A caries-preventive effect of 3-year erythritol consumption as compared to sorbitol was established in children with mixed dentition. The effect persisted up to 3 years after the end of the intervention. Lenkkeri et al (2012) The results suggest that in relatively low-caries conditions the school-based use of xylitol/maltitol or erythritol/maltitol lozenges would not have additional caries-preventive effect when compared with comprehensive prevention.De Cock et al (2016) To provide a comprehensive overview of published evidence on the impact of erythritol, a noncaloric polyol bulk sweetener, on oral health. Methods. A literature review was conducted regarding the potential effects of erythritol on dental plaque (biofilm), dental caries, and periodontal therapy. The efficacy of erythritol on oral health was compared with xylitol and sorbitol. Results. Erythritol effectively decreased weight of dental plaque and adherence of common streptococcal oral bacteria to tooth surfaces, inhibited growth and activity of associated bacteria like S. mutans, decreased expression of bacterial genes involved in sucrose metabolism, reduced the overall number of dental caries, and served as a suitable matrix for subgingival air-polishing to replace traditional root scaling. Conclusions. Important differences were reported in the effect of individual polyols on oral health. The current review provides evidence demonstrating better efficacy of erythritol compared to sorbitol and xylitol to maintain and improve oral health.Krishnan et al (2018) compared the anticariogenic effectiveness of Casein phosphopeptide- Amorphous Calcium phosphate

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(CPP-ACP) and xylitol chewing gums based on salivary pH, buffer capacity, and Streptococcus mutans levels. They have concluded that CPP-ACP has better ability than xylitol in improving the pH of saliva. Both CPP-ACP and xylitol gums individually have remarkable ability in bringing down S. mutans levels while simultaneously improving the pH and buffer of saliva. Shila et al (2015) evaluated the effect of sugar-free chewing gum containing casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) and xylitol on salivary Streptococcus mutans. It was concluded that Daily consumption of chewing gum containing CPP-ACP and xylitol significantly reduces the level of salivary S. mutans, but chewing gum containing CPP-ACP can reduce the level of salivary S. mutans in more than xylitol chewing gum. Browen and Pearson (1992) Clinical studies have demonstrated the caries promoting effects of sugar based gum when compared with non sugar chewing controls. Sucrose gum has been shown to stimulate plaque growth and increase its adhesivity. Acid produced in plaque and mixed saliva whilst chewing sugar gum is counteracted by the buffering action of mastication induced saliva. However the vast majority of studies measuring plaque pH has demonstrated acidification of plaque during use of sugar gum into the decalcifying zone (pH < or = 5.5), or after the gum is taken out. Sugar gum causes a more pronounced fall in plaque pH in individuals with an increased caries risk compared to the pH drop in more caries resistant individuals. Sorbitol, by itself or in combination with mannitol is slowly converted to acids by the plaque microorganisms. Chewing gums sweetened with these sugar alcohols do not cause a critical acidification of the plaque and appear not to promote caries in the clinical trial. Twelve weeks use of sorbitol chewing gum has been shown to induce a plaque more adapted to form acids from this sugar alcohol. This adaptation has been shown to persist for up to twelve weeks after cessation of the use of the sorbitol gum. Xylitol has generally been considered non-cariogenic because of its non-fermentability by most important plaque microorganisms. Plaque pH and pH of mixed saliva is increased during and following the use of xylitol based chewing gum. Prolonged use of xylitol or xylitol containing chewing gum reduces Streptococcus mutans counts in plaque and saliva, at the same time fostering remineralization of early caries lesions. Regular use of xylitol reduces the acidogenic potential of the plaque as well as its adhesiveness, at the same time increasing its mineral content. No adaptive changes in plaque metabolism resulting in the fermentation of xylitol have been reported, not even after long term, intense use. Xylitol chewing gum therefore is eminently suited to be used as part of a caries preventive regimen notably for high caries risk patients and those suffering from xerostomia. Adding mineral salts to sugar based chewing gum has been demonstrated to significantly inhibit caries development. Possible additional caries preventive benefits of mineral compounds added to sugar-free chewing gum have, so far not been reported. Sugar-free chewing gum has been shown to be an excellent vehicle for Fluoride. The plaque-growth retarding properties of Chlorhexidine-containing chewing gum have been shown to equal that of a Chlorhexidine mouthwash. Ureum added to a sugar-free chewing gum helps to neutralize plaque acids by liberating basic ammonia (Sorderling,1987). Aluckal and Ankola (2018) reported thatchewing sugar-free gum has potential beneficial effects on dental health. Xylitol-containing chewing gums can be used as an adjunct to regular home care preventive procedures to prevent dental caries.Jacques Véronneau, (2018) reported the declining prevalence of dental caries in industrialized countries during the past decades, predominately due to fluoride use, dental caries is still a major problem in most industrialized countries, affecting 60% to 90% of children, and the vast majority of adults. Also, there is mounting international evidence that this decline is ending and that many dental patients are still highly infected with cariogenic bacteria Streptococcus mutans/mL of saliva).Daily use of xylitol lozenges did not result in a statistically or clinically significant reduction in 33-month caries increment among adults at an elevated risk of developing caries.Bader et al (2013) investigated dental caries preventive therapies in adult populations and evaluated the effectiveness of xylitol lozenges in preventing caries in adults at elevated risk of developing caries. Milgrom et al (2009) evaluated the effectiveness of a xylitol pediatric topical oral syrup to reduce the incidence of dental caries among very young children and to evaluate the effect of xylitol in reducing acute otitis media in a subsequent study. Taipale et al (2013) evaluated the role of Probiotic bifidobacteria in the prevention of childhood diseases. These bacteria are also associated with caries occurrence. He further evaluated the effect of early administration of Bifidobacterium animalis in a low-caries population and also identified lactis BB-12 (BB-12) on caries occurrence as markers of dental decay in early childhood. Zhan et al (2012) investigated the efficacy of the use of xylitol-containing tooth-wipes in preventing dental caries in young children.

In a double-blinded randomized controlled clinical trial, 44 mothers with active caries and their 6-to 35-month-old children were randomized to xylitol-wipe or placebo-wipe groups. The children's caries scores were recorded at baseline and 1 year. Salivary levels of mutans streptococci and lactobacilli were enumerated at baseline, 3, 6, and 12 months. Kovari et al (2003) questioned the use of toothbrushes in daycare centers because of the possibility of infections spreading through unsupervised brushing. Several field studies have demonstrated a caries preventive effect of xylitol chewing gum, a measure that could be a practical way of taking care of oral hygiene during daycare hours without brushing. A community trial was conducted in Savonlinna, Finland to test the caries preventive effect of xylitol chewing gum at these centers. Alanen et al (2000). Sealants and xylitol have been demonstrated to prevent dental decay, but their effect has never been compared in the same study. Regular use of xylitol chewing gum during 2 or 3 school years was compared with application of occlusal sealants in a randomized study. The reliability of the clinical observations was controlled by examining the presence of dental decay in the same teeth through radiographs in a blind study. After 5 years, no statistically significant differences between the sealant and xylitol groups were found. Chi et al (2014) assessed the efficacy of supervised tooth-brushing with xylitol toothpaste to prevent early childhood caries (ECC) and reduce mutans streptococci. In this cluster-randomized efficacy trial, 196 four-to five-year-old children in four Head Start classrooms in the Marshall Islands were randomly assigned to supervised tooth brushing with 1,400 ppm/31 percent fluoride xylitol or 1,450 ppm fluoride sorbitol toothpaste and hypothesized no difference in efficacy between them. Alanen et al (2000) reported significant reductions in dental caries ccurrence in children associated with the use of chewing gum containing xylitol. Assev et al (2002) observed the long term xylitol consumption leads to the emergence of xylitol resistant (X- R) mutans streptococci. Six strains of mutans streptococci, three X- R and three X- S strains, were studied. Xylitol resistance and sensitivity were confirmed by growth in xylitol supplemented media. Acid production from glucose or fructose or uptake of xylitol was initiated by adding 14C- labelled glucose, fructose or xylitol to bacterial suspensions. Deshpande (2008) conducted a systematic review of original studies that was designed to assess the impact of polyol-containing chewing gum on dental caries compared with the effect with no chewing gum. Fontana (212) observed the anticaries effects of polyols, particularly xylitol, and a great many studies have focused on xylitol's antimicrobial properties. Researched xylitol vehicles have mostly included chewing gums, followed by lozenges/candies, toothpastes, and others (eg., syrup). Good evidence supports the claims that xylitol is non-cariogenic and has a dose-/frequency-dependent antimicrobial effect on dental plaque/mutans streptococci, and that polyol use is very safe. Lee et al (2012) Streptococcus mutans metabolize carbohydrates, such as glucose and sucrose, to produce acid and enhance biofilm formation with the early colonizing bacteria to induce dental caries. Xylitol has been used as a reliable substitute for carbohydrate to inhibit the acid production of S. mutans. However, long-term xylitol consumption leads to the emergence of xylitol-resistance in S. mutans. The aim of this study was to investigate the cariogenic trait of Xylitol-resistant (XR) S. mutans using biofilm formation and coaggregation of xylitol-sensitive. Milgrom et al (2012) observed that Xylitol is a safe dental caries preventive when incorporated into chewing gum or confections used habitually. Xylitol is effective when used by the mother prenatally or after delivery to prevent mutans transmission and subsequent dental caries in the offspring. One new completed trial confirmed that children of mothers who used xylitol lozenges after delivery had less dental caries than a comparison group. Xylitol has been demonstrated to be a safe and effective toothdecay-preventive agent when used habitually. Nevertheless, its application has been limited by absence of formulations that demand minimal user adherence and are acceptable and safe in settings where chewing gum may not be allowed. A substantial body of literature suggests that a minimum of 5 to 6 grams and 3 exposures per day from chewing gum or candies are needed for a clinical effect to be achieved. At the same time, there is conflicting evidence in the literature. Moynihan and Kelly (2014) studied the positive correlation between the amount of sugars intake and dental caries and the effect of restricting sugars intake to< 10% and< 5% energy (E) on caries formation updated the information to World Health Organization to generate guidelines on sugars consumption. Takahasmi and Washio (2011) reported that the dental caries is initiated by demineralization of the tooth surface through acid production from sugar by plaque biofilm. Fluoride and xylitol have been used worldwide as caries-preventive reagents, based on in vitro-proven inhibitory mechanisms on bacterial acid production. They further attempted to confirm the inhibitory mechanisms of fluoride and xylitol in vivo by performing metabolome analysis on the central carbon metabolism in supragingival plaque using the combination of capillary electrophoresis and a time-of-flight mass. Xylitol as an antibacterial agent in Chewing gum has been the most tested vehicle for xylitol delivery in clinical studies. Several clinical trials and literature reviews have confirmed the potential of xylitol to reduce cariogenic bacteria using chewing gum. This evidence has allowed Health Canada to officially recognize xylitol gums as an antibacterial agent on cariogenic bacteria, and also as a saliva stimulating agent. Xylitol as a therapeutic agent, systematic xylitol use leads to impressive reductions in caries incidence.This has been reported by many researchers and in literature review. With chewing gum, several studies show carious lesion reduction among children after exposure of 12 to 40 monthsand systematic reviews reported some high preventive fractions on caries experiences. Therapeutic effects were estimated from xylitol trials using menthols, candies, syrup (8 grams/day), wipes and milkwith success. An observational study showed effectiveness of xylitol gum-lozenges on root caries lesions.In 1990, two trials used toothpaste as a vehicle for xylitol 10% (0.1 g/tooth brushing). One trial combined it to NaF (Sintes et al., 1995) and in the other, Sodium of Monofluorophaste (Sintes et al 2002) using a total of 4 800 school children and reported a negligible prevention fraction of 10 % and 13% respectively. The authors concluded that xylitol in toothpaste might be irrelevant.According to recent stats, the prevalence of caries in at-risk individuals increased between 1994 and 2012, despite exposure to various fluoride products. As well, patients are increasingly drawn to and are buying natural dental products even though they contain no therapeutic agents. This is contributing to a rise in carious lesions. This is the rationale behind the development and introduction of an effective caries reducing natural toothpaste containing 25% concentrated xylitol as the sole anti-caries therapeutic and anti-bacterial agent.

Galina Pancu (2017) assessed the effect of xyilitol from oral hygiene products (toothpastes, mouthwashes, chewing gums) on the saliva parameters (saliva micro-crystallisation index (IMK), saliva resting flow rate (RFR), saliva stimulated flow rate (SFR), saliva buffering capacity (BC)) and the carioactivity of bacteria biofilm (ATP) for patients with medium cariogenic risk. He concluded that the use of xylitol-based products in oral hygiene is effective both in the improvement of salivary parameters and the decrease of bacterial biofilm activity for patients with high cariogenic risk.Bader et al. (2013) found that 3-5 grams xylitol daily decreased the risk of carious disease with 11%, without significant statistical difference with placebo group. The first studies highlighting the dental benefits of xylitol were performed in 1970. Xylitol can be considered a non-cariogenic replacer of sugar. Xylitol is found in various products as follows: chewing gums, toothpastes, mouthwashes. Researches related to xylitol effects show different effects on the decreasing of dental caries incidence and changes of Streptococcus mutans levels to children, following a consume from 4 grams to 15 grams daily, divided in 3-7 doses . The validity of these results is influenced by numerous problems related to their design and performance . The unconvincing data are found both in relation to the xylitol effect on short term and long term regarding both the decrease of Streptococcus mutans levels and dental caries, due to the use of high frequency doses (4-5 times daily) unrelated to the usual current practice. Abdulla et al (2017) evaluated the effectiveness of xylitol in reducing dental caries in children compared to no treatment, a placebo, or preventive strategies. The primary endpoint was caries reduction measured by mean decayed, missing, and filled primary and permanent surfaces/ teeth (dmfs/t, DMFS/T, respectively). The and chi-square test for heterogeneity were used to detect trial heterogeneity. Meta-analyses were performed and quality was evaluated using GRADE profiler software. Analysis of five randomized controlled trials (RCTs) showed that xylitol had a small effect on reducing dental caries (standardized mean difference [SMD] equals -0.24; 95 percent confidence interval [CI] equals -0.48 to 0.01; P=0.06) with a very low quality of evidence and considerable heterogeneity. Studies with higher xylitol doses (greater than four grams per day) demonstrated a medium caries reduction (SMD equals -0.54; 95 percent CI equals -1.14 to 0.05; P=0.07), with these studies also having considerable heterogeneity and very low quality of evidence. Lynch and Milgrom (2003) suggested the potential clinical dental applications for xylitol.

II. SUMMARY:

Exhaustive research work on role of xylitol in dental caries management are available in literature but still more research is requiredto understand the exact mechanisms of action of xylitol alone as well as in combination of other anti-caries compound in children and adults.The clinical significance of xylitol resistance, and the effect of xylitol on the plaque–saliva distribution of mutans streptococci (MS) need advanced evaluation. Properly designed randomized controlled clinical trials are needed to demonstrate the feasibility of xylitol prevention in different populations with different dietary and oral hygiene habits. Further, suitable delivery vehicles for xylitol and the extent to which xylitol can be "diluted" with other polyols without losing the caries-preventive effects have to be ascertained methodically. A minimum daily dose and frequency necessary for xylitol effects on MS, plaque, and caries occurrence should be calibrated.

REFERENCES.

[1]. Abdullah, A., Marghalani, E. G., Minhthu, P., Vineet, D., Norman, T. (2017). Effectiveness of Xylitol in Reducing Dental Caries in Children. Pediatric Dentistry 39 (2).

[2]. Alanen, P., Holsti, M.L., Pienihäkkinen, K.(2000).Sealants and xylitol chewing gum are equal in caries prevention. Acta Odontologica …, 2000 - Taylor & Francis

[3]. Aluckal E, Ankola AV. Effectiveness of xylitol and polyol chewing gum on salivary streptococcus mutans in children: A randomized controlled trial. Indian J Dent Res 2018;29:445-9.

[4]. American Academy of Pediatric Dentistry (2010). Policy on the use of xylitol in caries prevention. Pediatr. Dent. 32:36–38.

[5]. Assev, S., Stig, S., Scheie, A.A.(2002). Cariogenic traits in xylitol- resistant and xylitol- sensitive mutans streptococci. Oral microbiology and immunology, 2002 - Wiley Online Library.

[6]. Bar A., Caries prevention with xylitol. (1988). A review of the scientific evidence.World Rev. Nutr. Diet55:183-209.

[7]. Bär, A. (1988). Caries prevention with xylitol. A review of the scientific evidence. World Rev. Nutrition Diet.55:183–209.

[8]. Bowen, W.H., Pearson, S.K. (1992). The effects of sucralose, xylitol, and sorbitol on remineralization of caries lesions in rats. J. Dent. Res. 71:1166–1168.

[9]. Brett, Duane (2010). Xylitol gum, plaque pH and mutans streptococci. Evid. Based Dent.11(4):109-10.

[10]. Brett, Duane (2020). Xylitol gum, plaque pH and mutans streptococci. Based Dent. 11(4):109-10.

[11]. Campus, G., Cagetti, M.G., Sacco, G., Solinas, G., Mastroberardino, S., Lingström, P. (2009). Six months of daily high-dose xylitol in high-risk schoolchildren: a randomized clinical trial on plaque pH and salivary mutans streptococci.Caries Res. 43(6):455-61.

[12]. Campus, G., Cagetti,M.G., Sacco,G., Solinas,G., Mastroberardino,S., Lingström,P. (2009). Six months of daily high-dose xylitol in high-risk schoolchildren: a randomized clinical trial on plaque pH and salivary mutans streptococci.Caries Res. 43(6):455-61.

[13]. Chi, D.L., Tut, O., Milgrom,P. (2014). Cluster-randomized xylitol toothpaste trial for earlychildhood caries prevention.Journal of dentistry for children, 2014 - ingentaconnect.com

[14]. de Cock, P., Mäkinen, K., Honkala, E., Saag, M., Kennepohl, E., Eapen, A. (2016). Erythritol Is More Effective Than Xylitol and Sorbitol in Managing Oral Health Endpoints.Int J Dent. 2016:9868421.

[15]. Decker, E.M., Maier, G., Axmann, D., Brecx, M., vonOhle, C. (2008) Effect of xylitol/chlorhexidine versus xylitol or chlorhexidine as single rinses on initial biofilm formation of cariogenic streptococci. Quintessence Int. 39(1):17–22.

[16]. Deshpande, A., Jadad, A.R. (2008).The impact of polyol-containing chewing gums on dental caries: a systematic review of original randomized controlled trials and observational studies.The Journal of the American Dental Association, 2008 - Elsevier

[17]. Deshpande, A., Jadad, A.R.(2008). The impact of polyol-containing chewing gums on dental caries: a systematic review of original randomized controlled trials and observational studies. J. Am. Dent. Assoc. 139(12):1602–1614.

[18]. Falony G, Honkala S, Runnel R, Olak J, Nõmmela R, Russak S, Saag M, Mäkinen PL, Mäkinen K, Vahlberg T, Honkala (2016). Long-Term Effect of Erythritol on Dental Caries Development during Childhood: A Posttreatment Survival Analysis.Caries Res. 2016;50(6):579-588.

[19]. Fontana, M.,(2012). Are we ready for definitive clinical guidelines on xylitol/polyol use?Advances in dental …, 2012 - journals.sagepub.com

[20]. Galina, P., Sorin, A., Simona, S., Angela, G., Irina, N., Claudiu, T., Moldovanu, A., Nicoleta, T., Gianina, I., Grigore, T. P. (2017). The effect of xylitol-based oral hygiene products on saliva parameters and

International Journal Dental and Medical Sciences Research
Volume 3, Issue 2, Mar-Apr 2021 pp 51-64 www.ijdmsrjournal.com ISSN: 2582-6018

bacterial biofilm carioactivity. Romanian Journal of Oral Rehabilitation : 9(2).
[21]. Heather, Lynch 1., Peter, Milgrom (2003). Xylitol and dental caries: an overview for clinicians.Calif Dent Assoc. 31(3):205-9.
[22]. Hujoel, P.P., Makinen, K.K., Bennett, C.A, et al. (1999). The optimum time to initiate habitual xylitol gum-chewing for obtaining long-term caries prevention. J. Dent. Res. 78:797–803.
[23]. Isokangas, P., Söderling, E., Pienihäkkinen, K., Alanen, P. (2000). Occurrence of dental decay in children after maternal consumption of xylitol chewing gum, a follow-up from 0 to 5 years of age. J. Dent. Res. 79:1885–1889.
[24]. Jaana, T. Autio (2002). Effect of xylitol chewing gum on salivary Streptococcus mutans in preschool children. ASDC. J. Dent. Child. 69(1):81-6, 13.Kiet, A Ly., Peter, Milgrom., Marilynn, Rothen (2006) Xylitol, sweeteners, and dental caries. Pediatr. 28(2):154-63.
[25]. Jacques Véronneau (2018) Medical Treatment of Dental Caries With a New 25% Xylitol Formulation. J Am Dent Assoc 2013.144(1):21-30.
[26]. James, D. B.1., William, M.V., Daniel, A., Shugars, G. H. G., Bennett, T., Amaechi, John P Brown., Reesa, L. L., Kimberly, A. F., Sonia, K. M., André, V. R., Michael, C. Leo.(2013) Results from the Xylitol for Adult Caries Trial (X-ACT) jada.archive.2013.0010.
[27]. JD Bader, WM Vollmer, DA Shugars, GH Gilbert (2013). Results from the xylitol for adult caries trial (X-ACT). The Journal of the …, 2013 - Elsevie.
[28]. Kontiokari, T., Uhari, M., Koskela, M. (1995). Effects of xylitol on growth of nasopharyngeal bacteria in vitro. Antimicrob Agents Chemother. 39(8):1820–1823.
[29]. Kovari, H., Pienihäkkinen, K., Alanen, P. (2003). Use of xylitol chewing gum in daycare centers: a follow- up study in Savonlinna, Finland. Acta odontologica. 2003 - Taylor & Francis
[30]. Kovari, H., Pienihakkinen, K., Alanen, P. (2003). Use of xylitol chewing gum in daycare centers: a follow-up study in Savonlinna, Finland. Acta Odontol . Scand. 61:267–270.
[31]. Krishnan, Padminee., Saravanan, Poorni., Davidson, Diana., Dasarathan, Duraivel., Manali, Ramakrishnan Srinivasan (2018). Effectiveness of casein phosphopeptide-amorphous calcium phosphate and xylitol chewing gums on salivary pH, buffer capacity, and Streptococcus mutans levels: An interventional study. Indian J. Dent. Res. 29(5):616-621.
[32]. Lee et al (2015) examined the effects of xylitol gummy bear snacks on dental caries progression in primary and permanent teeth of inner-city school children.
[33]. Lee, S.H., Choi, B.K., Kim,Y.J (2012). The cariogenic characters of xylitol-resistant and xylitol-sensitive Streptococcus mutans in biofilm formation with salivary bacteria. Archives of Oral Biology, 2012 - Elsevier.
[34]. Lee, W., Spiekerman, C., Heima, M., Eggertsson, H. (2015).The effectiveness of xylitol in a school-based cluster-randomized clinical trial.Caries. karger.com
[35]. Lenkkeri, A.M., Pienihäkkinen, K., Hurme, S., Alanen, P. (2012). The caries preventive effect of xylitol/maltitol and erythritol/maltitol lozenges: results of a double-blinded, cluster-randomized clinical trial in an area of natural fluoridation.Int J Paediatr Dent. 22(3):180-90.
[36]. lenkkeri, AMH., Pienihäkkinen, K. (2012). The cariespreventive effect of xylitol/maltitol and erythritol/maltitol lozenges: results of a double- blinded, cluster- randomized clinical trial in an area of natural.International Journal of Paediatric Dentistry 2012; 22: 180–190.
[37]. Lif Holgerson P., Ö.C., Rönnlund A., Johansson I., (2007). Xylitol and its effects on oral ecology–clinical studies in children and adolescents. Department of Odontolgy, ed. U. University. Umea.
[38]. Ly, K.A., Riedy, C.A., Milgrom, P., Rothen, M., Roberts, M.C., Zhou, L. (2008) Xylitol gummy bear snacks: a school-based randomized clinical trial. BMC Oral Health. 8(20):1–11.
[39]. Lynch H, Milgrom P. (2003) Department of Dental Public Health Sciences, Northwest/Alaska Center to Reduce Oral Health Disparities, University of Washington, Seattle 98195-7475, USA.
[40]. Lynch H, Milgrom P.(2003) Xylitol and dental caries: an overview for clinicians.J Calif Dent Assoc. 31(3):205-9.
[41]. Lynch, H., Milgrom, P. (2003). Xylitol and dental caries: an overview for clinicians.Journal of the California Dental Association.

[42]. Mäkinen, K.K., Saag, M., Isotupa, K.P., Olak, J., Nõmmela, R., Söderling, E.,Mäkinen, P-L (2005). Similarity of he effects of erythritol and xylitol on some risk factors of dental caries. Caries Res.39(3):207-

[43]. Mäkinen. K.K., Isotupa, K.P., Kivilompolo,T., Mäkinen, P.L., Toivanen, J., Söderling, E. (2001). Comparison of erythritol and xylitol saliva stimulants in the control of dental plaque and mutans streptococci. Caries Res.35(2):129-35.

[44]. Marttinen, A.M., Ruas-Madiedo, P., Hidalgo-Cantabrana, C., Saari, M.A., Ihalin, R.A., Söderling, E.M. (2012). Effects of xylitol on xylitol-sensitive versus xylitol-resistant Streptococcus mutans strains in a three-species in vitro biofilm. Curr Microbiol. 65:237–243.

[45]. Mickenautsch, S., Yengopal, V. (2012). Anticariogenic effect of xylitol versus fluoride–a quantitative systematic review of clinical trials. Int Dent J62(1): 6-20.

[46]. Milgrom, P., Ly, K.A. and Tut, O. et al. (2009). Xylitol pediatric topical oral syrup to prevent dental caries. Arch. Pediatr. Adolesc. Med. 163(7):601–607.

[47]. Milgrom, P., Ly, K.A., Roberts, M.E., Rothen, M., Mueller, G., Yamaguchi, D.K. (2006). Mutants streptococci dose response to xylitol chewing gum. J. Dent. Res. 8:177–181.

[48]. Milgrom, P., Ly, K.A., Rothen, M.(2009)Xylitol and its vehicles for public health needs. Advances in dental research, 2009 - journals.sagepub.com

[49]. Milgrom, P., Ly, K.A., Tut, O.K., Mancl, L. (2009).Xylitol pediatric topical oral syrup to prevent dental caries: a double-blind randomized clinical trial of efficacy. of pediatrics & …, 2009 - jamanetwork.com.

[50]. Milgrom, P., Söderling, E.M., Nelson, S. (2012). Clinical evidence for polyol efficacy. Advances in dental …, 2012 - journals.sagepub.com

[51]. Mitali, R. Shinde., Jasmin, Winnier (2020). Comparative evaluation of Stevia and Xylitol chewing gum on salivary Streptococcus mutans count - A pilot study. J. Clin. Exp. Dent. 12(6):e568-e573.

[52]. Moynihan, P.A., Kelly, S.A.M. (2014). Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. Journal of dental research, 2014 - journals.sagepub.com

[53]. Murthykumar, K. (2013). The impact of milk with xylitol on dental caries: a review. J. Pharm. Sci. Res. 5(9):178–180.

[54]. Nakai, Y., Shinga-Ishihara, C., Kaji, M., Moriya, K., Murakami-Yamanaka, K., Takimura, M. (2010). Xylitol gum and maternal transmission of mutans streptococci. J. Dent. Res. 89(1):56–60.

[55]. Nordblad, A., Suominen-Taipale, L., Murtomaa, H., Vartiainen, E., Koskela, K. (1995). Smart Habit xylitol campaign, a new approach in oral health promotion. Community Dent Health. 12:230–234.

[56]. Pediatr Dent 2017;39(2):103-10) Received January 25, 2016 | Last Revision February 17, 2017 | Accepted February 18, 2017.

[57]. Petersson, L.G., Birkhed, D., Gleerup, A., Johansson, M., Jonsson, G. (1991) Caries-preventive effect of dentifrices containing various types and concentrations of fluorides and sugar alcohols. Caries Res. 25(1):74.

[58]. Ribelles Llop, M., Guinot Jimeno, F., Mayné Acién,R., Bellet Dalmau,L. J (2010). Effects of xylitol chewing gum on salivary flow rate, pH, buffering capacity and presence of Streptococcus mutans in saliva. Eur. J. Paediatr. Dent.11(1):9-14.

[59]. Runnel,R., Makinen,K.K., Honkala, S., Olak,J., Mäkinen,P.L., Nõmmela,R., Vahlberg,T., Honkala,E., Saag.M. (2013) Effect of three-year consumption of erythritol, xylitol and sorbitol candies on various plaque and salivary caries-related variables. J Dent.41(12):1236-44.

[60]. S, Haresaku., T, Hanioka., A, Tsutsui., M, Yamamoto., T, Chou., Y, Gunjishima (2007). Long-term effect of xylitol gum use on mutans streptococci in adults. Caries Res. 41(3):198-203.

[61]. S., K., Historical review of remineralization research. Journal of Clinical Dentistry, 1999. 10(2): 56-64.

[62]. Scheie, A.A., Fejerskov, O.B. (1998). Xylitol in caries prevention: what is the evidence for clinical efficacy? Oral Dis. 4:268–278.

[63]. Shila, Emamieh., Yosra, Khaterizadeh., Hossein, Goudarzi., Amir, Ghasemi., Alireza, Akbarzadeh Baghban., Hasan, Torabzadeh(2015). The effect of two types chewing gumcontaining casein phosphopeptide-amorphous calcium phosphate and xylitol on salivary Streptococcus mutans. J. Conserv. Dent. 18(3):192-5.

[64]. Shyama, M., Honkala, E., Honkala, S., Al-Mutawa, S.A. (2006). Effect of xylitol candies on plaque and gingival indices in physically disabled school pupils. J. Clin. Dent. 17:17–21.

[65]. Sintes J.L., E.C., Stewart B., McCool J.J., Garcia L., Volpe A.R., Triol C., Enhanced anticaries efficacy of a 0.243% sodium fluoride/10 % xylitol/silica dentifrice: 3-year clinical results. Am J Dent., 1995. 8(5): 231-5.

[66]. Sintes, J.L., E.-B.A., Stewart, B., Volpe, A.R., Lovett,J. (2002). Anticaries efficacy of sodium monofluorophosphate dentifrice containing xylitiol in a dicalcium phosphate dehydrate base. A 30 months caries clinical study in Costa Rica. Am J Dent . 15(4): 215-9

[67]. Sneha, Girdhari Tulsani., Nagarathna, Chikkanarasaiah., Shakuntala, Bethur Siddaiah., Navin, H. Krishnamurthy (2014). The effect of Propolis and Xylitol chewing gums on salivary Streptococcus mutans count: a clinical trial. Indian J. Dent. Res. 25(6):737-41.

[68]. Soderling E., I.P., Pienihakkinen K., Tenovuo J., Alanen P., (2001). Influence of maternal xylitol consumption on mother-child transmission of mutans streptococci: 6-year follow-up.35(3):173-7. 85.

[69]. Söderling, E., Isokangas, P., Pienihäkkinen, K., Tenovuo, J. (2000). Influence of maternal xylitol consumption on acquisition of mutans streptococci by infants. J. Dent. Res. 79:882–887.

[70]. Soderling, E., Talonpoika, J., Makinen, K.K. (1987) Effect of xylitol-containing carbohydrate mixtures on acid and ammonia production in suspensions of salivary sediment. Scand. J. Dent. Res. 95:405–410.

[71]. Taipale, T., Pienihäkkinen, K., Alanen, P., Jokela, J (2013). Administration of Bifidobacteriumanimalis subsp. lactis BB-12 in early childhood: a post-trial effect on caries occurrence at four years of age. Caries …, 2013 - karger.com

[72]. Takahashi, N., Washio, J., (2011). Metabolomic Effects of Xylitol and Fluoride on Plaque Biofilm. Journal of dental research, sagepub.com

[73]. Tanzer, J.M., Thompson, A., Wen, Z.T., Burne, R.A. (2006). Streptococcus mutans: fructose transport, xylitol resistance, and virulence. J Dent Res. 85(4):369–373. Maguire, A., Rugg-Gunn, A.J. (2003). Xylitol and caries prevention: is it a magic bullet? Br. Dent J. 194:429–436.

[74]. Tanzer,JM., Thompson,A., Wen, Z.T., … (2006) Streptococcus mutans: Fructose Transport, Xylitol Resistance, and Virulence. Journal of dental …. journals.sagepub.com

[75]. Thaweboon, S., Thaweboon, B.,Soo-Ampon, S. (2004).The effect of xylitol chewing gum on mutans streptococci in saliva and dental plaque. Southeast Asian J Trop Med Public Health. 35(4):1024-7.

[76]. Toors, F.A., (1992). Chewing gum and dental health. Review. Rev. Belge. Med. Dent. 47(3):67-92

[77]. Trahan L., (1995). Xylitol : a review of its action on mutans steptococci and dental plaque-its clinical significance. Int Dent J, 1995. 45: 77-92.

[78]. Twetman, S., Stecksén-Blicks, C. (2008).Probiotics and oral health effects in children. Int. J. Ped. Dent.18:3–10.

[79]. Ur-Rehman S., M.Z., Zahoor T., Jamil A., Murtaza M.A. (2015). Xylitol: a review on bioproduction, application, health benefits, and related safety issues. Crit. Rev. Food Sci. Nutr.55(11) :1514-28.

[80]. Vadeboncoeur, C., Trahan, L., Mouton, C., Mayrand, D. (1983). Effect of xylitol on the growth and glycolysis of acidogenic oral bacteria. J. Dent. Res. 62:882–884.

[81]. Veronneau J., L.-X.B., Begzati A., Bytyci A., Kutlovci T., Rexhepi A., (2016). Effectiveness of xylitol toothpaste to decrease cariogenic bacteria among adults within 3-month period. not published yet, 2016.

[82]. Zhan, L., Cheng, J., Chang, P., Ngo, M. (2012). Effects of xylitol wipes on cariogenic bacteriaand caries in young children. Journal of dental …, 2012 - journals.sagepub.com.