Intake of dairy foods and oral health: review of epidemiological data

Running title: Review on dairy foods and oral health

Amanda R A Adegboye [1]; Mariana Tomaz[1]; Charlotte A Jeavons [2]; Berit L Heitmann [3-5]

[1] University of Westminster, Faculty of Science and Technology, Department of Life Sciences Human Food, Nutrition and Public Health Division

[2] University of Greenwich, Faculty of Education and Health, Psychology, Social Work and Counselling Department

[3] Research Unit for Dietary Studies, at The Parker Institute, Bispebjerg and Frederiksberg University Hospital, The Capital Region, Denmark

[4] Department of Public Health, University of Copenhagen, Denmark

[5] National Institute of Public Health, University of Southern Denmark, Denmark

Corresponding author:

Dr Amanda R A Adegboye

115 New Cavendish Street, London, W1W 6UW

Tel: +44 (0)20 7911 5000 ext. 64981 | Fax: +44 (0)20 7911 5079

Email: a.adegboye@westminster.ac.uk

Abstract

Introduction The relationship between diet and oral health is intriguing. Various components of milk have been suggested to be protective against oral health problems, although specific mechanisms linking dairy components to the pathogenesis of certain diseases are still unclear.

Purpose: To provide an overview of the associations between intake of milk and dairy products and dental plaque, periodontal disease and tooth loss based on currently available literature.

Methods: We performed a review of relevant literature with critical appraisal of those human epidemiological studies evaluating the association between intake of milk or dairy products and periodontal disease , plaque score or tooth loss among adults and elderly.

Results: Nine studies were included in the review, eight of which were cross-sectional and only one applied a longitudinal design. None of the studies included institutionalised participants. Overall, reported studies suggested an inverse association between dairy intake and plaque score and periodontal disease . Results related to tooth loss were inclusive.

Conclusion: The methodological quality of reviewed studies was moderate to low with only one longitudinal design. Therefore, well-designed, confounding-controlled, longitudinal studies are warranted to be able to conclude on the potential protective effect of dairy intake on periodontal disease , dental plaque and tooth loss.

Key words: dairy foods, dental plaque, diet, milk, oral health, periodontal disease , tooth loss

Word count: 202

Abstrakt

Baggrund: Sammenhængen mellem kost og det orale helbred er uafklaret. Nogle tidligere studier har fundet at mejeriprodukter yder beskyttelse mod parodontale sygdomme, men de egentlige mekanismer bag disse sammenhænge er ikke helt klarlagte.

Formål: At gennemgå de tidligere studier, der har undersøgt sammenhænge mellem på den ene side indtag af mælk og andre mejeriprodukter, og på den anden forekomsten af plak, parodontalsygdom og tandtab.

Metode: Litteraturgennemgang med fokus på epidemiologiske studier af sammenhængen mellem indtag af mejeriprodukter og orale forhold hos voksne og ældre.

Resultater: Otte ud af ni inkluderede studier var tværsnitsstudier, og kun et´ havde et longitudinelt design. Studierne tydede generelt på en sammenhæng mellem et lavt indtag af mejeriprodukter og et højt plak score eller parodontal sygdom, mens der ikke sås konsistente sammenhænge i relation til tandtab. Alle studier omfattede hjemmeboende.

Konklusion: Kvaliteten af studierne var generelt moderat til lav og kun et' studie var longitudinelt. Der er derfor stadig behov for at nye langtidsstudier med god konfounderkontrol gennemføres, før der kan drages endelige konklusioner omkring de mulige forebyggende effekter af et højt indtag mejeriprodukter i forhold til forekomst af plak, parodontalsundhed og tandtab.

Clinical Perspective

Oral health can be greatly enhanced by optimal daily oral hygiene and regular professional dental care. The role of diet, largely sugar consumption, on the development of dental plaque and its potential to increase dental disease has been known for some time, but original research of a good quality on this is surprisingly scarce. Many studies are decades old and would not meet modern criteria of quality or ethics. Therefore an overview of current research into this area is needed to equip clinicians with the knowledge they need to inform and support their patients. This paper provides such data. Clinician's will be able to judge for themselves the quality of the evidence sourced and presented here and subsequently trust that the messages that they are passing on to patients are based on current, peer reviewed, ethically sound research. Equally from the information provided here, clinical dental researchers will be able to identify promising areas for further much needed research into diet as a modifiable variable using research methods not yet employed in this area, such as RCTs or longitudinal studies.

Word count: 180

Introduction

Recently, the possibility that consumption of dairy foods may be beneficial to the prevention of oral health problems has received attention (1). Various components of bovine milk have been considered to be protective against periodontal disease , dental plaque and tooth loss, namely minerals (e.g. calcium), vitamins, proteins (e.g. casein and whey) as well as lipids (2-4). In many countries, cow's milk is the most common type of milk consumed, and there is little information on dental properties of milk other than bovine milk (2, 3). The systemic effects of such nutrients may include the influence on tooth development and growth or the resistance to development of dental disease. In addition, diet may affect the virulence of certain microorganisms (5, 6). Local effects include the influence of diet on dental plaque formation, which is the primary aetiological factor for the initiation of periodontal disease, and the amount, composition and acidity of the saliva (3, 5) are factors that also affect periodontitis and caries risk.

Effect of milk and dairy products on mineral retention and prevention of alveolar bone loss

Tooth loss has been associated with low bone mineral status in the alveolar and hip bones (7). Loss of natural teeth that are replaced with a partial denture is known to increase the risk of periodontal disease in sites near to the abutment (8). Studies have suggested that high intakes of calcium and vitamin D may enhance enamel remineralisation, reduce demineralization (9), and prevent alveolar bone loss with consequent improvement in retention of the natural dentition (10). In addition, dietary calcium has a local enamel-protective effect which improves tooth retention by reducing the risk of extraction due to carious lesions (11). The nutrients content of dairy foods such as lactose and casein phosphopeptides may also enhance calcium absorption and mineral retention (4, 12).

Previous Danish studies in adults (30-60 years) and elderly (66-95 years) found that higher intake of dairy calcium, but not non-dairy calcium, was protective against tooth loss and periodontal disease (13, 14). It has been suggested that sufficient vitamin D in the diet was of importance for the

appearance of the significant benefits of higher calcium intakes (15). During a RCT for prevention of osteoporosis, 11 of the 82 (13%) elderly subjects taking supplement of calcium citrate (500 mg) and vitamin D (700 IU) and 17 of the 63 subjects (27%) taking placebo lost one or more teeth. Similar results were reported after two years of follow-up and suggest that intake levels of calcium and vitamin D aimed at preventing osteoporosis in elderly (71 years ± 5 years) may also have a beneficial effect on tooth retention (10).

Effect of milk and dairy foods on dental plaque and periodontal disease

Adequate plaque control from an optimal oral hygiene routine is essential for preventing the development of dental plaque and subsequent oral diseases (16). The presence of saliva is vital for the maintenance of healthy oral tissues. Saliva contains antimicrobial lysozyme and histatins that control bacterial growth, including those associated with caries and periodontal disease (17).

The saliva-stimulating effect from consuming dairy products, particularly hard cheese, has been debated in dental literature for some time, although much of this research has focused on the potential benefits of minimising caries rather than periodontal disease (18). An experimental study found that Cheddar consumption after ingestion of a sugary food rapidly returned plaque pH toward neutrality (19). In addition, it was observed that cheese consumption stimulated salivary flow, and as such it was proposed that the pH-raising effect of cheese was attributable to the stimulation of salivary flow (19).

Several studies have measured the effects of milk on acid production in human dental plaque (20). It has been found that ingestion of milk produced only a minimal drop in plaque pH, but cheese consumption seems to not lead to decrease in pH and may even help to neutralise the plaque pH after consumption of acidogenic foods (20, 21). More specifically, in a recent study by Ravishankar, *et al.* (22) consumption of cheese and yogurt was followed by a statistically significant rise in mean plaque concentrations of calcium and phosphorus, whereas milk showed a lower rise (22). As such high

concentrations of calcium and phosphate in saliva may inhibit bacterial biofilm formation (4, 23) and whey protein might enhance immune system function and inhibit plaque formation (24). Furthermore, Oral Lactobacilli may play an important role on oral health by regulating the immune system and preventing the growth of periodontal pathogens in the oral cavity (25), suggesting that fermented milk products with probiotic properties may have a prophylactic effect in the oral cavity. Additionally, it has been proposed that milk has bioactive peptides with activity against bacterial adhesion and may have prophylactic and therapeutic values in controlling the development of oral pathologies such as caries and periodontal disease (26).

The effect of probiotics, defined as living microorganisms that, when administered in adequate amounts, confer a health benefit on the host and periodontal disease has been investigated in a number of clinical trials (27-30). These studies have indicated that probiotics may be effective in reducing bacterial plaque deposition (27), in lowering cytokine levels (a marker of inflammation) and by reducing bleeding on probing (BOP) (29). However, even if the results may seem promising, the majority of the studies were short-term and the magnitude of the effect was limited. Consequently the clinical relevance of these findings is still questionable (25).

The aim of this paper is to provide an overview of the epidemiological studies linking intake of milk and dairy products to dental plaque, periodontal disease and tooth loss. Despite the fact that dietary guidelines are usually based on nutrient contents, individuals eat ‘food’; thus, nutritional advice for health promotion and disease prevention should be based on foods or combinations of foods that can meet nutrient requirements rather than on how each specific nutrient is provided in adequate amounts. Therefore, this review is not particularly focused on the effects of consumption of specific nutrients, but rather on the overall effect of dairy consumption.

Methods

The following sources were searched: MEDLINE, Cochrane Database of Systematic Reviews (CDSR) and Cochrane Central Register of Controlled Trials (CENTRAL). Reference lists of original studies and other systematic reviews were also examined. The following words were applied in the Title/ Abstract field: ‘periodont*’ OR ‘pocket depth’ OR ‘attachment loss’ OR ‘dental plaque’ OR ‘dental’ OR ‘plaque’ OR ‘tooth loss’ AND ‘milk’ OR ‘dairy’ OR ‘cheese’ OR ‘yogurt’ OR ‘cream’ OR ‘ice-cram’. MeSH terms were also used: "periodontitis" and "dairy product" and "tooth loss". A filter for human studies was applied in MEDLINE search. Electronic searches and reviewing of results were performed by one reviewer. Another reviewer also assessed the relevance of identified studies for inclusion, and disagreements were resolved by consensus. No restrictions regarding date of publication and language were applied.

Studies were included on the basis of: (i) human epidemiological studies (cross-sectional, cohort, case-control or clinical trials) in adult (aged 18 years or older) and/or elderly population (aged 65 years or older); (ii) milk or dairy products considered as independent variable; and (iii) periodontitis (defined according to the authors), pocket depth (PD), bleeding on probing (BOP), clinical attachment loss (CAL), dental plaque (including plaque index or plaque score) or tooth loss (including number of remaining teeth) as one of the main outcomes. In vitro studies, animal studies and studies on human milk were not considered in this review. Experimental studies and observational human studies focusing on probiotics or specific micronutrients, such as calcium, vitamin D, casein and whey proteins, instead of dairy consumption per se were not included.

Results

The search yield 1012 hits in MEDLINE and 281 hits in the Cochrane Library. Two additional studies were found via hand search. After excluding duplication and not eligible studies on the basis of title and abstract examination, 17 studies were selected for full-text assessment. Only nine studies met the inclusion criteria. Of the nine studies included in this review, four were carried out in Japan

(31-34), one in USA (35) three in Europe (13, 15, 36), and one in Georgia (37). Most studies included adult populations (31, 33, 35, 37), three studies only included elderly (≥ 65 years) (14, 15, 34), one included young adults (36) and one included pregnant women (32). All studies involved community dwelling individuals. The general characteristics of included studies and main results are summarized in table 1 and 2, respectively.

Dental Plaque

Studies related to dental plaque levels of caries-related microorganisms such as Mutans streptococci were not considered. Studies on probiotics were not included, but a summary of existing data is presented in the introduction.

Only 3 studies reported data using dental plaque as an outcome. One study defined plaque score as the presence or absence of visible plaque on any surface of the tooth (17), another study as the percentage of tooth surfaces exhibiting plaque (14, 37). One study used aproximal plaque index (API) (36). All studies used a cross-sectional design.

In a pilot cross-sectional study with 40 participants (young adults), Kantorowicz *et al* (2014) (36) found that men who consumed milk and dairy products three times a week had statistically lower API values relative to the mean index value. However, the association was not statistically significant among women.

Adegboye *et al* (13) found that among 606 elderly Danish adults, a daily intake of three or more servings of dairy foods was significantly associated with a lower plaque score (OR = 0.54; 95% CI = 0.33-0.89) even after adjustments for age, gender, education, intakes of alcohol, sucrose and mineral supplements, smoking, diseases, number of teeth, visits to the dentist, use of dental floss/tooth pick and salivary flow. However, vitamin D intake also played a role, and associations were seen among those with relatively high vitamin D intake, only. These findings were in contrast to those of Tsitaishvili *et al* (45), who did not find any association between dairy intake and plaque

score. However, their sample size was small, there was no control for confounding factors, and vitamin D intake was not considered.

Periodontal disease

There were five cross-sectional studies (14, 31, 35-37) and only one longitudinal study (34), which specifically analysed the relationship between consumption of dairy products and periodontal disease or clinical measures of periodontal risk. No randomized clinical trials (RCT) were found. Most results from RCTs available in the literature involved purely calcium and vitamin D supplementation and were therefore not included in this review.

Al-Zahrani (2006) (35) using data from the US NHANES III reported a significant inverse association between intake of dairy products and prevalence of periodontal disease among 12,764 adults over the age of 18 years. After adjustment for confounders, individuals who were in the highest quintile of intake of dairy products were 20% less likely to have periodontal disease than individuals in the lowest quintile. The study covered intake of various milk and milk products. The authors suggested that calcium and vitamin D might explain the results, partly due to the link between osteoporosis and susceptibility to loss of alveolar bone support (35).

Shimazaki *et al.* (2008) in a multivariate analysis, found no significant inverse association between intake of milk (which was high in this population) and periodontal disease among 942 Japanese adults aged 40-79 years. Instead, a strong inverse association between intake of fermented dairy and periodontitis was reported. The authors speculated that calcium intake alone may not be important for periodontal disease prevention as the amount of calcium in milk is similar to that in yogurt, and suggested that lactic acid foods may have a beneficial effect on periodontal disease due to a probiotic effect of lactobacilli in fermented dairy foods (31).

Kantorowicz *et al* (36) found that a frequent consumption of dairy products was inversely associated with BOP (p =0.02) among men, only. In contrast, data from a population-based survey in Georgia (n = 2370) demonstrated that consumption of dairy products did not directly associate with periodontal status (37). However, according to the authors, education level and family income defined food selection in general and in this way could contribute to the overall health and potentially impact oral health as well. Individuals with high education and family income were more frequent consumers of dairy and meat products compared to those of low household income and lower education (37). Since adjusted analysis was not presented, it is possible that the results were affected by confounders (e.g. social economic status).

Adegboye *et al* (13) found that total dairy foods (IRR = 0.96; p = 0.003), milk (IRR = 0.96; p = 0.028) and fermented foods intake (IRR = 0.97; p = 0.029) were associated with a reduced risk of periodontal disease among older Danish adults, but the intake of cheese and other dairy foods were not. In this study, the associations between intake of either milk or fermented foods with periodontal disease did not significantly differ (p > 0.05). However, it cannot be excluded that this lack of association with cheese intake might be due to inadequate statistical power attributable to the low range of cheese consumption (0 g to 354 g) compared to that of milk (0 g to 2197 g) or of fermented foods (0 g to 1000 g) (13).

The only longitudinal study identified, involved 600 participants aged 70 and found a significant inverse relationship between the amount of daily milk intake and the incidence of root carious lesions (34). However, no associations of milk intake were found to the number of periodontal disease events during the 6 years of follow up. The authors highlighted that it was not possible to confirm a clear cause–effect relationship between nutrition and oral health (caries and periodontal disease) because of a lack of information on the longitudinal change in nutrition during the 6 years of

follow up (34). To explore the actual relationship between dairy intake and periodontal disease , further prospective studies and particularly clinical trials are warranted.

Tooth loss

Only two cross-sectional studies have investigated the association between intake of milk or milk products and tooth loss (32, 33). Wakai *et al* designed a study to examine the association between number of teeth and dietary intake among 20,366 Japanese dentists, who participated in a nationwide cohort study from 2001 to 2006, and found that low consumption of milk and dairy was associated with an increasing number of teeth lost (33). The association between number of teeth (categorized as 0, 1–9, 10–19, 20–24, and 25–28 teeth) and dietary intake was independent of age, sex, smoking habits, physical activity, or history of diabetes. Tanaka *et al* investigated the relationship between consumption frequencies of various beverages, including milk and the prevalence of tooth loss (defined as experience of extraction of one or more permanent teeth and the number of remaining teeth) among 1002 young pregnant adult women in Japan and found no significant associations (32). Thus, the results on diary intake and tooth loss from observational studies are inconclusive.

Discussion

Both caries and periodontal disease are preventable by optimal oral hygiene and this should be promoted by private and public dental care services. However, despite the increased use of dental care system in some countries like Denmark, no significant changes in oral hygiene habits has been seen at population level (38, 39) and this brings a need for identifying other preventive measures, including other modifiable lifestyle factors, such as diet to address this public health problem.

This review pointed out some potential beneficial effects of dairy intake on oral health, for instance an inverse association between dairy intake and plaque score and pocket depth and attachment loss, while results related to tooth loss were inclusive. However, the methodological quality of reviewed

studies was moderate to low with most studies cross sectional in design and only one longitudinal in design which provide a lower level of evidence in support of a causal effect, compared to RCTs and more longitudinal studies. Furthermore, studies focusing on specific age groups (elderly, young adults, pregnant women, etc.) were rarely found, and information on confounding and dietary intake was incomplete in some publications. Most of the studies used crude information on dairy intake and only few studies applied validated dietary assessment instruments. Dietary intake is often assessed by asking individuals to report their previous or habitual intake. However, irrespective of instrumentation used to asses habitual intake, diet reporting is prone to error as information on habitual intake always rely on self-report, and hence on individual memory, capacity to generalize and willingness to report accurate intake (40). Such biased reporting seems particularly liable to cause underestimation of consumption of unhealthy foods rich in fat (e.g. whole milk, butter, cream and ice creams) and simple carbohydrates (sugars) and overestimation of intakes of healthy foods including fruits and vegetables, and potentially of some low-fat dairy products (*e.g.* low-fat cheese and skimmed milk) (40).

Observational studies of dietary intake and health outcomes are usually affected by confounding factors. Therefore, it is crucial to ponder the influence of confounders into the relationship between diet and periodontal disease in the analysis. Most previous studies controlled for some confounding factors, but only few actually considered a wide range of potential confounders, such as gender, socioeconomic status, caloric intake, lifestyle, dental care visits, number of remaining teeth, medication, salivary flow and oral hygiene status. The possibility that milk or dairy foods intake is merely a marker of healthier diets or diets higher in nutritional quality cannot be completed ruled out (41) .Thus, some studies might have been affected by residual confounding that may partially explain the discrepancy in their results. Furthermore, synergies between foods and/or nutrients, as those observed between dairy and vitamin D intake, were rarely considered in previous studies.

When specific nutrients as well as their food groups are both associated with a health condition, those associations are less likely to be spurious (13). In many countries, dietary reference values provide population-wide guidance on intakes of various nutrients. However, people do not eat food groups and nutrients in isolation, but rather in combination. Therefore, the use of nutrient-based guidelines alone for health promotion and disease prevention is unlikely to enable changes in food consumption habits. Milk and dairy products contain minerals (particularly calcium) and proteins (casein and whey) which might have a specific role in oral health (2, 5). A previous systematic review on the effect of specific nutrients such as calcium and vitamin D confirm this hypothesis (42). In a previous longitudinal study, Garcia *et al* (43) reported that calcium and vitamin D supplementation had a modest direct effect on periodontal health. Nishida *et al.* (2003) (44) showed an inverse relation between calcium intake and risk of periodontal disease , and Dietrich *et al.* (2004) (45) an inverse relation between vitamin D and periodontal disease .

Although this review was inconclusive regarding the effect of dairy intake and tooth loss based on cross-sectional studies, it is important to consider that due to the long-term nature of alveolar bone resorption, it might be the diet of several years ago that is responsible for the actual tooth retention. Furthermore, study results might have been affected by reverse causation, whereby once people, particularly older adults, have lost their teeth and consequently reduced chewing ability, they might have started consuming more soft foods, such as milk, yogurt and cheese. This change of behaviour after disease develops could make it seem as if a high intake of dairy is the cause of tooth loss. Therefore, long-term RCT or longitudinal studies in which information on dairy intake is collected several years before the outcome development are needed to clarify the potential influence of dairy intake on tooth loss.

Conclusion

We have performed an overview on the impact of intake of dairy foods on oral health. Meta-analysis was not carried out and therefore it is not possible to draw firm conclusions on the benefits of dairy intake on oral health.

Our findings suggest some health benefits of dairy products on oral health, however the majority of studies included in this review were based on results from cross-sectional studies with limited control for confounders. Therefore, these promising results need to be confirmed in well-designed prospective, and not least, RCT studies, in order to infer causality as the possibility that dairy intake may simply be a marker of a high-quality diet or healthier lifestyle, having no favourable effect per se in oral health could not be excluded. Addressing these research gaps might help clarify the effect of dairy on oral health and settle the place of milk and dairy in the healthy eating paradigm, hence contributing to better informed evidence-based decisions.

We recommend that clinicians should review the literature constantly to expand their prophylactic and therapeutic options and to be able to give their patients the most appropriate advice to improve or maintain their oral health.

Characters count: 18912 without spaces

Acknowledgements and Financial support

None

Literature

1. Watt RG. Strategies and approaches in oral disease prevention and health promotion. Bull World Health Organ. 2005 Sep;83(9):711-8.
2. Johansson I. Milk and dairy products: possible effects on dental health. Scand J Nutr. 2002;46(3):119-22.
3. Johansson I, Lif Holgerson P. Milk and oral health. Nestle Nutr Workshop Ser Pediatr Program. 2011;67:55-66.
4. Aimutis WR. Bioactive properties of milk proteins with particular focus on anticariogenesis. J Nutr. 2004 Apr;134(4):989S-95S.
5. Bowen WH. Effects of dairy products on oral health. Scand J Nutr. 2002;46(4):178-9.

6. Konig KG. Diet and oral health. Int Dent J. 2000 Jun;50(3):162-74.
7. Krall EA, Garcia RI, Dawson-Hughes B. Increased risk of tooth loss is related to bone loss at the whole body, hip, and spine. Calcif Tissue Int. 1996 Dec;59(6):433-7.
8. Greene PR, Jackson M. The periodontium, tooth deposits and periodontal disease. In: Ireland RE, editor. Clinical Textbook of Dental Hygiene and Therapy. Oxford: Blackwell Munksgaard; 2006.
9. Ferrazzano GF, Cantile T, Quarto M, Ingenito A, Chianese L, Addeo F. Protective effect of yogurt extract on dental enamel demineralization in vitro. Aust Dent J. 2008 Dec;53(4):314-9.
10. Krall EA, Wehler C, Garcia RI, Harris SS, Dawson-Hughes B. Calcium and vitamin D supplements reduce tooth loss in the elderly. Am J Med. 2001 Oct 15;111(6):452-6.
11. Papas AS, Joshi A, Palmer CA, Giunta JL, Dwyer JT. Relationship of diet to root caries. Am J Clin Nutr. 1995 Feb;61(2):423S-9S.
12. Gueguen L, Pointillart A. The bioavailability of dietary calcium. J Am Coll Nutr. 2000 Apr;19(2 Suppl):119S-36S.
13. Adegboye AR, Christensen LB, Holm-Pedersen P, Avlund K, Boucher BJ, Heitmann BL. Intake of dairy products in relation to periodontitis in older Danish adults. Nutrients. [Research Support, Non-U.S. Gov't]. 2012 Sep;4(9):1219-29.
14. Adegboye AR, Twetman S, Christensen LB, Heitmann BL. Intake of dairy calcium and tooth loss among adult Danish men and women. Nutrition. 2012 Jul;28(7-8):779-84.
15. Adegboye AR, Christensen LB, Holm-Pedersen P, Avlund K, Boucher BJ, Heitmann BL. Intakes of calcium, vitamin D, and dairy servings and dental plaque in older Danish adults. Nutr J. 2013;12:61.
16. Public Health England. Delivering Better Oral Health: an evidence based tool kit for prevention. 3rd ed: Department of Health; 2014.
17. Brock GR, Butterworth CJ, Matthews JB, Chapple IL. Local and systemic total antioxidant capacity in periodontitis and health. J Clin Periodontol. 2004 Jul;31(7):515-21.
18. Herod EL. The effect of cheese on dental caries: a review of the literature. Aust Dent J. 1991 Apr;36(2):120-5.
19. Rugg-Gunn AJ, Edgar WM, Geddes DA, Jenkins GN. The effect of different meal patterns upon plaque pH in human subjects. Br Dent J. 1975 Nov 4;139(9):351-6.
20. Jensen ME, Schachtele CF. The acidogenic potential of reference foods and snacks at interproximal sites in the human dentition. J Dent Res. 1983 Aug;62(8):889-92.
21. Graf H. The glycolytic activity of plaque and its relation to hard tissues pathology--recent findings from intraoral pH telemetry research. Int Dent J. 1970 Sep;20(3):426-35.
22. Ravishankar TL, Yadav V, Tangade PS, Tirth A, Chaitra TR. Effect of consuming different dairy products on calcium, phosphorus and pH levels of human dental plaque: a comparative study. Eur Arch Paediatr Dent. 2012 Jun;13(3):144-8.
23. Danielsson Niemi L, Hernell O, Johansson I. Human milk compounds inhibiting adhesion of mutans streptococci to host ligand-coated hydroxyapatite in vitro. Caries Res. 2009;43(3):171-8.
24. Krissansen GW. Emerging health properties of whey proteins and their clinical implications. J Am Coll Nutr. 2007 Dec;26(6):713S-23S.
25. Haukioja A. Probiotics and oral health. Eur J Dent. 2010 Jul;4(3):348-55.
26. Signoretto C CP, Stauder M, Vezzulli L. Functional foods and strategies contrasting bacterial adhesion. Curr Opin Biotechnol. 2012;23(2):160-7.
27. Krasse P, Carlsson B, Dahl C, Paulsson A, Nilsson A, Sinkiewicz G. Decreased gum bleeding and reduced gingivitis by the probiotic Lactobacillus reuteri. Swed Dent J. 2006;30(2):55-60.
28. Shimauchi H, Mayanagi G, Nakaya S, Minamibuchi M, Ito Y, Yamaki K, et al. Improvement of periodontal condition by probiotics with Lactobacillus salivarius WB21: a randomized, double-blind, placebo-controlled study. J Clin Periodontol. 2008 Oct;35(10):897-905.
29. Twetman S DB, Keller M, Ekstrand K, Yucel-Lindberg T, Steckse´n-Blicks C. Short-term effect of chewing gums containing probiotic Lactobacillus reuteri on the levels of inflammatory mediators in gingival crevicular fluid. Acta Odontol Scand. 2009;67(1):19-24.

30. Pinto GS, Cenci MS, Azevedo MS, Epifanio M, Jones MH. Effect of yogurt containing Bifidobacterium animalis subsp . lactis DN-173010 probiotic on dental plaque and saliva in orthodontic patients. . Caries Res. 2014;48(1):63-8.
31. Shimazaki Y, Shirota T, Uchida K, Yonemoto K, Kiyohara Y, Iida M, et al. Intake of dairy products and periodontal disease: the Hisayama Study. J Periodontol. 2008 Jan;79(1):131-7.
32. Tanaka K, Miyake Y, Sasaki S, Ohya Y, Matsunaga I, Yoshida T, et al. Beverage consumption and the prevalence of tooth loss in pregnant Japanese women: the Osaka Maternal and Child Health Study. Fukuoka Igaku Zasshi. 2008 Apr;99(4):80-9.
33. Wakai K, Naito M, Naito T, Kojima M, Nakagaki H, Umemura O, et al. Tooth loss and intakes of nutrients and foods: a nationwide survey of Japanese dentists. Community Dent Oral Epidemiol. 2010 Feb;38(1):43-9.
34. Yoshihara A, Watanabe R, Hanada N, Miyazaki H. A longitudinal study of the relationship between diet intake and dental caries and periodontal disease in elderly Japanese subjects. Gerodontology. 2009 Jun;26(2):130-6.
35. Al-Zahrani MS. Increased intake of dairy products is related to lower periodontitis prevalence. J Periodontol. 2006 Feb;77(2):289-94.
36. Kantorowicz M, Olszewska-Czyz I, Kolarzyk E, Chomyszyn-Gajewska M. Influence of diet on oral health in young adults--pilot study. Przegl Lek. 2014;71(10):505-11.
37. Tsitaishvili L, Margvelashvili M, Kalandadze M, Margvelashvili V. The prevalence of periodontal diseases among adult population in Georgia. Georgian Med News. 2014 Sep(234):25-32.
38. Christensen LB, Petersen PE, Krustrup U, Kjoller M. Self-reported oral hygiene practices among adults in Denmark. Community Dent Health. 2003 Dec;20(4):229-35.
39. Christensen GJ. Providing oral care for the aging patient. J Am Dent Assoc. 2007 Feb;138(2):239-42.
40. Heitmann BL, Lissner L. Dietary underreporting by obese individuals--is it specific or non-specific? BMJ. 1995 Oct 14;311(7011):986-9.
41. Lamarche B, Givens DI, Soedamah-Muthu S, Krauss RM, Jakobsen MU, Bischoff-Ferrari HA, et al. Does Milk Consumption Contribute to Cardiometabolic Health and Overall Diet Quality? Can J Cardiol. 2016 Aug;32(8):1026-32.
42. van der Putten GJ, Vanobbergen J, De Visschere L, Schols J, de Baat C. Association of some specific nutrient deficiencies with periodontal disease in elderly people: A systematic literature review. Nutrition. [Review]. 2009 Jul-Aug;25(7-8):717-22.
43. Garcia MN, Hildebolt CF, Miley DD, Dixon DA, Couture RA, Spearie CL, et al. One-year effects of vitamin D and calcium supplementation on chronic periodontitis. J Periodontol. 2011 Jan;82(1):25-32.
44. Nishida M. [Calcium and the risk for periodontal disease]. Clin Calcium. 2003 May;13(5):618-22.
45. Dietrich T, Joshipura KJ, Dawson-Hughes B, Bischoff-Ferrari HA. Association between serum concentrations of 25-hydroxyvitamin D3 and periodontal disease in the US population. Am J Clin Nutr. 2004 Jul;80(1):108-13.

Table 1. General characteristics of reviewed studies

Author, year	Country	N	Population	Age	Study Design	Dairy	Dietary Assessment	Outcome
Adegboye, 2013	DK	606	Older Danish adults (men & women)	≥65y	CS	<3 vs ≥3 servings of dairy/d	Diet history interview	Plaque score
Adegboye, 2012	DK	135	Older Danish adults (men & women)	≥65y	CS	Dairy food intake (g/d) classified into 4 groups: milk, cheese, fermented foods and other foods.	Diet history interview	Periodontitis (number of teeth with attachment loss ≥3 mm)
Al-Zahrani, 2006	USA	12,764	Adult men and women from NHANES III	≥18y	CS	Milk and dairy products categorised in quintiles	24-h dietary recall	Periodontitis
Kantorowicz, 2014	Poland	40	Young adult men and	19-21y	CS (pilot)	Milk and dairy products intake	FFQ	Plaque index BOP

			women			three times a week or less (yes/no)		
Shimazaki,2008	Japan	942	Adult men and women	40-79y	CS	Milk and dairy products intake (g/d) in quartiles	FFQ	PD, CAL
Tanaka, 2008	Japan	1002	Pregnant Japanese women	≥31y	CS	Milk intake in tertiles	Validated diet history questionnaire	Tooth loss (extraction of ≥ 1 permanent teeth excluding 3rd molars, and the number of remaining teeth)
Tsitaishvili, 2014	Georgia	2,370	Adults men and women spilt in 4 age groups	20-34y 35-44 y 45-64y ≥65 y	CS/PBS	Dairy products categorized by no consumption, once a week or rarely, 2-4 times a week or	Validated FFQ	Plaque score, Calculus score, PD, BOP, CAL & Periodontitis

						everyday		
Wakai, 2009	Japan	20,366	Japanese dentists	26-98y	CS	Milk and dairy products intake (g/d)	Validated FFQ	Number of remaining teeth (calculated as 28 minus the number of lost teeth irrespective of use of dentures) divided into 5 categories
Yoshihara, 2009	Japan	600	Elderly Japanese	≥70y	LS	Drinking milk everyday (yes/no) and dairy products (g/kg)	FFQ	Periodontitis progression

CAL, clinical attachment loss; CS, cross-sectional; BOP, bleeding on probing; DK, Denmark; FFQ, food frequency questionnaire; LG, longitudinal; NS, non-significant association; PBS, population-based survey; PD, Pocket depth; Y, year

Table 2. Summary of the key findings of reviewed studies

Author, year	Type of analysis	Direction/ significance of results	Results Analysis	Confounders
Adegboye, 2013	Logistic regression	Inverse association (Plaque Score *)	Intakes of dairy servings within recommendations (≥3 servings/d) was associated with lower plaque score, among those with higher, but not lower, vitamin D intakes	Age; gender; education; alcohol intake; sucrose intake; smoking; supplements; diseases; number teeth and dental visits.
Adegboye, 2012	Poisson regression	Inverse association (Periodontitis*)	Total dairy foods, milk and fermented foods intakes were associated with reduced risk of periodontitis, but cheese and other dairy foods intakes were	Age, gender, education, sucrose intake, alcohol consumption, smoking, physical activity, vitamin D intake, heart

			not.	disease, visit to the dentist, use of dental floss, number of remaining teeth and BOP
Al-Zahrani, 2006	Logistic regression	Inverse association (Periodontitis rate***)	Prevalence of periodontitis was 41% lower for individuals in the highest quintile of intake of dairy products than those in the lowest quintile (P<0.001 for trend). After adjusting for confounding factors individuals in the highest quintile of intake were 20% less likely to have periodontitis than those in the lowest quintile (P=0.024 for	Age, gender, race\ethnicity, cigarette smoking, education, diabetes, poverty index, vitamin use, body mass index, physical activity, time since the last dental visit, dental calculus, and gingival bleeding

			trend)	
Kantorowicz, 2014	T-test	Inverse association (Plaque*, BOP**)	Men who consumed milk and dairy products three times a week or less had statistically lower plaque index (p = 0.05) and BOP values (p = 0.02), relative to the mean index values	No adjustments
Shimazaki, 2008	Linear regression	Inverse association (PD***, CAL **)	Daily intake of dairy products was significantly lower in subjects with generalized PD/ severe CAL than in subjects with localized PD or slight CAL. Subjects eating > or =55 g lactic acid foods per day had a significantly lower prevalence of	For CAL: Age, gender, number of teeth, smoking, plasma glucose and HDL. For PD: the above mentioned plus alcohol intake, total energy intake, tooth brushing

			PD and severe CAL compared to those not eating these foods after adjusting for confounding	and medication
Tanaka, 2008	Logistic regression	Inverse association (tooth loss ^{NS})	There was no significant association of intake of milk with tooth loss	Age, gestation, parity, smoking, passive smoking at home and at work, family income, education, changes in diet in the previous month, season when data were collected and body mass index
Tsitaishvili, 2014	Chi^2 test; T-test	NS association for all outcomes	Data NA	No adjustments
Wakai, 2009	Linear regression	Inverse association (tooth	The mean intakes of milk and	Age, sex, smoking,

		loss*)	dairy products decreased with the increasing number of teeth lost (P for trend <0.05)	physical activity and history of diabetes
Yoshihara, 2009	Linear (stepwise) and logistic regression	Inverse (periodontitis ^{NS})	Periodontal disease progression from baseline to follow-up among individuals who did not drink milk everyday compared with those who drank every day was 95.7% and 95.8% respectively. The OR of periodontal disease progression for the subjects who did not drink milk every day was 0.97, but not statistically significant after adjustment for confounding factors	Gender, age and education

NS, non-significant; * p-value < 0.05; ** p-value <0.01; *** p-value <0.001; NA, not available