Protein Intake and Oral Health in Older Adults

Subjects: Others
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Oral health is vital to general health and well-being for all ages, and as with other chronic conditions, oral health problems increase with age. There is a bi-directional link between nutrition and oral health, in that nutrition affects the health of oral tissues and saliva, and the health of the mouth may affect the foods consumed. Evidence suggests that a healthy diet generally has a positive impact on oral health in older adults. Although studies examining the direct link between oral health and protein intake in older adults are limited, some have explored the relationship via malnutrition, which is also prevalent among older adults. Protein–energy malnutrition (PEM) may be associated with poor oral health, dental caries, enamel hypoplasia, and salivary gland atrophy.

older adults | protein intake | periodontitis | amino acid composition | oral health

1. Introduction

Oral health encompasses the condition of a person's teeth, gums, oral secretions, jaw bones, and facial muscles [1], and is a key indicator of overall health, well-being, and quality of life [2][3]. While oral health problems increase with age, adults over the age of 65 have more such problems than the rest of the population [4]. These problems include tooth loss, tooth decay, periodontal (gum) disease, dry mouth, and oral cancer, all of which can significantly impact general health [5], and may be the direct result of suboptimal care of the teeth and mouth [6].

Periodontitis (gum disease) is highly prevalent in older adults. Around 42% of dentate adults over 30 years old have periodontitis, which increases to >60% in adults over 65 years [7][8]. Periodontitis is an inflammatory disease characterised by the destruction of connective tissues and alveolar bone surrounding the teeth, and is a major cause of tooth loss. Periodontitis is associated with chronic diseases, particularly hyperglycemic states associated with poorly controlled diabetes mellitus [9], cardiovascular disease [10] and chronic kidney disease [11]. Factors associated with ageing also increase the risk of dental caries (tooth decay) in older adults due to an ecological imbalance in oral biofilm, leading to the demineralisation of teeth [12]. A recent systematic review reported that 50% or more of older adults had untreated dental caries [13]. Evidence from both association and controlled clinical depletion studies show that periodontitis and dental caries may be influenced by inherited risk factors, as well as those acquired over a lifetime, including poor oral health and sub-optimal dietary patterns [14][15][16][17][18]. A consensus report [14] concluded that the role of genetic factors in the development of periodontal diseases and caries was moderately strong, possibly contributing up to 50% of the risk. Much of this inherited risk is associated with specific genes associated with immune function (Fc gamma receptor, IL10) and the vitamin D receptor [14].

Oral structures, such as teeth, tongue, and salivary glands, play significant roles in maintaining a person's oral health. At least twenty teeth are considered necessary for a functional dentition [19]. The tongue is equipped with muscles, nerves and hormones, together regulating taste perception and satiety, and helping mastication and swallowing food [20]. Salivary glands produce approximately 0.5–1.5 L of saliva daily [21]. Saliva contains specific antimicrobial proteins such as lysozyme, lactoferrin, peroxidase enzymes, histatin and proline-rich proteins, and other substances, such as mucins, glycoproteins, fibronectin, beta-macroglobulin, lysozyme, and secretory-IgA, that clump bacteria [22][23]. Saliva also protects the oral and peri-oral tissues via lubrication, antimicrobial and cleansing activity, buffering (neutralising) acid production, controlling plaque pH with bicarbonate, and enhancing chewing, swallowing and initiation of digestion [24]. The structure of salivary glands and the flow and composition of saliva tend to change with ageing and age-associated diseases (such as Sjögren's syndrome) [25]. When saliva flow is reduced, and the pH is low (due to reduced buffering capacity), oral health problems such as dental caries and oral infections may develop due to acidic demineralisation of tooth structure and irritation of oral mucosal surfaces [26]. Oral diseases are detrimental to masticatory function, which is a crucial first step for processing food in the mouth. Mastication and subsequent nutrition acquisition are essential determinants of food choices and subsequent nutritional and health status, respectively [27].

Nutrition and oral health are intricately linked. Proper nutrition is essential for establishing good oral health in pre- and post-eruptive phases. Proteins and vitamins A, C and D, as well as calcium, phosphorous and fluoride, are nutrients essential for the development and maintenance of teeth [28]. In addition, the collagen in dentine is dependent on vitamin C for normal synthesis, and keratin incorporation into the enamel requires vitamin A. Daily intake of a variety of nutrient-dense food, rich in the above-mentioned nutrients, promote healthy teeth and gums.

Oral health is vital for ensuring proper dietary intake at any age. Older adults have increased risk of inadequate nourishment due to reduced chewing function because of tooth loss, pain or discomfort (e.g., from poorly fitting dentures), and impaired cognitive function [27][29][30]. For instance, edentulism can reduce the functionality of the mouth, making chewing and swallowing more challenging, thus compromising nutrition, contributing to low body mass index (BMI) [31]. Compromised nutrition due to altered food choices results in individuals selecting soft, easy-to-chew foods, that are often lower in fibre, protein and iron, amongst other nutrients [32]. Importantly, poor nutritional status is both a cause and consequence of poor oral health among older adults [33]. This combination of poor oral health and malnutrition can lead to lasting physical and psychological disabilities, reducing the quality of life of older adults.

It is essential to understand that appropriate nutrition and improved oral health outcomes go hand in hand. There are several expert opinions and multiple sources of evidence on the Recommended Dietary Allowance (RDA) of protein required for the prevention of malnutrition in older adults [34][35]. Protein is a crucial nutrient for older adults, especially as it is imperative for muscle health, maintaining energy balance, weight management, bone mineralisation, and cardiovascular function [36].

Proteins are made of various amino acids (AAs), including non-essential, essential (must be obtained from the diet), and branch-chain AAs (BCAAs) [37]. Protein plays a vital role in oral health as a building block for bone and the periodontium, including its role in tissue repair [38][39]. Protein is also crucial for preventing sarcopenia [40], maintaining normal immune function, and supporting wound healing. Higher protein intake is associated with improved periodontal healing [7]. The evidence about the impact of protein containing oral nutritional supplements (ONS) on the nutritional status of older adults is inconclusive. For instance, the results of a recent randomised control trial showed that daily intake of a nutritionally complete ONS powder improved nutritional outcomes of free-living adults at risk of malnutrition [41]. In contrast, a meta-analysis showed little evidence of ONS reducing malnutrition or its associated adverse outcomes in frail older adults [42].

2. Effect of Various Dietary Protein Sources on Oral Health

Protein is a vital macronutrient in a well-balanced diet, and is essential for growth, muscle strength and function, immune function, wound healing, and overall tissue homeostasis. In addition to general health, dietary proteins play a vital role in good oral health [43].

Not all protein is created equal. Dietary protein comes from non-animal (plants) and animal (meats, eggs, milk) sources. The quality of a protein is determined by its biological value (ratio of essential to non-essential amino acids), protein efficiency ratio (the ability of a protein to support growth), and net protein utilisation (the percentage of amino acids converted to tissue protein versus the amino acids digested). Furthermore, other nutrients in protein-rich foods (especially animal protein), such as calcium and vitamin D, have a beneficial effect on tooth retention in older adults [44]. Importantly, the calcium and phosphorus inherent in dairy foods, such as cheese and milk, help protect teeth against demineralisation by preventing the pH in the mouth from falling below 5.5, thereby reducing the risk of dental decay [43][45]. Additionally, there is an inverse association between the consumption of milk and dairy foods and the prevalence of periodontitis in the adult population [46]. While the exact mechanism behind this association has not yet been revealed yet, researchers postulate that lactic acid in fermented dairy products inhibits the growth of periodontal pathogens by decreasing oral pH [47].

Milk is an excellent protein food, providing essential amino acids and organic nitrogen for humans of all ages—allergic responses and lactose intolerance aside. Data from a rat study indicates that the whey portion of milk protein increases bone collagen, enhances bone strength, and prevents alveolar bone loss by increasing hydroxyproline, which can strengthen the coherence of bone [48][49]. In addition to the predominant milk proteins, casein and whey, there are also minor milk proteins and bioactive peptides, such as lactoferrin and transferrin. Several in vitro, in situ, and in vivo studies have shown that these bioactive dairy peptides reduce the risk of dental decay [50]. For example, salivary lactoferrin contributes to oral antimicrobial defences by inhibiting the growth of bacteria associated with periodontal disease and modulating the associated inflammatory processes [51]. Moreover, casein phosphopeptides–amorphous calcium phosphate (CPP-ACP) is a bioactive agent present in milk that is formulated from casein phosphopeptides (CPP) and amorphous calcium phosphate (ACP). CPP in milk is capable of stabilising calcium phosphate and increasing the calcium phosphate content in dental plaques [52]. Additionally, the incorporation of CPP-ACP into oral care products has been shown to prevent the formation of biofilm by *Streptococcus mutans*, a common cariogenic bacterium in the oral cavity involved in plaque formation [53]. This prevents *S. mutans* from adhering to the tooth surface, thus reducing the risk for dental caries [53]. However, this effect from the ingestion of typical dietary intakes of dairy products has, to date, not been demonstrated.

Dietary Amino Acid Composition and Its Effect on Oral Health

Multiple AAs are linked by peptide bonds to form a protein. Twenty-one AAs build up the proteins found in humans, of which nine must be obtained from the diet—these are the essential AAs [54].

It is important to consider the AA composition in proteins and how these affect oral health. AAs have a range of impacts on oral tissues; most are beneficial and act by reducing bacterial colonisation of oral tissues, modulating the inflammatory response, which reduces gingivitis and mucositis, reducing the risk of dental decay by enhancing the properties of saliva in neutralising acids or mineral homeostasis, and impacting the immune system to promote the phagocytosis of bacteria. **Table 1** details some of the known roles AAs play in oral health.

L-arginine, for example, inhibits bacterial coaggregation in the human oral cavity and stops plaque formation [55]. Kolderman's study also demonstrated that L-arginine monohydrochloride moderates multi-species oral biofilm development and community composition and enhances the activity of cetylpyridinium chloride, an antimicrobial compound. In adolescents aged 12–15 years, lower levels of histidine (a non-essential AA) appears to increase the risk of dental caries [56].

Valine, leucine, and isoleucine are BCAAs, essential for building muscle, protecting against muscle loss during exercise, and can be converted into energy. Research has indicated a negative impact of imbalanced dietary BCAAs on health and ageing [57], yet their effect on oral health in older adults has been barely explored.

Table 1. Effect of amino acids on oral health.

Amino Acid	Effect on Oral Health	Material	References
Alanine	Alanine and histidine form citrulline. A higher concentration of citrulline in saliva is correlated with periodontitis.	Human	[58]
Arginine	Arginine improves calcium absorption by the formation of soluble complexes with calcium that maintain calcium in an absorbent form, which is important for enamel maturation. Higher concentration saliva in Stage III Grade C generalised periodontitis.	Human	[58]
L-Arginine	L-Arginine monohydrochloride in saliva inhibits bacterial coaggregation in the oral cavity by decreasing the viscosity of extracellular polymeric substances produced by bacteria and altering cellular metabolism resulting in biofilm dispersion and reducing antibiotic tolerance.	Human	[55]

Amino Acid	Effect on Oral Health	Material	References
Aspartic acid	Adult age estimation is based on aspartic acid racemisation in dentine.	Human	[59]
Cysteine	Toxic to oral Streptococci through inhibiting an enzymatic step in the valine-leucine biosynthetic pathway.	Human	[60]
	Reduces bacterial biofilm adherence and biofilm biomass.	A multi-species plaque-derived biofilm model	[61]
N-Acetyl-L-cysteine (from L-cysteine)	Reduces pain and hypersensitivity of teeth. Protects gingivae from white lesions and oral mucosal inflammation after using bleaching agents.	Human	[62]
	As mouthwash, it treats and prevents gingivitis	Human	[63]
Glutamic acid	Higher in Stage III Grade C generalised periodontitis.	Human	[58]
Glutamine	Topical administration to patients receiving stomatoxic chemotherapy resulted in 20% decrease in moderate and severe oral mucositis.	Human	[64]
Glycine	Glycine supplement reduced dental caries development by 65.7% through the changes in the fatty acid composition of the tooth and a reduction in growth rate (no effect on the retention of either calcium or phosphorus by dietary glycine).	Rodent (rat)	[65]
	Glycine is an integral part of collagen that is an intrinsic component of the tooth structure. Reduced level of saliva glycine has been associated with collagen degradation. Hence, higher salivary glycine has been associated with reduced risk of dental caries and periodontitis through reduced collagen degradation and decreased collagenase activity, leading to less inflammation in gingiva.	Human	[66][67]
Histidine †	Reduces the risk of dental caries. Lack of histidine and its derivatives in saliva results in chelation, i.e., formation of metal complexes with amino acids, leading to initial lesion and secondary to destruction of the organic matrix by the action of proteolytic bacteria.	Human	[56]
Isoleucine †	Found in carious dentine	Human	[68]
Leucine †	Repaired carious enamel.	Human	[69]
	Leucine-rich amelogenin peptide regulates receptor activator of NF-kappa B ligand (RANKL) expression in	Rodent (mouse)	[70]

Amino Acid	Effect on Oral Health	Material	References
	cementoblast/periodontal ligament cells.		
Lysine †	Important for the integrity of dentally attached epithelium to act as a barrier to microbial products.	Lysine decarboxylas extracted on *Eikenella corrodens* bacterial cell surface	[71]
Methionine †	Methionine reduces the adverse effect of fluorides on soft tissue, and this has been found to be optimal for the prevention of the adverse effects of chronic fluoride intoxication together with vitamin E in drinking water.	Rodent (rat)	[72]
Phenylalanine †	May inhibit dental caries development. In bacteria, phenylalanine is converted to phenylpropionate or phenylacetate, resulting in alkali environment which is an essential factor in maintaining plaque pH homeostasis.	Human	[73]
Proline	Salivary proline-rich glycoprotein regulates the oral calcium homeostasis by controlling the supersaturated state of saliva with respect to calcium phosphate salts, countering the plaque acidity, formation of dental pellicle, and influencing the composition of plaque.	Human	[74]
	Moreover, this prevents the adherence of oral microorganisms inhibiting their growth and neutralises acids from biofilms protecting from dental caries.	Human	[75]
Serine and threonine †	Interact with host cytoplasmic phosphoproteins, facilitating internalisation of bacteria.	Primary cultures of human gingival epithelial cells	[76][77]
Tryptophan †	Tryptophan metabolites generated from oral supplementation of tryptophan promote regulatory T-cell (Treg) differentiation and suppress proinflammatory T-helper cell (Th)1 and Th17 phenotypes.	Rodent (mice)	[78]
	Higher saliva tryptophan level was observed in Stage III Grade B generalised periodontitis.	Human	[58]
Tyrosine	Potential biomarker of oral lichen planus (lower levels). Tyrosine is suggested to be involved in the antioxidative defence. [36]	Human	[79]
Valine †	Detected in sound dentine compared to carious dentine.	Human	[68]
Homocysteine ‡	[34][35] Associated with high narrow palate, mandibular prognathia (protruding lower jaw), crowding and early [36]	Human	[80]

ults is 0.8
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n range of
(men) for adults up to 70 years, and 0.94 g/kg (women)–1.07 (men) for >70 year olds [81]. Where protein intake is above the RDA of 0.8 g/kg/day in healthy older adults (52–75 years), whole-body net protein balance has been shown to be greater [82]. It is estimated that about 46% of older adults do not meet the protein intake recommendation [83], and a

Amino Acid	Effect on Oral Health	Material	References
	[37]		
	eruption of teeth and short dental roots.		[84]

† Essential amino acids, + is an AA but not present in the diet and not included in 21AAs.

f very old cally, total protein intake and differing AA composition in proteins may have different effects on the oral health of older adults. Significantly, older adults have anabolic resistance to AA intake compared to younger individuals. Therefore, older adults may in fact require higher levels of dietary protein (or essential AA) consumption [85]. Ultimately, insufficient protein and/or energy intake may lead to malnutrition [86].

4. Protein–Energy Malnutrition and Oral Health in Older Adults

PEM is prevalent among older adults [87]. It occurs when the body does not receive or absorb enough protein for its physiological metabolism [88]. When PEM occurs in early childhood, it affects the developing immune system, reducing the ability to respond to periodontal pathogens in later life [45]. Anorexia, also common in older adults, contributes to malnutrition due to links to the neurotransmitters and hormones that affect the central feeding drive and the peripheral satiation system [89]. Fluctuating hormones, reduced dentition and some medications decrease the appetite, leading to dietary alterations [90]. These problems are exaggerated due to changes in the absorption and metabolism of essential nutrients that occurs with advancing age.

Malnutrition affects oral health, and poor oral health, in turn, may lead to malnutrition [91]. Research on oral health determinants of community-dwelling older adults identified xerostomia, loss of teeth, and toothache while chewing as determinants of incident malnutrition in community-dwelling older adults [92]. Adverse effects of malnutrition on oral structures include: reduced tooth size, increased enamel solubility, and salivary gland dysfunction [91][93]. There are several mechanisms through which malnutrition is associated with dental caries: (1) enamel hypomineralisation and hypoplasia; (2) under-functioning salivary glands, with reduced flow and changes in composition, affecting buffering capacity and antimicrobial components [23]; and (3) reduced capacity for tissue healing and resisting microbial biofilms [91]. Additionally, it is the lower protein intake that may result in mTORC1 (mammalian target of rapamycin complex 1) failing to activate S6K1 (Ribosomal protein S6 kinase beta-1), leading to less muscle protein synthesis and a possible decrease in chewing function [94]. However, there is a paucity of data on the impact of AA composition and protein intake on oral health.

Hidden hunger, characterised by a deficiency in essential micronutrients, is prevalent in older adults [95]. Therefore, low protein intake, in combination with micronutrient deficiencies, (e.g., vitamin A, zinc and iron), may lead to progression of oral disease including tooth decay [96]. **Figure 1** demonstrates the links between low food intake and oral health in older adults.

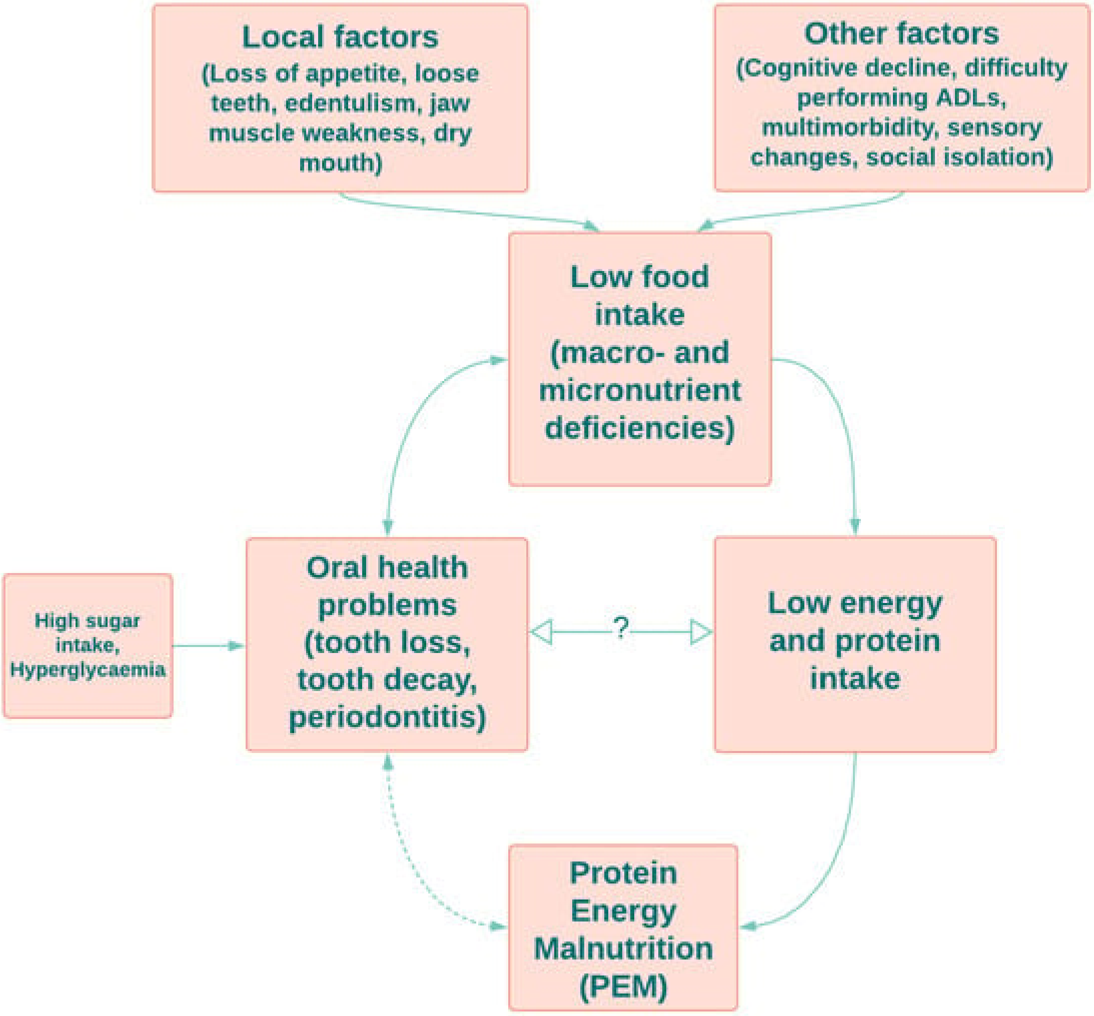

Figure 1. A summary of known and putative links between food and protein intake and oral health in older adults.

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