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Correlation between vegetarian diet and oral health: a systematic review

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Abstract. – OBJECTIVE: Nutrition plays a significant role in preserving the balance of the human body. Considering each person's particular characteristics, diet can directly and indirectly alter the body's immune response.

The purpose of this study is to draw attention to the connection between a vegetarian diet and its impact on oral health.

MATERIALS AND METHODS: To determine the connection between a vegetarian diet and dental health, a search of the literature was conducted on the PubMed, Scopus, and Web of Science databases. English language and a publication year between January 1, 2013, and March 1, 2023, were the inclusion criteria for the search.

RESULTS: There were 167 articles in total that addressed the subject of interest, and 18 of them were chosen for qualitative analysis.

CONCLUSIONS: This study suggests that a vegetarian diet may alter oral health, namely periodontal health, tooth erosion, and oral microbiome. Even if the data collected prevents the effect of a vegetarian diet on oral health from being confirmed, this study acts as a starting point for future, more focused research.

Key Words:
Vegetarian diet, Oral health, Periodontitis, Microbiome, Metabolome, Dental erosion.

Abbreviations

American Dietetic Association (ADA); body mass index (BMI); coronary heart disease (CHD); decay missed filled teeth (DMFT); European prospective project (EPP); gingival recession (GR); non-carious cervical lesion (NCCL); non-vegetarians (NVGTs); vegetarians (VGTs).

Introduction

Vegetarianism emphasizes a high intake of plant foods and little or no consumption of animal products. Meat and poultry are usually excluded from the diet[1].

Vegetarian and vegan diets have grown in acceptance over the past few decades, with a reported 350% increase in prevalence globally[2,3].

It is separated into five categories based on the foods consumed: veganism (which uses only plant-based foods), ovo vegetarianism (which consumes plant foods and eggs), lacto vegetarianism (which consumes plant foods and dairy products), lacto-ovo vegetarianism (which consumes plant foods, dairy products, and eggs), and pisco vegetarianism (plant foods, dairy supplies, egg, and fish consumption)[4] (Figure 1).

Vegetarianism Today

Worldwide, the number of vegetarians (VGTs) is rising now. Apart from India, where around one-third of the population is vegetarian, VGTs continue to constitute a small minority in all other nations. There are many various motivations for adopting a vegetarian or vegan lifestyle, from health awareness to environmental concerns, socioeconomic factors, ethical considerations, or spiritual/religious views[5-7]. A well-planned vegetarian diet is safe for all ages and in all physiological states, including childhood, adolescence, pregnancy, and lactation, according to the American Dietetic Association (ADA). The effects of the vegetarian diet on health are also significant[8-10].

Health Impact of the Vegetarian Diet

For their health benefits, plant-based diets that consume relatively few animal products are becoming more and more popular[11]. Several studies[12,13] have discovered that eating a plant-based diet, particularly one that is rich in high-quality

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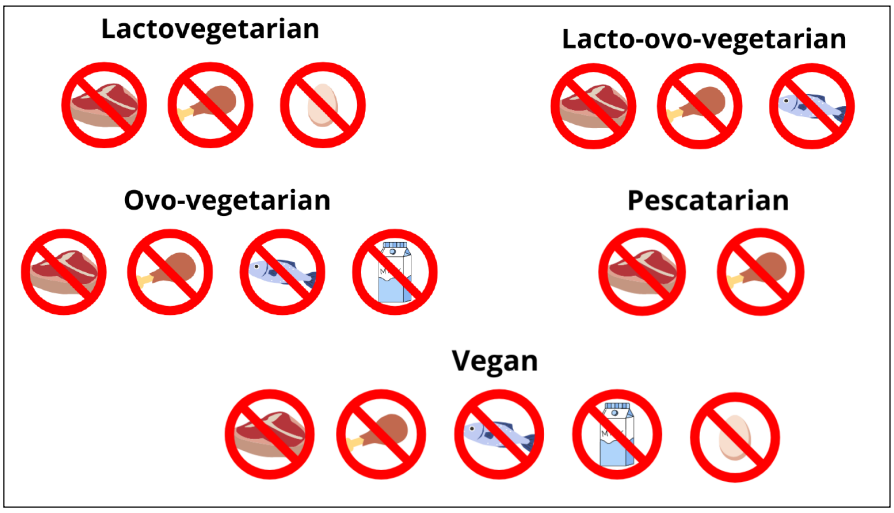

Figure 1. Types of vegetarians.

plant foods including grains, fruits, and vegetables, may reduce your chance of getting sick.

Body Mass Index

Compared to non-vegetarians (NVGTs), VGTs typically have a lower body mass index (BMI) and are more concerned about their health[14]. A previous study[15] found that consuming more animal products raises BMI. According to the European Prospective Project (EPP), meat eaters have the highest BMI, vegans have the lowest, and fish eaters have a medium BMI. The benefits of vegetarianism in preventing obesity may come from avoiding certain food groups, shifting calories to satisfy hunger or other factors[16].

Many studies[17-19] have also demonstrated that VGTs live longer and consume less meat, which has been linked to better longevity.

Reduced consumption of potentially harmful food components, such as saturated fat, cholesterol, animal proteins, and meat, as well as increased consumption of beneficial food components, such as fruits, vegetables, whole grains, legumes, and nuts, which are high in dietary fiber, antioxidants, and phytochemicals, are likely to result in these benefits[20,21].

Cancer

When compared with others living in the same communities, individuals adhering to a vegetarian diet tend to experience slightly lower cancer rates and higher life expectancies[22,23].

Consumption of fresh fruit was associated with reduced risk in a dose-dependent relationship in the development of oral cancer, whereas chewing areca nut, betel nut, and gutka were correlated with the development of oral cancer[24].

Case-control evidence suggests that specific diets, particularly fruits, and vegetables, may protect amentgainst mouth cancer[24]. It is also highlighted that dietary components can counterbalance the negative effects of alcohol, smoking, and hygiene, suggesting a possible protective impact of specific meals[25].

In a recent study[25] suggesting the risk-reducing impact of fruits and vegetables on oral squamous cell carcinoma, garlic, carrots, green vegetables, cruciferous vegetables, and tomatoes emerged as potentially protective. The study indicates that the greatest benefit is observed when these foods are consumed raw.

Beta-carotene, vitamin A, vitamin C, selenium and coffee may all be foods that are suggested to people at risk (smokers and drinkers) since they have strong antioxidant capabilities[26]. It was discovered that subjects with oral cancer had lower total antioxidant capacity as well as salivary peroxidase and superoxide dismutase activity in comparison to controls in a study comparing the antioxidant enzyme activity in saliva among patients with oral cancer and odontogenic cysts to healthy controls[26].

The outcomes for tumors, however, are less compelling and call for additional research[27].

Cardiovascular Disease

The most reliable research[28,29] on the health advantages of a vegetarian diet shows a decreased risk of coronary heart disease (CHD), a decreased risk of intermediate risk factors, and a decreased risk of coronary heart disease death.

High blood pressure is a significant risk factor for heart disease. Avoiding cardiac issues requires managing blood pressure with a healthy lifestyle

(exercise and a balanced diet). Much research[30] on the impact of vegetarian diets on blood pressure has been conducted; however, the findings are frequently ambiguous.

A meta-analysis[31] of previous studies examining the relationship between vegetarian diets and blood pressure has been conducted by researchers in Osaka, Japan. According to the research, a vegetarian diet is strongly associated with lower blood pressure.

Diabetes

Vegetarian diets incorporating therapeutic foods like grains, legumes, fruits, and polyphenol-rich vegetables hold significant potential for managing and preventing diabetes. Observational studies[4,32-34] have shown that VGTs have a much lower risk of developing type 2 diabetes than non-vegetarians (NVGTs).

Many research and clinical practices[32] have established a bidirectional relationship where dental health improves the overall health of the individual and systemic diseases, particularly metabolic disorders, influence oral health (OH). Gum health is compromised by inadequate blood sugar control, and in turn, impaired gum health can lead to inadequate blood sugar control. Both diabetic and prediabetic patients' glucose levels are negatively impacted by severe periodontitis[32].

Periodontal disease causes the tissue complex that supports the teeth, the periodontium, to become inflamed, which exacerbates diabetes-related inflammation by triggering the release of more inflammatory mediators into the bloodstream[35].

Others Correlations

A vegetarian diet may also lower the risk of developing other illnesses such as diverticular disease, gallstones, rheumatoid arthritis, and kidney disease, according to limited evidence[36-43].

Contraindications of a Vegetarian Diet

However, the argument that a vegetarian diet is healthier than a Mediterranean one because there is a difference in health-related biomarkers is still much debated[44].

So, unless careful monitoring and adequate supplementation are offered regularly, vegetarian dietary practices may cause problems with health[45].

In comparison to NVGTs, VGTs had lower levels of iron, copper, zinc, calcium, and selenium. However, only calcium, copper, and zinc had significantly lower levels than NVGTs, which may be due to either their lower bioavailability from this type of diet or the fact that some of the accessed micronutrients are present in lower levels in the vegetarian diet[46].

A larger intake of other vitamins and micronutrients may offer a superior antioxidant defense despite the possibility that the vegetarian diet may cause a lack of micronutrients necessary for DNA metabolism and stability, such as vitamins B and D[47,48].

VGTs have shorter telomeres, a poorer glutathione antioxidant defense system, greater homocysteine levels, and more genomic damage from micronuclei and DNA strand breaks. This shows that adding nutrients from animals to this particular dietary group's diet can help several evaluated health-related indicators improve[49].

Effects of a Vegetarian Diet on Oral Health, Oral Microbiota, and Oral Metabolome

There is currently conflicting scientific research[50] about the potential effects of a vegetarian diet on dental and oral health (OH).

With consideration for each person's unique traits, diet can both directly and indirectly affect the body's immunological response and the oral microbiota and metabolome[51,52].

Many connections between nutrition and dental health have been discovered, including the link between sugar consumption and the onset of periodontal disease and tooth decay[35,53-56]. There are also links between the consumption of acidic foods and dental erosion[33,57,58].

Studies[50,59] concentrating on general food habits and oral disease, however, are less prevalent.

Therefore, our review aimed to review associations between a vegetarian diet and possible consequences for OH.

Materials and Methods

Protocol and Registration

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

Search Processing

A search on PubMed, Scopus, and Web of Science was performed to find papers that matched the topic of the influence of vegetarian diet and OH, dating from 1 January 2013 to 1 March 2023. The search strategy used the Boolean keywords: ("vegetarian diet" AND "oral health") OR ("vegetarian diet" AND "periodontitis").

Inclusion Criteria

The following inclusion criteria were considered: (1) studies with human subjects; (2) open-access studies; (3) studies that investigated the relationship between vegetarian diet, periodontal tissues, and OH, (4) randomized clinical trials, retrospective and observational studies, (5) English language, and (6) full-text. Papers that did not match the above criteria were excluded.

Exclusion Criteria

The exclusion criteria were as follows: (1) animal studies; (2) *in vitro* studies; (3) off-topic; (4) reviews, case reports, case series, letters, or comments; (5) no English language.

Data Processing

Three reviewers (M.C., M.G., and I.P.) independently consulted the databases to collect the studies and rated their quality based on selection criteria. The selected articles were downloaded into Zotero (version 6.0.15). Any divergence between the three authors was settled by a discussion with a senior reviewer (F.I.).

Results

Study Selection and Characteristics

The electronic database search identified a total of 167 articles (Scopus N=64, PubMed N=53, Web of Science N=50), and no articles were included through the hand search.

After the deletion of duplicates, 105 studies were screened by evaluating the title and abstract, focusing on the association between a vegetarian diet and OH. There were 61 articles off-topic, and they did not meet the inclusion criteria, leading to 44 records being selected. Subsequently, 4 non-retrieved records were excluded, and then 22 reports were excluded because they did not meet the inclusion criteria. After eligibility, 18 records[70-77,83,91,91-97,102-105] were selected for qualitative analysis. The selection process and the summary of selected records are shown in Figure 2 and Table I, respectively.

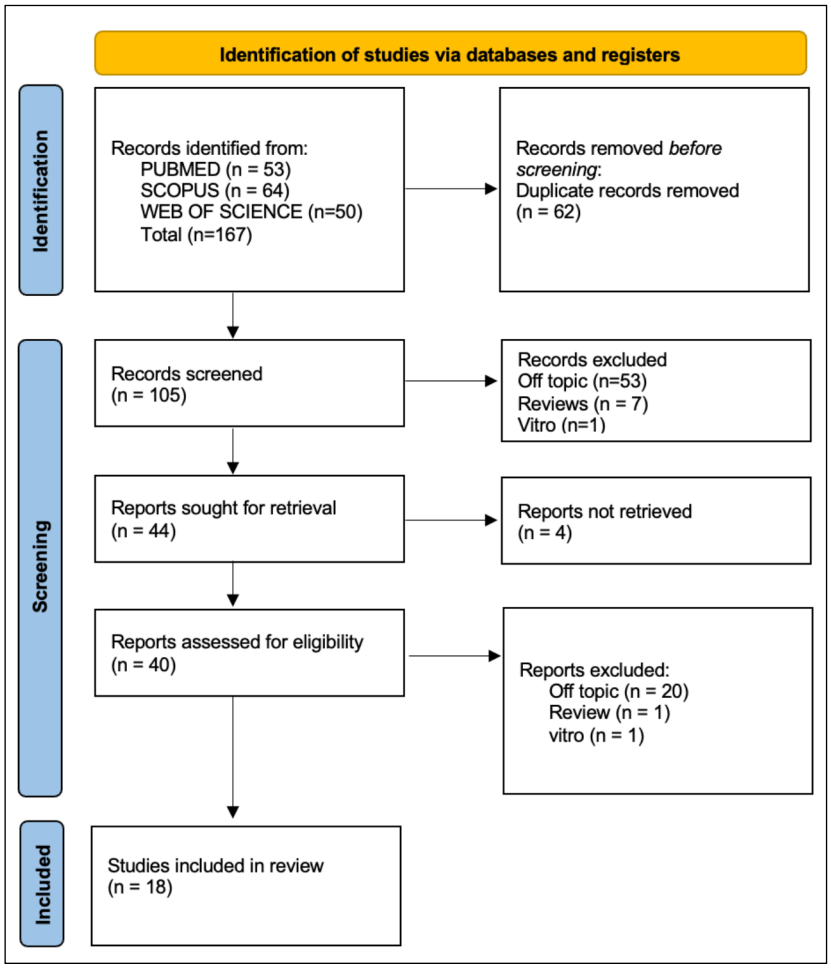

Figure 2. Literature search Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram and database search indicators.

Table I. Descriptive summary of item selection.

Authors	Study type	Aim of the study	Number of patients	Gender and the average age	Materials and Methods	Results
Eberhard et al[70], 2022	Randomized clinical trial	The scope was to compare the effects of two macronutrient interventions on OH using a 2 x 2 factorial dietary design.	113 participants, 67 included.	65-75 years old	Participants received for four weeks unlimited access to one of four experimental diets. Before and after the intervention, data from the periodontal examination were recorded.	The number of sites with a clinical attachment loss <5 mm increased between baseline and follow-up (mean difference 5.11 9.68, p=.039), whereas the amount of gingival crevicular fluid decreased (mean differences 23.42 39.42 Periotron Units, p=.050) for the semi-vegetarian high-fat diet. Significant differences between the tested diets were calculated for the mean proportion of locations with probing pocket depth reduction of >1 mm and clinical attachment loss gain of >1 mm. The alterations in the oral microbiota were not related to the clinical parameters.
Chowdhury et al[102], 2022	Cross-Sectional Study	In this work, the influence of vegetarian and non-vegetarian diets on periodontal health will be compared.	240 participants were included. They were divided into two groups: Group 1 (120 VGTs), and Group 2 (120 NVGTs).	Group 1: 65 females and 55 males with a mean age of 42.12±15.1 years. Group 2: 65 females and 55 males with a mean age of 41.23 figure 12.13.	This study had 240 individuals in total. A periodontal examination and a dental examination were performed. In addition, questionnaires were administered regarding demographic details, diet, oral habits, and dental visits.	In comparison to nonvegetarian groups, VGTs showed significantly lower bleeding on probing, probing pocket depth, plaque index, periodontal screening index, and oral hygiene index (p<0.05). However, there were insignificant changes between the two groups in terms of clinical attachment loss, gingival recession, and the number of movable teeth. No significant difference was seen among groups in terms of decayed, missing, and filled teeth. In comparison to Group 2, Group 1 performed oral hygiene maintenance treatments more frequently (p=0.05). Across the groups, there were statistically significant differences in the number of dental appointments. Group 2 had more dental visits than Group 1. Both groups' subjects showed no signs of oral habits. In the vegetarian group, the average number of days on a vegetarian diet was 33.1 +/- 5.32.
Jalil Mozhdehi et al[83], 2021	Cross-Sectional Study	The purpose of this research is to determine whether those who eat vegetarian, vegan, or omnivorous diets have different taste sensitivities.	80 participants: 22 vegans, 23 VGTs, and 35 omnivores.	80 females, in the vegan group the age, ranged from 18 to 44 years, in the vegetarian group from 18 to 33 years, and in the omnivore group from 18 to 44 years.	Eighty New Zealand European girls in good health, aged 18 to 45, were included in this study. Of these, 22 were vegans, 23 were VGTs, and 35 were omnivores. A total of 80 individuals had their taste detection thresholds for six substances evaluated.	In comparison to the vegetarian or vegan groups, which had significantly increased sensitivity to metallic and decreased sensitivity to sweetness, the omnivore group had distinct taste sensitivity patterns across all six chemicals. In addition, as compared to the other two groups, the vegetarian group had a much lower detection threshold for bitterness.
Kumar et al[103], 2018	Cross-Sectional Study	With the aid of a questionnaire survey, the primary aim of this study was to analyze any potential associations between the type of diet and Wear patterns (erosion, abrasion, attrition), periodontal state (gingival index, periodontal pocket depth), plaque index, and OH factors.	260 participants: 130 VGTs and 130 NVGTs.	18-50 years old	260 healthy male and female volunteers were divided equally into vegetarian and non-vegetarian groups from a sample size of 260. The subjects' ages ranged from 18 to 50. All the metrics will be examined during the clinical evaluation. To evaluate the participants' dietary practices, oral hygiene knowledge, and OH behaviors, a questionnaire has been created for them.	The comparison of periodontal findings between the two groups did not reach statistical significance. According to the questionnaire survey, NVGTs had statistically significantly higher rates of halitosis than VGTs.

Table continued

Table I *(Continued)*. Descriptive summary of item selection.

Authors	Study type	Aim of the study	Number of patients	Gender and the average age	Materials and methods	Results
Khocht et al[78], 2021	Cross-Sectional study	This study set out to test the idea that a vegetarian diet's lower inflammation would encourage a more commensal subgingival bacterial profile.	39 participants: 23 VGTs and 16 NVGTs.	unspecified	A complete periodontal examination, collecting gingival crevicular fluid and subgingival plaque samples was done along with a meal frequency questionnaire to gauge dietary intake.	VGTs have greater levels of phyla that are linked to healthy gingival tissue (*Actinobacteria, and Proteobacteria*). *Veillonella rogosae* and *Mogibacterium timidum*, two organisms that have been linked to periodontitis, predominated in NVGTs.
Zumbo et al[104], 2022	Cross-Sectional study	To highlight the connections between nutrition and OH and to underline how OH care professionals can incorporate nutrition counseling to improve their patients' OH into their practices, the goal of this study is to assess the oral habits, oral status, and nutritive habits of a sample of women in Italy.	120 participants	120 females from 15 to 60 years old	A randomized sample of 120 Italian women was given an anonymous questionnaire with 20 questions during the months of February and July 2020.	Even though most women claim to have strong physical dexterity when it comes to dental hygiene, only around half of them brush their teeth more than three times per day. The frequency of dental checkups and dental mobility, halitosis, flossing frequency, and gum bleeding all showed statistically significant associations. For vegetarian and vegan women, there was a stronger correlation between food type and OH status in terms of halitosis sensitivity and xerostomia.
Ashworth et al[76], 2019	Cross-Sectional study	This study's primary objectives included estimating the dietary nitrate intake of VGTs in comparison to omnivores, figuring out salivary and plasma nitrate and nitrite concentrations, and figuring out the activity and diversity of oral bacteria in both groups.	41 participants: 22 VGTs and 19 omnivores.	41 participants were from 18 to 45 years old.	Dietary nitrate intake, blood pressure, and Resting Metabolic Rate were investigated in 22 young, healthy VGTs and 19 omnivores with comparable features using a non-randomized, cross-over, and single-blinded methodology. We also assessed oral nitrate-reduction rate, oral microbiota, and salivary and plasma nitrate and nitrite concentrations in both groups.	Vegetarians' dietary nitrate intake did not statistically differ from that of omnivores. Furthermore, comparable between VGTs and omnivores were their oral nitrate-reducing capacity, the abundance of oral bacterial species, blood pressure, and Resting Metabolic Rate.
Atarbashi-Moghadam et al[73], 2020	Cross-Sectional study	The purpose of the current study was to assess how the raw vegan diet affected several periodontal and dental health indicators.	118 participants were included. They were divided into two groups: 59 raw vegans and 59 omnivores.	Raw vegans (25 men and 34 women) aged between 18 and 77 years. Omnivores (25 men and 34 women, aged between 20 and 77 years.	118 participants in all (59 raw vegans and 59 controls) were questioned about their educational background and dental hygiene practices. Dental and periodontal characteristics were assessed together with samples of entire, unstimulated saliva for pH analysis. Subsequently, a statistical analysis was carried out.	The dental hygiene of raw vegans was better. Raw vegans had significantly lower levels of probing depth, blood on probing, and simplified oral hygiene score. Several regression studies revealed a strong relationship between the probing depth and bleeding on probing and the debris index.
Pedrão et al[94], 2018	Clinical study	This study's objective was to evaluate how dietary habits – vegetarian, lacto-ovo vegetarian, and omnivore – affect erosive tooth wear.	207 participants: 29 VGTs, 96 lacto-ovo VGTs and 82 omnivores.	35-74 years old, 57% of the subjects were females.	The participants were subjected to an oral examination and asked to complete questionnaires regarding their diet and oral hygiene.	The erosive tooth wear of VGTs and lacto-ovo VGTs was statistically substantially higher than that of omnivores (p=0.004). In contrast, lacto-ovo VGTs showed less tooth loss than omnivores (0.027). Compared to omnivores, VGTs and, lacto-ovo VGTs had a higher probability of showing signs of erosive tooth wear.

Table continued

Table I *(Continued)*. Descriptive summary of item selection.

Authors	Study type	Aim of the study	Number of patients	Gender and the average age	Materials and Methods	Results
Hansen et al[77], 2018	Clinical Trial	The goal of the research is to advance the standing of dietary influences on the oral microbial community by examining the diversity, composition, and functional potential of the salivary microbiota.	160 participants: 78 vegans and 82 omnivores.	18-65 years old	With the help of 16S rRNA gene amplicon sequencing, 160 healthy vegans and omnivores were examined. We also looked for microorganisms in saliva that might be linked to inflammatory indicators in the host.	Several metabolic pathways were found to be differentially prevalent in vegans and omnivores, according to an analysis of imputed genomic potential, indicating potential consequences of macro- and micronutrient intake. Additionally, they demonstrate a connection between specific oral bacteria and the host's overall inflammatory condition.
Mazur et al[72], 2020	Cross-Sectional study	In this study, people who had been following a plant-based diet for at least 24 months were examined to determine their general and clinical OH status.	77 subjects following a plant-based diet.	35 males, 42 females; range 21-67	A total of 77 adult participants were enrolled. Two surveys were given to the respondents.	The patient had a plant-based diet for the previous four years on average, ate four meals per day, and brushed their teeth twice each day. For 48 of the participants, fruit t was the morning food that they ate the most frequently.
Kesserwani et al[105], 2022	Clinical Trial	The purpose of this study was to examine the morphological and morphometric alterations in vegetarian subjects' oral mucosa cells.	60 adults were divided into two groups: VGTs (composed of 30 subjects) and Control group composed of 30 NVGTs	In both groups, there were 14 males and 16 females aged between 18 and 58 years.	60 adult individuals (30 vegans and 30 controls) had their tongue and buccal mucosa tested. Smears were examined for three morphometric variables and morphologically.	Comparing vegans to controls, the cytoplasm area of the tongue was smaller (but not greater).
Zotti et al[95], 2014	Case-control study	The main objective of the study and to see the difference in dental demineralizations and white spots between patients on the Mediterranean diet and vegan patients, as well as to evaluate the beneficial effects of fluoride therapy in vegan patients with these lesions.	First phase: 50 patients that follow a Mediterranean diet (control group), 50 patients that follow a vegan diet (study group). The study group was divided into two subgroups. Second phase: 25 patients (subgroup 1) that follow a vegan diet and fluoride therapy (study group). 25 patients (subgroup 2) that follow a vegan diet and without fluoride therapy (control group).	28 men and 22 women in the control group and study group, from 24 to 60 years in both groups.	The first phase of the study evaluated mainly: the presence of white spots and tooth demineralization in patients that follow a Mediterranean diet and in patients that follow a vegan diet. The second phase of the study evaluated the effects of fluoride therapy on the OH of vegan patients.	In the first phase of the study, lesions were uniformly located on the buccal surfaces of premolars and molars in the study group, and there were few lesions in the control group. In the second phase of the study, the lesions decreased the diameter and the smaller ones disappeared after 1 year of sodium fluoride application.

Decay missed filled teeth (DMFT); European prospective project (EPP); gingival recession (GR); non-carious cervical lesion (NCCL); non-vegetarians (NVGTs); vegetarians (VGTs).

Table I *(Continued)*. Descriptive summary of item selection.

Authors	Study type	Aim of the study	Number of patients	Gender and the average age	Materials and Methods	Results
Patil et al[91], 2017	Cross-sectional observational study	The scope was to compare the prevalence of candidal species in VGTs and NVGTs.	238 subjects: 108 VGTs, 130 NVGTs.	VGTs: 17 men and 91 women NVGTs: 37 men 93 women 21.85 years in both groups.	Subjects were required to gargle a 10-mL solution of phosphate-buffered saline for one minute before depositing it in a sterile container.	The candidal prevalence in VGTs (68.5%) was higher than in NVGTs (40.7%). *C. krusei:* only in VGTs (4.6%), *C. glabrata*: 30.5% in VGTs and 10.1%, in NVGTs. *C. tropicalis*: 8.4% in VGTs and 2.3% in NVGTs.
Kumar et al[96], 2015	Cross-sectional study	This study aimed to identify risk factors in the development of such lesions and suggest treatments that prevent Non-Carious Cervical Lesion (NCCL) development and progression.	383 children: 167 VGTs, 216 follow a mixed diet.	Children were aged 12-15 years, 170 boys and 213 girls.	To gather data on sociodemographic traits, oral hygiene routines, dietary habits, and risk factors for NCCLs, a questionnaire was created.	Compared to participants who had a varied diet, vegetarian participants had a significantly higher likelihood (Odds Ratio, 1.86; p=0.027) of developing cervical lesions. Eating a vegetarian diet may subject people to more erosive difficulties, which could result in NCCL.
De Filippis et al[74], 2014	Comparative study	The study aimed to evaluate if dietary practices could influence the composition of the salivary metabolome and microbiota, perhaps putting one at risk for disease.	161 participants: 55 omnivores, 55 ovo-lacto-VGTs, 51 vegans.	18-55 years old	Unstimulated whole saliva was collected into sterile Falcon tubes. Saliva samples were collected on three different days over three consecutive weeks, and the three samples were pooled before the microbiota and metabolome analyses.	There is currently no evidence that an omnivore, ovo-lacto-vegetarian, or vegan diet can cause certain features in the oral microbiota, however, microbial equilibrium may be disturbed in situations of poor dental hygiene or other unidentified environmental variables.
Chopra et al[97], 2015	Cross-sectional study	This study aimed to evaluate the correlation between body mass index, diet, and dental caries.	810 children	12-15 years old	Child demographic details and diet history for 5 days were recorded. All the recruited children received clinical examinations by two trained and calibrated examiners.	When compared to kids who ate a varied diet, VGTs had a higher Decay Missed Filled Teeth (DMFT) (1.72). (1.70). Children with oral health diet scores of 59 and less and 60-74, respectively, exhibited lower mean DMFT scores than those with oral health diet scores of 75-89. However, no statistically significant results were discovered.
Staufenbiel, et al[71], 2013	Prospective and controlled clinical trial	This study evaluated periodontal and dental conditions in VGTs and NVGTs patients.	200 patients: 100 VGTs (89 lacto-ovo-VGTs and 11 vegans), 100 NVGTs.	VGTs: 71 women and 29 men, 41.5±14.1 years, NVGTs: 71 women and 29 men, 41.7±15.3 year.	All patients had a complete periodontal examination: probing pocket depth, periodontal screening index gingival recession (GR), clinical attachment level, and, bleeding on probing assessed at six sites. They had a dental examination, and they responded to a questionnaire on oral hygiene education and diet.	VGTs had significantly lower probing pocket depth (p=0.039), periodontal screening index (p=0.012), bleeding on probing (p=0.001), tooth mobility (p=0.037), and number of mobile teeth (p=0.013), than NVGTs. VGTs had significantly more decayed teeth (p=0.001) and erosion. (p=0.026) than NVGTs. VGTs had a significantly higher frequency of oral hygiene procedures than NVGTs.

Decay missed filled teeth (DMFT); European prospective project (EPP); gingival recession (GR); non-carious cervical lesion (NCCL); non-vegetarians (NVGTs); vegetarians (VGTs).

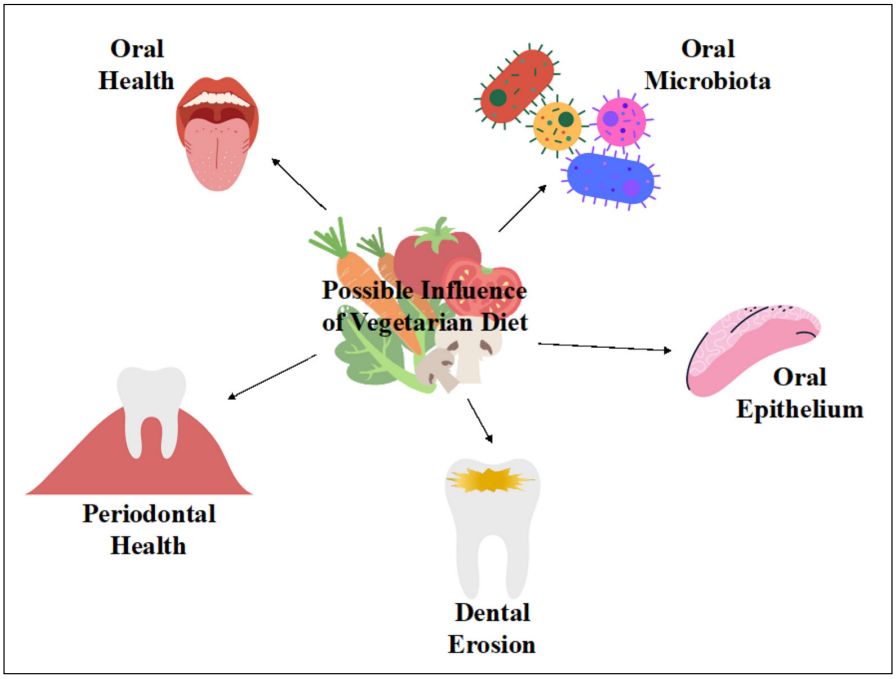

Figure 3. Main subjects discussed.

Discussion

There are several systematic reviews in the literature clarifying the impact of a vegetarian diet on health[12,60-65]. However, the implications of a vegetarian diet for OH have been poorly investigated. This study aims to further clarify the link between a vegetarian diet and OH by bringing data updated to the last 10 years (Figure 3).

Vegetarian Diet, Periodontal Health and Inflammation

The biological explanation supporting the notion that adopting a vegetarian diet could enhance periodontal health is grounded in the correlation between this dietary choice and reduced levels of C-reactive protein (CRP) observed in individuals following it, compared to omnivores[66]. However, it's worth noting that not all studies concur on affirming this association[49,61]. According to Jenzsch et al[67], patients had lower probing depth, fewer symptoms of inflammation, and lower concentrations of interleukin-1 and interleukin-6 in the gingival crevicular fluid a year after making dietary changes without affecting oral hygiene or receiving dental therapy. Scientific literature shows that there is increased production of inflammatory mediators (prostaglandin E2, interleukin lß, C-reactive protein, interleukin-6) that help promote the development of gingivitis and periodontitis in diabetic patients[32,68,69]. Actually, the link between periodontal disease and diabetes is becoming more and more clear; diabetics are 2-3 times more likely to acquire or have chronic periodontal disease than healthy people[33].

Eberhard et al[70] affirmed that the dietary intervention did not change the composition of the oral microbiota. Furthermore, they did not find any association between the oral microbiota and the clinical parameters. The study by Staufenbiel et al[71] found that VGTs had significantly lower probing pocket depths (p=0.039), bleeding on probing (p=0.001), periodontal screening index (p=0.012), a better hygiene index (p=0.001) and less mobile teeth (p=0.013). Studies[72,73] showed a positive association between periodontal health and a vegetarian diet, although the evidence is not strong. One factor that might influence these results is lifestyle and the greater attention paid to the overall health of VGTs.

Thus, the collected literature is not sufficient to confirm a direct beneficial effect of a vegetarian diet on periodontal health but certainly shows a positive correlation between adopting this type of diet and periodontal clinical parameters.

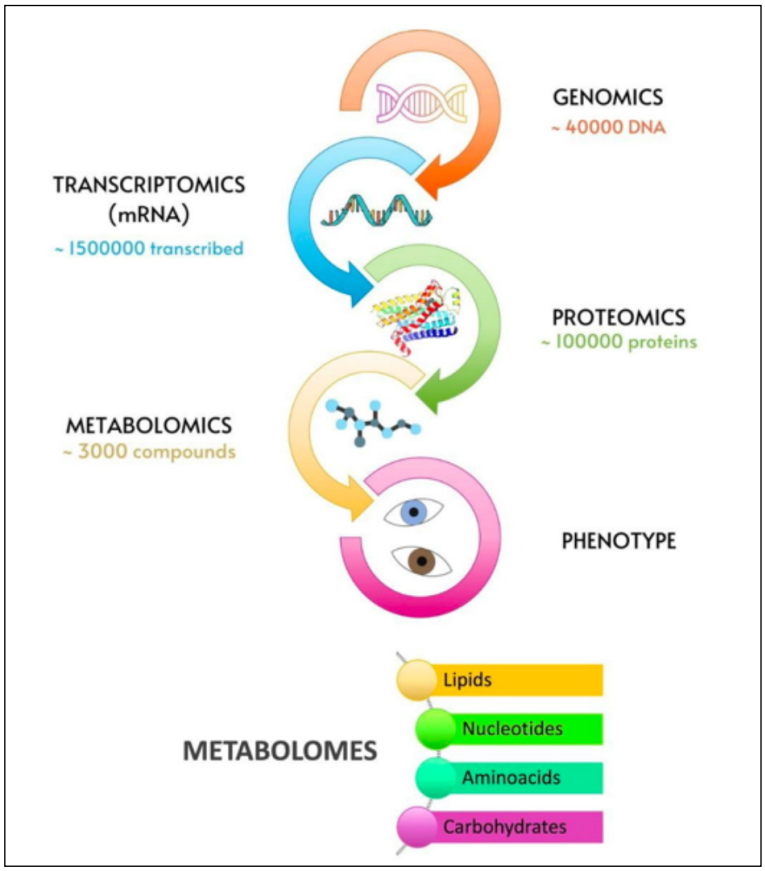

Figure 4. Graphic representation of the omics sciences cascade. An approach to understand the influence of the interactions that may influence the phenotype.

Vegetarian Diet, Oral Microbiota and Metaboloma

The correlation between different diets and change in the oral microbiota is debated, however, several studies[74,75] agree in denying an actual influence of nutrients on oral bacterial composition.

Consistent with this evidence, there are two studies[74,76] included in this review. Ashworth et al[76] did not confirm a bacterial population shift and nitrate-reducing bacteria in VGTs.

According to De Filippis et al[74], ovo-lacto-vegetarian or vegan diets do not significantly alter the salivary microbiome. This study analyzed the microbial diversity and metabolomic profiles of the saliva of 161 healthy individuals who followed an omnivore or ovo-lacto-vegetarian or vegan diet. The linkages between microbial communities shown in the study's healthy participants demonstrate that species balance exists regardless of dietary habits. The linkages between microbial communities, as shown in the study's healthy participants, demonstrate that species balance exists regardless of dietary habits.

There is currently no evidence that an omnivore, ovo-lacto-vegetarian, or vegan diet can cause certain features in the oral microbiota; however, microbial equilibrium may be disturbed in situations of poor dental hygiene or other unidentified environmental variables[74].

Two other studies[77,78], however, support the role of the vegetarian diet in changing the salivary microbiota, particularly in favor of bacteria such as *Actinobacteria* and *Proteobacteria* compatible with periodontal health[78].

Poor eating habits, the presence of orthodontic appliances in the oral cavity, and poor oral cleanliness all influence the microbiota's ability to maintain its proper balance [51]. These elements can change the microbiota's composition and behavior, which could exacerbate demineralization, caries processes, and periodontal disease[55,57]. Some bacterial strains multiply more frequently during

dysbiosis, which is promoted by an acidic environment, favoring cariogenic ones like *Bifidobacterium dentium*, *Bifidobacterium longum*, and *Streptococcus mutans* over *Streptococcus salivarius*, and *Actinomyces viscosus*[33,79]. Moreover, Firmicutes reproduce more frequently than Bacteroidetes. Probiotics and prebiotics can be used to manage and cure dental infections and restore microbial equilibrium, as suggested by mouthwashes or dietary modifications that can impact the balance of the microbiota[33,79]. The rich and varied oral microbiota is made up of more than seven hundred families of bacteria. Eubiosis refers to the equilibrium of the microbial system, whereas dysbiosis refers to an imbalance brought on by an excess of pathogenic bacteria[80]. Oral dysbiosis affects both OH (caries and periodontal disease) and systemic illnesses like diabetes or cardiovascular disease[81]. Dental caries is caused by the growth of cariogenic bacteria, including *Streptococcus mutants*, *Lactobacillus*, and other *Actinomyces* with a dysbiotic microbiome. These bacteria produce acid by fermenting fermentable carbohydrates, which demineralizes tooth surfaces[82]. Despite the complexity of dental caries, microbiome dysbiosis caused by dietary habits and sugar consumption may be a factor[83]. Periodontal disease is usually caused by periodontal pathogens such as *Porphyromonas gingivalis* and results in tooth loss in adults[84].

The oral microbiome and tumorigenesis are closely related, according to recent studies[85,86]. The bacteria *Porphyromonas gingivalis* and *Fusobacterium nucleatum* have been linked to the development of many carcinomas. *Fusobacterium nucleatum* is a Gram-negative anaerobic bacillus mainly localized in the oral cavity and gastrointestinal tract and is found in significant concentrations *in situ* in oral squamous cell cancer[86]. As previously mentioned, *Porphyromonas gingivalis* is a Gram-negative anaerobic pathogenic bacterium that plays a role in periodontitis' destructive process. It has recently been determined that it is present in the neoplastic tissue of oral squamous cell carcinoma *in situ,* and it influences the growth of tumors due to its capacity to disrupt epithelial tissues and host defense mechanisms[85,87,88].

The composition of the microbial community (Metagenome), the study of its transcripts (Metatranscriptome), its proteins (Metaproteome), or the examination of the products produced by the community as a whole can all be used to describe it (Metabolomics)[89].

The study of a system's overall metabolite profiles is known as metabolomics (cell, tissue, or organism)[90]. Changes in the metabolome are amplified in comparison to changes in the transcriptome and proteome because it is the final downstream product of gene transcription[90]. Oral metabolomic analysis has been employed to investigate salivary biomarkers in a variety of cancer forms, including mouth cancer[89] (Figure 4).

Furthermore, Patil et al[91] observed a high prevalence of oral candida in VGTs (68.5%) compared with NVGTs (40.7%). *Candida krusei* was isolated only in VGTs; *Candida glabrata* and *Candida tropicalis* were prevalent in NVGTs. Instead, *Candida albicans* was prevalent in VGTs. The diet conducted shifts in the intraoral environment and played an impactful role in the variation of candida species.

Vegetarian Diet and Dental Implications

Erosion is a chemical process not caused by bacteria that involves the hard tissues of the tooth[92]. One of the extrinsic factors with the highest erosive potential is the consumption of fruit, one of the staple foods of the vegetarian diet[46,93]. VGTs also appear to be more prone to dental erosion[94], as they had already been hypothesized[50]. Zotti et al[95] observed the presence of white spots and areas of dental demineralization in patients following a vegan diet and those following the Mediterranean diet and saw that these lesions were more present in the former group. It was also seen that the salivary pH of vegan patients (5.5±0.3) was lower than those who followed the Mediterranean diet (7.4±0.2).

Kumar et al[96] compared to participants who had a varied diet, vegetarian participants had a significantly higher likelihood of developing cervical lesions.

Nutritional variables play a significant role in the emergence of non-carious cervical lesions (NCCL). Compared to kids who ate a varied diet, vegetarian kids had a higher risk of developing NCCL. Similar outcomes were observed by Smits et al[50]. Eating a vegetarian diet may cause people to have more erosive difficulties, which could result in NCCL[96].

Chopra et al[97] said that for kids who ate a varied diet, VGTs had a higher Decayed- Missing – Filled – Teeth (DMFT). Children with oral health diet scores of 59 and less and 60-74, respectively, exhibited lower mean DMFT scores than those with oral dental diet scores of 75-89. However, no statistically significant results were discovered.

Compared to children who ate a mixed diet, vegetarian youngsters had a slightly higher rate

of dental decay. The fact that the result was not significant could be attributed to the mixed-diet group's small sample size. Also, it may be hypothesized that people who eat more protein-rich foods than sugar will have less oral acidification and will be comparatively protected from dental caries. This might be the cause of the reduced incidence of instances among people who eat a varied diet or are NVGTs[97-101].

Staufenbiel et al[71] found on dental examinations significantly fewer missing teeth (p=0.018) but also more decayed (p=0.001) and eroded (p=0.026) teeth in VGTs. Furthermore, VGTs had a higher level of education (p=0.001) but visited dentists less frequently. VGTs revealed improved periodontal conditions but more decayed teeth and more erosion.

Other Correlations

The other three studies included in this review addressed interesting correlations between a vegetarian diet and OH. Compared with omnivores, vegetarians showed greater sensitivity to metallic taste and reduced sensitivity to sweetness and bitterness[83].

The process of atrophy of the oral epithelium appears to be associated with the vegetarian diet, although an actual cause-and-effect relationship has not been established yet.

The association between adherence to a vegetarian diet and a healthy lifestyle has been confirmed, and this is reflected not only in general health but also in OH.

Limitations of the Study

This study has some limitations. The literature on this topic is controversial, and the authors reported different results in their studies. The included papers are few and heterogeneous, so there was no possibility of assessing their quality. In some research, the subgroup and duration of the vegetarian diet were not specified.

Conclusions

Plant-based diets are increasingly recommended for their health benefits, and more and more people are adhering to a vegetarian diet. Therefore, the literature has been busy studying the effects of a vegetarian diet on general health. This research shows that VGTs had better periodontal conditions than NVGTs but more dental problems, such as erosions and tooth demineralization. These variations could be attributed to dietary practice and the different oral microbiomes, but the evidence collected regarding the relationship between the microbiome and the vegetarian diet is conflicting. Therefore, it was not possible to establish its actual impact. Although the data cannot confirm and quantify the actual impact of vegetarian diets on OH, this review is certainly a starting point for further specific research.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Contributions

Conceptualization, A.D.I., A.M.I., F.P., A.P., I.P., and M.G.; methodology, A.G, G.D., E.D.R., and G.C., software, D.D.V., A.P., M.G., F.I., and G.D.; validation, A.P., D.D.V., M.G., F.I., and G.D.; formal analysis, A.D.I., G.C., A.P., A.M.I., I.P., M.G., D.D.V., F.I., and G.D.; resources, A.D.I., A.M.I., M.G., and A.P.; data curation, I.P., M.G., E.D.R.., F.I., and G.D.; writing-original draft reparations A.D.I., A.M.I., E.D.R., D.D.V., F.I., and G.D.; writing-review and editing, A.P., E.D.R., M.C.F., I.R.B. and S.B. visualization, G.P., C.D.P., G.L., F.I., A.P., V.S. and I.R.B.; supervision, A.D.I., A.M.I., D.D.V., F.I. and G.D.; project administration, M.G., F.I. and G.D. All authors have read and agreed to the published version of the manuscript.

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