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Prevention of Dental Biofilm Formation with Polyphenols: A Systematic Review

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ABSTRACT

Polyphenols are plant secondary products with health-promoting properties against various degenerative or infectious diseases, and thus may help in the prevention of oral diseases. The aim of the present systematic review was to investigate polyphenols as a possible adjuvant in inhibiting dental biofilm formation, which is an important precondition for the most prevalent oral disease – caries and periodontitis. A literature search was conducted using the databases PubMed, CENTRAL and Scopus. Only studies with oral healthy participants and plaque level as outcome were included. Data search and extraction was conducted by two authors independently. Of the 211 initially identified studies, only six met all inclusion criteria. Meta-analysis was performed with five studies using the random effect model. Treatment with polyphenols reduced the plaque level in comparison to a negative control, but not significantly. Strong evidence of heterogeneity was observed. The diversity and complexity of polyphenols and their preparation need to be considered. There is no clear evidence that clinical use of polyphenols can prevent dental biofilm formation. Additional research with more and larger randomized controlled trials are required.

Introduction

After polyphenols had been identified as health-promoting substances against various infectious and degenerative diseases, they were investigated more intensively over the last decades [1, 2]. According to the definition by Quideau et al. [2], polyphenols are plant secondary metabolites of the shikimate-derived phenylpropanoid or the polyketide pathway, that have more than one phenolic ring and do not contain any nitrogen-based functional groups in their basic structure. The aromatic system and the degree of the hydroxylation forms the variety of polyphenols and is responsible for their different properties (▶ **Fig. 1**).They are abundant in fruits, seeds, and leaves in particular, but are also commonly added to functional foods [2]. Thanks to the phenolic groups, polyphenols can scavenge free radicals and act as antioxidants, helping against numerous diseases such as cancer, neurodegenerative or cardiovascular diseases [3]. A diet rich in polyphenols can not only prevent different diseases, but is also inexpensive, easily accessible, and sustainable due to the natural origin of polyphenols.

Despite this, polyphenols can form complexes with metal ions and proteins, which is why they are increasingly being investi-

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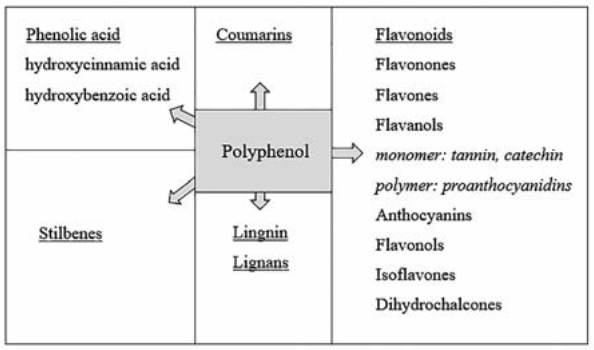

▶ **Fig. 1** Overview on the different chemical classes of phenols.

gated in dental research [4]. Of all oral diseases, dental caries has the highest prevalence, despite established preventive measures such as the use of fluoridated dentifrices [5, 6].

This underlines the need for additive preventive strategies. Polyphenols have been used in traditional medicine for thousands of years. With the growing demand for biological alternatives, polyphenols form an attractive group for biological approaches in preventive dentistry.

Therefore, in the present systematic review, we searched and analyzed the literature for the influence of polyphenols on dental plaque, a critical etiological factor for caries [7]. The starting point for bacterial attachment is the pellicle, a bacteria-free protein layer on the tooth surface [8]. Polyphenols can denature and crosslink pellicle proteins [9] and thus lead to pellicle modification, which can diminish bacterial adherence [10–12]. This influence on proteins of the saliva and the pellicle is called the tanning effect [13]. By interaction with bacterial enzymes, polyphenols can inhibit glucan formation, which also plays a role in bacterial adherence [14]. Furthermore, polyphenols can interact with the bacterial membrane and complex metal ions that are essential for bacteria, which ultimately lead to antibacterial effects [15, 16]. Due to the heterogeneity of polyphenols and bacterial diversity in dental biofilms, no generalized conclusion is possible.

Several clinical studies have been conducted to demonstrate the efficacy of polyphenols on biofilm formation [4]. However, a systematic evaluation has not yet been performed. The aim of the present systematic review was to evaluate the body of evidence concerning the efficacy of polyphenols on dental biofilm formation. If there is clear evidence, a polyphenolic diet could provide a significant benefit for the patient with respect to oral health.

Material and Methods

The present systematic review was performed following the PRISMA (Preferred Re-ported Items for Systematic Review and Meta-analysis) guidelines [17].

MEDLINE search terms. The search strategy was individually adjusted for CENTRAL and Scopus.

Population:

(subjects OR humans)

Intervention:

AND (polyphenol [MeSH] OR phenolic acid OR benzoic acid OR hydroxybenzoic acid OR gallic acid OR ellagic acid OR hydrolysable tannin OR gallotannin OR tannic acid OR ellagitannin OR punicalagin OR punicalin OR cinnamic acid OR coumaric acid OR caffeic acid OR ferulic acid OR sinapic acid OR stilbene OR resveratrol OR lignan OR flavonoid OR flavonol OR quercetin OR kaempferol OR flavone OR luteolin OR apigenin OR flavanone OR naringenin OR hesperetin OR eriodictyol OR anthocyanidin OR flavanol OR catechin OR epicatechin OR epigallocatechin OR epicatechin-3-gallate OR epigallocatechin-3-gallate OR proanthocyanidin OR condensed tannin OR anthocyanidin OR cyanidin OR delphinidin OR pelargonidin OR isoflavone OR genistein OR daidzein OR neoflavonoid OR dalbergin OR chalcone OR flavanonol OR taxifolin)

Outcome:

AND (dental caries [MeSH] OR plaque index OR dental biofilm OR dental health services [MeSH] OR dental plaque [MeSH] OR dental health surveys [MeSH])

Study design:

AND (research article OR experimental study OR observational study OR in-vivo) NOT (case study OR in-vitro OR in-situ OR review article)

▶ **Fig. 2** Specific search terms.

Eligibility criteria

In order to evaluate whether polyphenols can prevent dental biofilm formation, different eligibility criteria were defined. Human subjects with oral health who did not receive antibiotic treatment in the last month were included. Regarding intervention, subjects were treated with polyphenols and negative, or positive control such as fluoride and chlorhexidine. Additional prophylactic measures were not allowed. After treatment, supragingival plaque levels were recorded. However, plaque levels on teeth with orthodontic appliances were not considered. Laboratory *in situ* and *in vitro* studies were excluded from the systematic review.

Search strategy

The electronic databases PubMed, CENTRAL and Scopus were searched up to October 2021. Published studies in German or English language were included. Handsearching was not conducted. Specific search terms are shown in ▶ **Fig. 2**. When titles and abstracts fulfilled the eligibility criteria, the full texts were screened, and appropriate papers were processed for data extraction. Data collection and extraction was performed independently by two reviewers. Disagreements were resolved by discussion.

Data items

Information was extracted from full texts that fulfilled the eligibility criteria: (1) population (number of participants, age, sample size calculation); (2) intervention (type of polyphenol and carrier in experimental group, baseline, type of intervention in control group, frequency and duration of intervention, washout period in studies with cross-over design); (3) outcome; (4) study design; and (5) risk of bias (selection bias, processing bias, measurement bias, attrition bias; common markers were randomization, blind-

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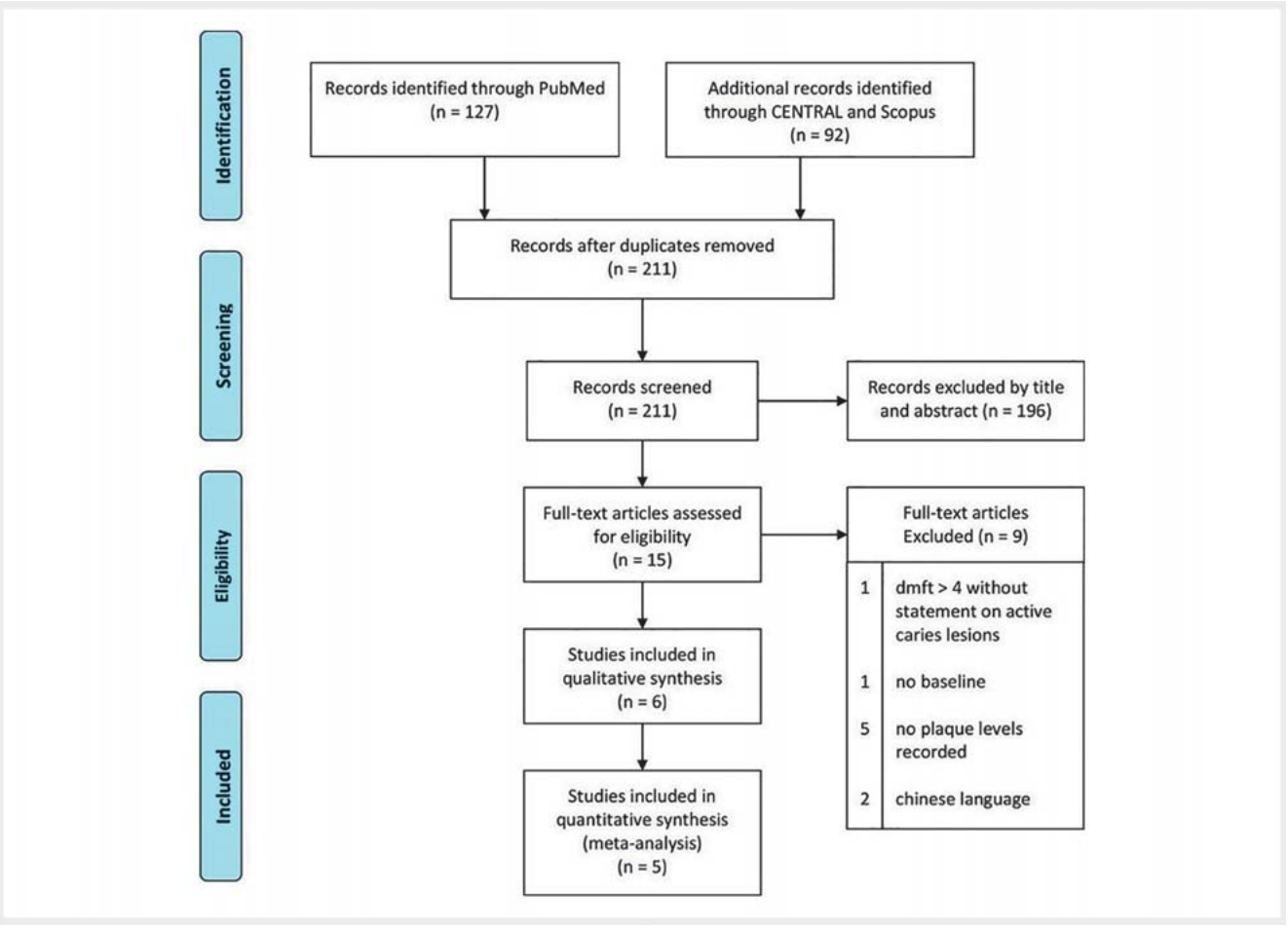

▶ **Fig. 3** Flow chart of study selection process. Studies with no baseline or no recorded plaque levels, no information on active caries lesions or articles written in languages other than English were excluded.

ing, objectivity of outcome measurement, performing daily oral hygiene). Studies were not excluded because of their risk for bias.

Data analysis

Studies recording the final plaque levels of both the experimental group and negative control group or baseline were plotted. The standardized mean difference was used since different plaque level scores were recorded and calculated using the random effect model due to the low number of included studies. In some studies, the control group was compared several times. In this case, the number of subjects in the control group was divided by the number of comparisons. Heterogeneity was tested by visual examination of plots and statistically with chi-square test and I^2 statistic. Investigation of publication bias with a funnel plot was not conducted due to the low number of included studies. Data analysis was performed with Review Manager (RevMan). Version 5.4, The Cochrane Collaboration, 2020.

Results

Study selection

A total of 211 records were identified from databases PubMed, CENTRAL and Scopus. After reviewing titles and abstracts, 15 studies were included for further full-text screening. Nine studies did not meet the inclusion criteria, as shown in ▶ **Fig. 3** and **Table 1** [18–23]. The remaining six studies were processed for data extraction. The study characteristics are shown in ▶ **Table 2** [24–28].

Quality assessment

Risk of bias are presented in ▶ **Table 3**. In most studies, treatment was randomly assigned and at least single-blinded. In the study by Krahwinkel and Willershausen [27], no randomization was carried out, and uncontrolled regular oral hygiene was allowed in addition to the trial, which overall represents an increased risk of bias. The study by Kaur et al. [26] has a risk of measurement bias due to blinding and outcome. There was no attrition bias in any of the studies.

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▶ **Table 1** Characteristics of excluded studies.

Study	Reasons for exclusion
De Souza et al., 2017 [18]	The effect of a gel containing the polyphenol epigallocatechin-3-gallate (EGCG) on the protein profile of the acquired enamel pellicle was investigated. Plaque levels were not recorded.
Goyal et al., 2017 [19]	The effect of a mouth rinse containing catechins from green tea was investigated. Subjects with a dmft > 4 were included in the study without any statement on active caries lesions.
Hirasawa et al., 2006 [20]	The effect of mouth rinses with different polyphenols on the pH value of dental plaque was investigated. At the baseline stage, neither professional oral hygiene nor tartar removal was performed.
Hu et al., 2011 [21]	The effect of a lollipop containing the polyphenol glycyrrhizol A on the number of Streptococcus mutans in saliva was investigated. Plaque levels were not recorded.
Liu et al., 2000 [22]	The effect of tablets containing green tea polyphenols on plaque indices was investigated. The manuscript is in Chinese.
Peters et al., 2010 [23]	The effect of lollipops containing liquorice root extract on the number of Streptococcus mutans in saliva was investigated. Plaque levels were not recorded.

▶ **Table 2** Study characteristics.

Source	Population	Intervention	Outcome	Study design	Results
Diaz Sanchez et al. [24] 2017	20, older than 18	carrier: pill; experimental: 36 mg of oligomeric proanthocyanidins and 120 mg vitamin C; negative control: placebo; regimen: 2/d for 3 weeks	Turesky plaque index, record after 2 and 3 weeks	RCT, double-blinded	significantly more plaque in experimental group than control group after 3 weeks
Hambire et al. [25] 2015	60, 9–14 years old	carrier: mouth rinse; experimental: 0.5% solution of Camellia sinensis (green tea), positive control: 0.2% chlorhexidine; 0.05% sodium fluoride; negative control: baseline; regimen: 2/d for 2 weeks	plaque index by Silness and Loe; record at baseline, after first rinse, first week and second week	RCT, triple-blinded	less plaque in experimental group after 3 weeks than at baseline; statistical results (comparison of experimental group to control groups and baseline after 3 weeks) are not listed
Kaur et al. [26] 2014	30, 18–25 years old	carrier: mouth rinse, 15 ml; experimental: 0.25% catechin; positive control: 0.12% chlorhexidine; regimen: 2/d for 1 week; washout period of 15 d	Quigley-Hein plaque index, record after 1 week	cross-over design; single-blinded; randomized	experimental and control group with similar plaque scores; no significant difference
Krahwinkel and Willershausen [27] 2000	47, mean age of 25.76 years	carrier: chew candy; experimental: green tea extract (1,55%); negative control: placebo; regimen: 8/d for 4 weeks	approximal plaque index, record after 1 week and 4 weeks	double blind	slightly less plaque in experimental group than control group after 4 weeks, not significant
Moran et al. [28] 1992	18, mean age of 26.33 years	carrier: mouth rinse; experimental: natural products (eugenol, thymol, chamomile, myrrh, rhatany, sodium lauryl sulphate) and 6 other mouth rinses; positive control: 0.2% chlorhexidine; negative control: 0.9% sodium chloride; regimen: 2/d for 4 days; 4-day plaque regrowth; washout period of 72 h	Turesky modified Quigley & Hein plaque index and plaque area, 4-day plaque regrowth	cross-over design, double-blinded	significantly less plaque (index) in experimental group than negative control group, but significantly more plaque than positive control group
Radafshar et al. [32] 2017	40, 18–25 years old	carrier: mouth rinse; experimental: green tea (1% tannin); positive control: 0.12% chlorhexidine; negative control: baseline; regimen: 2/d for 4 weeks	Turesky modified Quigley-Hein plaque index, record at baseline and after 1 and 4 weeks	RCT, double-blinded	significantly less plaque in experimental group after 4 weeks than at baseline; no significant difference between experimental and positive control group

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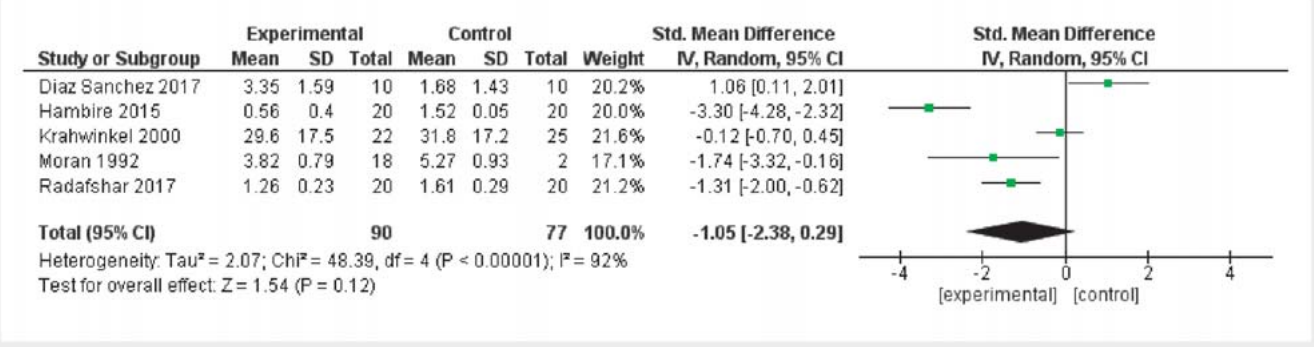
▶ **Table 3** Risk of bias.

Source	Selection bias	Processing bias	Measurement bias	Attrition bias
Diaz Sanchez et al. [24] 2017	no randomized by informatics programme LACER S. A.; double-blind	no complementary hygiene methods were not allowed; double-blind	no subjective outcome; but double-blinded	no
Hambire et al. [25] 2015	no randomized; triple-blinded; professional oral hygiene before trial	no children brushed their teeth additionally; however, the same tooth brush and fluoride tooth paste was used	no subjective outcome; triple-blinder	no
Kaur et al. [26] 2014	no cross over design; randomized; single-blinded; professional oral hygiene before trial	no oral hygiene (dentifrices, other mouth rinse) was not allowed	yes subjective outcome; single-blinded	no
Krahwinkel and Willershausen [27] 2000	yes double-blinded; however, no randomization; professional cleaning before trial	yes regular oral hygiene during trial was allowed and not controlled; double-blinded; no randomization	no objective outcome; double blinded	no
Moran et al. [28] 1992	no cross-over design; professional cleaning before trial	no cross-over design; normal oral hygiene was not allowed during trial	no subjective outcome; double blinded	no
Radafshar et al. [32] 2017	no randomized; professional cleaning before trial	no double-blinded; oral hygiene was allowed only with provided toothbrush and toothpaste	no subjective outcome; randomized; double-blinded	no



▶ **Fig. 4** Forest plot. Treatment with polyphenols reduced the plaque level in comparison to the negative control, but not significantly (p = 0.12). Strong evidence of heterogeneity was observed (Chi^2 = 48.39, p < 0.00001, I^2 = 92%).

Meta-analysis

Of the six studies identified for data extraction, five were running a negative control and three a positive control. Meta-analysis was performed with five studies by comparing the effects of polyphenols and negative controls on the plaque level (▶ **Fig. 4**). The study of Kaur et al. [26] was not included in the meta-analysis due to missing negative control. For each study, the mean, standard deviation, and number of subjects were listed, and standardized mean difference was calculated (▶ **Fig. 4**). Treatment with polyphenols reduced the plaque level in comparison to the negative control as indicated by the summary estimate, but not significantly (p = 0.12). Strong evidence of heterogeneity was observed (Chi^2 = 48.39, p < 0.00001, I^2 = 92%).

Discussion

Summary of evidence

Considering the six included studies, of which five were meta-analyzed, treatment with polyphenols favours a reduction of plaque levels in comparison to a negative control, but not significantly. According to the high number of laboratory and experimental *in situ* studies, there is a great interest for polyphenols in dental re-

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search [4]. Therefore, the present review was conducted in order to evaluate the clinical efficacy of polyphenols against dental biofilm formation and to find an alternate to current preventive measures, in particular fluorides and chlorhexidine. Despite the introduction of fluorides for oral health care and the associated decline in caries, the prevalence of caries is still high and, particularly in countries with a non-established market economy, fluorides are difficult to acquire [5]. Unlike fluorides, which interfere with the development of caries in different ways, chlorhexidine is considered the gold standard for plaque control and was often listed as a positive control in the included studies [29]. However, several side effects limit the long-term use of chlorhexidine, such as tooth discoloration, taste irritation and burning sensations of the oral mucosa [30]. Therefore, polyphenols were examined as alternates in the present review, which are often active components of natural products [31].

Initially, more than 200 studies were identified through three databases. Most studies were excluded based on their title and abstract. The reasons were typically that no polyphenols were used, the effect was not related to biofilm management, no plaque levels were recorded, or subjects suffered from periodontitis. Ultimately, six studies were included, of which five showed an inhibitory effect on plaque [25–28, 32] and one study showed the opposite effect [24]. While most studies had a negative control, the study by Kaur et al. [26] was running just a positive control according to a non-inferior design. The observed inhibitory effects were attributed to antibacterial and anti-adherent properties of polyphenols. Even in the study by Diaz Sanchez et al. [24] in which more plaque was found than in the negative control, the authors suggested a change in the bacterial composition of plaque as other collected data, such as the degree of gingival inflammation, decreased.

Overall, there is insufficient evidence that treatment with polyphenols can reduce plaque levels. Of the five studies that showed inhibitory effects, the results were statistically proven in only three studies [27, 28, 32]. In addition, sample size calculation was not performed in every study [24, 27, 28]. In the study by Moran et al. [28], significantly less plaque was found than in the negative control, but significantly more plaque than in the positive control chlorhexidine. On the one hand, in order to establish an alternate to chlorhexidine regarding plaque control, the novel agent must either be more effective or have similar efficacy but without the side effects. On the other hand, polyphenols are usually consumed with diet, so they do not represent an alternate but an additive and could support oral health in the form of a polyphenolic diet.

Another point to consider is that the reviewed studies did not explicitly address subjects with high risk for caries, who could particularly benefit from a treatment with polyphenols. Our conclusions do not apply to this important subset of population, since most studies included dental students who likely have good oral hygiene [24, 26, 32], or even assumed high standard for oral hygiene [28]. The small number of included studies and missing funnel-plot analysis did not allow to draw any conclusions about publication bias that could overestimate the inhibitory effect of polyphenols on dental plaque.

Limitations

The present review was limited by the diversity of polyphenols and plants as well as heterogeneity in interventions and outcomes of the included studies. It should be kept in mind that polyphenols represent a large heterogeneous group that shows various effects in the oral cavity [4, 33]. Since polyphenols include chemically very different substances, it is not possible to make a general statement about the effect of polyphenols on dental biofilm formation [34]. Polyphenols not only differ in their effect, but also growth conditions; the preparation and the pharmaceutical form/mode of delivery can have an influence on the efficacy. In addition, the frequency of application and the time of residence in the mouth differ, which can influence the outcomes. The polyphenols were applied using different carriers, such as pills, mouth rinses or chew candies. While all mouth rinses were used twice a day for 60 seconds, the amount applied ranged from 10 to 20 ml [25, 26, 28, 32]. In contrast, polyphenols integrated in candies were chewed 5 min and 8 times a day [27], whereas the pills did not provide any information on the intraoral exposure time since they were used until dissolution [24].

As polyphenols are mainly ingested through diet, effective and compatible extracts should first be identified in experimental studies and then verified with clinical studies. Then, polyphenols could contribute to oral health as part of a polyphenolic diet, e.g., by frequent consumption of berry juice or tea. In the included studies, various tannins and green tea extracts were used, whereby the latter contain other active components in addition to various polyphenols that can contribute to the anticariogenic properties of tea, such as fluorides [35]. Taken together, the heterogeneity in intervention may be related to the different observations made in each included study. Studies with longer clinical use can be evaluated as more reliable.

With regard to outcomes, also different plaque levels were recorded, which is why the standardized mean difference was calculated in the forest plot analysis. Apart from the study by Krahwinkel and Willershausen [27], only subjective plaque levels were used, such as the Turesky plaque index or the plaque index by Silness and Loe. Of these, the study by Kaur et al. [26] was the only one that was not blinded and measurement bias can therefore be assumed. However, several efforts have been made to reduce bias in general such as randomization and blinding. In addition, professional tooth cleaning was performed before the trial in most studies [25–28, 32], so that all subjects, regardless of their allocation to the experimental or control group, were brought down to a common denominator with respect to plaque levels. There is a risk of selection and processing bias in the study by Krahwinkel and Willershausen [27], since no randomization was carried out and regular oral hygiene was allowed during the trial, which was not controlled and could therefore have had a considerable impact on plaque formation.

The main limitation of the present review was the language restriction and consideration of plaque as the only outcome. However, polyphenols show different effects in the oral cavity, such as on gingival and periodontal health, that were not taken into account [36]. Furthermore, plaque represents only one etiological factor of the multifactorial disease caries, and anti-plaque agents do not necessarily inhibit caries [37].

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Conclusions

Given the level of interest in polyphenols in dental research, it was surprising to find few clinical studies. Polyphenols tended to reduce dental biofilm formation compared to a negative control, but without significance. Considering the small number of included studies and the significant heterogeneity, more and larger randomized controlled trials with the same outcome measurements are required to properly assess the clinical efficacy of polyphenols against dental biofilm formation. Therefore, clinical experimental studies to identify particularly effective substances and subsequently clinical controlled studies with longer observation phases should be conducted. Since patients with high risk for caries could particularly benefit from such a preventive measure, this group should be preferentially included. Finally, the adverse effects of polyphenols should also be systematically recorded.

Contributors' Statement

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare that they have no conflicts of interest.

References

[1] Rahman MM, Rahaman MS, Islam MR, Rahman F, Mithi FM, Alqahtani T, Almikhlafi MA, Alghamdi SQ, Alruwaili AS, Hossain MS, Ahmed M, Das R, Emran TB, Uddin MS. Role of phenolic compounds in human disease: Current knowledge and future prospects. Molecules 2022; 27: 233

[2] Quideau S, Deffieux D, Douat-Casassus C, Pouységu L. Plant polyphenols: chemical properties, biological activities, and synthesis. Angew Chem Int Ed Engl 2011; 50: 586–621

[3] Scalbert A, Manach C, Morand C, Rémésy C, Jiménez L. Dietary polyphenols and the prevention of diseases. Crit Rev Food Sci Nutr 2005; 45: 287–306

[4] Flemming J, Meyer-Probst CT, Speer K, Kölling-Speer I, Hannig C, Hannig M. Preventive applications of polyphenols in dentistry – a review. Int J Mol Sci 2021; 22: 4892

[5] Helderman WV, Mikx F. Priorities in oral health care in non-EME countries. Int Dent J 2002; 52: 30–34

[6] Kassebaum NJ, Smith AGC, Bernabé E, Fleming TD, Reynolds AE, Vos T, Murray CJL, Marcenes W; GBD 2015 Oral Health Collaborators. Global, regional, and national prevalence, incidence, and disability-adjusted life years for oral conditions for 195 countries, 1990–2015: A systematic analysis for the global burden of diseases, injuries, and risk factors. J Dent Res 2017; 96: 380–387

[7] Marsh PD, Martin MV. Orale Mikrobiologie. Stuttgart, New York: Georg Thieme; 2003

[8] Hannig M, Joiner A. The structure, function and properties of the acquired pellicle. Monogr Oral Sci 2006; 19: 29–64

[9] Hannig C, Sorg J, Spitzmuller B, Hannig M, Al-Ahmad A. Polyphenolic beverages reduce initial bacterial adherence to enamel in situ. J Dent 2009; 37: 560–566

[10] Rehage M, Delius J, Hofmann T, Hannig M. Oral astringent stimuli alter the enamel pellicle's ultrastructure as revealed by electron microscopy. J Dent 2017; 63: 21–29

[11] Wittpahl G, Kölling-Speer I, Basche S, Herrmann E, Hannig M, Speer K, Hannig C. The polyphenolic composition of Cistus incanus herbal tea and its antibacterial and anti-adherent activity against Streptococcus mutans. Planta Med 2015; 81: 1727–1735

[12] Hertel S, Pötschke S, Basche S, Delius J, Hoth-Hannig W, Hannig M, Hannig C. Effect of tannic acid on the protective properties of the in situ formed pellicle. Caries Res 2017; 51: 34–45

[13] Gibbins HL, Carpenter GH. Alternative mechanisms of astringency – What is the role of saliva? J Texture Stud 2013; 44: 364–375

[14] Wu-Yuan CD, Chen CY, Wu RT. Gallotannins inhibit growth, water-insoluble glucan synthesis, and aggregation of mutans streptococci. J Dent Res 1988; 67: 51–55

[15] Scalbert A, Mila I, Expert D, Marmolle F, Albrecht AM, Hurrell R, Huneau JF, Tome D. Polyphenols, metal ion complexation and biological consequences. Basic Life Sci 1999; 66: 545–554

[16] Yi SM, Zhu JL, Fu LL, Li JR. Tea polyphenols inhibit Pseudomonas aeruginosa through damage to the cell membrane. Int J Food Microbiol 2010; 144: 111–117

[17] Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. J Clin Epidemiol 2009; 62: e1–e34

[18] de Souza-E-Silva CM, da Silva Ventura TM, de Pau L, la Silva Cassiano, de Lima Leite A, Buzalaf MAR. Effect of gels containing chlorhexidine or epigallocatechin-3-gallate on the protein composition of the acquired enamel pellicle. Arch Oral Biol 2017; 82: 92–98

[19] Goyal AK, Bhat M, Sharma M, Garg M, Khairwa A, Garg R. Effect of green tea mouth rinse on Streptococcus mutans in plaque and saliva in children: An in vivo study. J Indian Soc Pedod Prev Dent 2017; 35: 41–46

[20] Hirasawa M, Takada K, Otake S. Inhibition of acid production in dental plaque bacteria by green tea catechins. Caries Res 2006; 40: 265–270

[21] Hu CH, He J, Eckert R, Wu XY, Li LN, Tian Y, Lux R, Shuffer JA, Gelman F, Mentes J, Spackman S, Bauer J, Anderson MH, Shi WY. Development and evaluation of a safe and effective sugar-free herbal lollipop that kills cavity-causing bacteria. Int J Oral Sci 2011; 3: 13–20

[22] Liu T, Chi Y. [Experimental study on polyphenol anti-plaque effect in human]. Zhonghua Kou Qiang Yi Xue Za Zhi 2000; 35: 383–384

[23] Peters MC, Tallman JA, Braun TM, Jacobson JJ. Clinical reduction of S. mutans in pre-school children using a novel liquorice root extract lollipop: a pilot study. Eur Arch Paediatr Dent 2010; 11: 274–278

[24] Díaz Sánchez RM, Castillo-Dalí G, Fernández-Olavarría A, Mosquera-Pérez R, Delgado-Muñoz JM, Gutiérrez-Pérez JL, Torres-Lagares D. A prospective, double-blind, randomized, controlled clinical trial in the gingivitis prevention with an oligomeric proanthocyanidin nutritional supplement. Mediators Inflamm 2017; 2017: 7460780

[25] Hambire CU, Jawade R, Patil A, Wani VR, Kulkarni AA, Nehete PB. Comparing the antiplaque efficacy of 0.5% Camellia sinensis extract, 0.05% sodium fluoride, and 0.2% chlorhexidine gluconate mouthwash in children. J Int Soc Prev Community Dent 2015; 5: 218–226

[26] Kaur H, Jain S, Kaur A. Comparative evaluation of the antiplaque effectiveness of green tea catechin mouthwash with chlorhexidine gluconate. J Indian Soc Periodontol 2014; 18: 178–182

[27] Krahwinkel T, Willershausen B. The effect of sugar-free green tea chew candies on the degree of inflammation of the gingiva. Eur J Med Res 2000; 5: 463–467

[28] Moran J, Addy M, Roberts S. A comparison of natural product, triclosan and chlorhexidine mouthrinses on 4-day plaque regrowth. J Clin Periodontol 1992; 19: 578–582

[29] Kaur S, Kour K. Short term side effects of 0.2% and 0.12% chlorhexidine mouthwash. IP Int J Periodontol Implantol 2020; 4: 138–140

[30] Mathur S, Mathur T, Srivastava R, Khatri R. Chlorhexidine: The gold standard in chemical plaque control. Natl J Physiol Pharm Pharmacol 2011; 1: 45–50

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[31] Cheng L, Li J, He L, Zhou X. Natural products and caries prevention. Caries Res 2015; 49 (Suppl. 1): 38–45

[32] Radafshar G, Ghotbizadeh M, Saadat F, Mirfarhadi N. Effects of green tea (Camellia sinensis) mouthwash containing 1% tannin on dental plaque and chronic gingivitis: a double-blinded, randomized, controlled trial. J Investig Clin Dent 2017; 8: 1–7

[33] Handique JG, Baruah JB. Polyphenolic compounds: An overview. React Funct Polym 2002; 52: 163–188

[34] Tsao R. Chemistry and biochemistry of dietary polyphenols. Nutrients 2010; 2: 1231–1246

[35] Zerabruk S, Chandravanshi BS, Zewge F. Fluoride in black and green tea (Camellia Sinensis) infusions in Ethiopia: Measurement and safety evaluation. Bull Chem Soc Ethiop 2010; 24: 327–338

[36] Palaska I, Papathanasiou E, Theoharides TC. Use of polyphenols in periodontal inflammation. Eur J Pharmacol 2013; 720: 77–83

[37] Caufield PW, Dasanayake AP, Li Y. The antimicrobial approach to caries management. J Dent Educ 2001; 65: 1091–1095

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