

Original Article



# Green Tea May Reduce Dental Caries and Erosion: A Systematic Review

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## Abstract

**Background:** In recent years, the use of mouthwashes containing green tea (GT) extract has been reported to prevent tooth decay. In laboratory studies, GT has been shown to be effective in controlling dental plaque and erosion. The aim of this review study was to evaluate the effectiveness of GT extract in controlling tooth decay and erosion in randomized clinical trials.

**Methods:** By searching related keywords in the Scopus, PubMed, and WOS (Web of Science) databases, as well as searching for related studies in the Google Scholar database randomized clinical trial (RCT) studies published in English by the end of 2019 were extracted. Then, eligible studies were carefully reviewed and the required data were extracted.

**Results:** A total of 12 eligible studies were included in the study. The inclusion criteria of the study were human RCT studies, English language, and GT intervention. The exclusion criteria of the study were lack of negative (placebo) or positive control group, studies examining the effect of GT derivatives, oral diseases such as periodontal disease, people undergoing orthodontic treatment, use of antibiotics at least two weeks before the study, incomplete methodology, defects in the results, and lack of access to the full text of articles. The number of subjects was 246 in the GT group, 157 in the placebo group, and 132 in the positive control group (sodium fluoride, chlorhexidine, neem extract, and probiotic). Eleven studies used GT mouthwash and one study used toothpaste containing GT extract. In studies with placebo, GT showed a significantly better effect on dental plaque, oral pH, modulation of dental erosion, and reduction of the number salivary *S. mutans* and lactobacilli colonies. Additionally, GT had a similar and comparable effect to positive control groups in modulating the above-mentioned indices.

**Conclusion:** GT extract can show anti-cariogenic and anti-erosive effects. Larger randomized clinical trials are needed to support our findings.

**Keywords:** Green tea, Dental caries, Dental erosion, Clinical trial



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## Background

Erosion and tooth decay are common problems in communities. Dental erosion begins with demineralization of the tooth which leads to tooth decay in advanced cases. More than 30% of adolescents and adults suffer from some degree of dental erosion, and 18% of them are in severe conditions (1). More than 40% of children and adolescents suffer from dental caries, which is more common in poor communities (2). Consumption of beverages and fruit juices, gastroesophageal reflux, acid production by oral bacterial flora, aging, and being male are among the main risk factors for tooth erosion and decay (1,3,4).

Prevention of tooth erosion and caries is the ideal way; however, many patients may refer to the dentist in advanced and symptomatic stages and the initial preventive strategy

may not be effective for them. The preventive strategy includes modulation or elimination of risk factors, diagnosis and initial treatment, using remineralization agents, and patient education (5).

The products containing fluoride have shown promising results in reducing dental erosion; however, fluoride has not played a completely preventive role (6). Brushing teeth with toothpaste containing fluoride is a common way to control tooth decay, but this method is not completely able to deal with the pathology of tooth decay, especially with the removal of dental plaque. The use of mouthwashes may enhance the anti-plaque and anti-bacterial effects of the toothpaste (7). The results of clinical studies show that the use of fluoride mouthwashes has been associated with a reduction in the incidence of caries,



tooth loss, and the need for dental restoration by up to 23% (8). Chlorhexidine (CHX) is another commonly used compound for preventing tooth decay and dental plaque, but it has side effects. Calculus formation, tooth and mucosa discoloration, taste disturbance, mucosal damage, and allergic reactions are among the side effects of CHX that may reduce its acceptance among people, especially in the long run (9).

In recent years, GT extract has been introduced as a protective agent against the acidic environment. Laboratory studies indicate that GT extract has a similar effect to fluoride and CHX compounds on the control of tooth decay, although more studies are needed for a definite conclusion (10-12). GT belongs to the family *Camellia sinensis*. It is used daily as a beverage in many countries, especially in Asia. GT leaf extract contains various chemicals. The main constituents of GT are caffeine, flavonoids, and polyphenols (13). Over the past two decades, an abundant number of studies have reported the effects of GT on health. These effects include anti-cancer effects (14), modulation of blood lipid (15) and type 2 diabetes (16), and antioxidant effects (17). The anti-bacterial effect of GT, treatment of periodontal disease (18,19) and controlling dental plaque (20) have the highest amount of evidence for the use of GT in dentistry.

The aim of this systematic review study was to evaluate the human clinical trials on the effect of GT extract on the control of dental erosion and caries.

## Materials and Methods

This systematic review study examined the effect of GT extract on the factors affecting tooth decay and erosion in human clinical trials. The reporting framework of this study is consistent with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist (21). First, the keywords based on MeSH, and the keywords of related articles were prepared as follows: (“green tea extract” OR “*Camellia sinensis* extract” OR “green tea mouthwash” OR “green tea mouth rinse”) AND (“tooth demineralization” OR “remineralization” OR “dental erosion” OR “dental caries” OR “oral flora” OR “anti-bacterial” OR “bacteria” OR “anti-cariogenic”)

Then, the keywords were searched in three databases: Scopus, PubMed, and Web of Science (WOS). Based on the items in the above-mentioned databases, the search was limited to randomized clinical trial (RCT) studies published in English by the end of 2019. Then, the article headlines were extracted. Articles were searched in March 2020.

Then, the articles were electronically sent to two reviewers (S.P, F.K). The reviewers evaluated the articles using Mendeley software version 19.3 for title, abstract, and text. Additionally, a checklist was given to reviewers to classify articles according to the study criteria. Then, eligible articles were merged. Differences in the selected articles of the two reviewers were examined and interpreted by the third reviewer (S.S). To increase the sensitivity of the

search, the first 50 relevant articles displayed in the Google Scholar database were reviewed and added to the study.

Inclusion criteria of the study were: Human RCT studies, English language and GT intervention.

Exclusion criteria of the study were: Lack of negative (placebo) or positive control group, studies examining the effect of GT derivatives, oral diseases such as periodontal disease, people undergoing orthodontic treatment, use antibiotics at least two weeks before the study, incomplete methodology, defects in the results reported, and lack of access to the full text of articles.

Then, the third reviewer (S.S) reviewed the final articles. Information including the type of study, number of participants, study groups, type of intervention, type and concentration of GT extract, evaluation method, study duration, and intervention results were carefully reviewed and extracted. The results of the interventions were reported to be effective (observing a significant difference between the GT group and the placebo, observing significantly superior results or not any significant difference between the GT group and the positive control group) or ineffective (not observing significant difference compared to the negative control group).

The CONSORT 2010 checklist was used to evaluate the quality of the studies (22). This checklist has 37 items. The result of the quality score of the articles was expressed as a percentage according to the items obtained from the checklist. The Cochrane Collaboration tool was used to examine the risk of bias in the studies. This checklist has five items and its bias level is classified as high (H), uncertain (U), and low (L) (23).

## Results

### Search Results

The article search results in the databases are shown in Figure 1. The initial search in the three databases of Scopus, PubMed, and WOS showed 4403 titles. After restricting and merging the titles, 596 titles remained which were sent to the two reviewers. Among these titles, 551 items were omitted for reasons such as unrelated studies, as well as cellular and animal studies. Among the 35 remaining titles and 10 related titles found in the Google Scholar database (n=45), 33 articles were excluded and 12 articles were reviewed finally. The reasons for omitting the articles are shown in Figure 1. Table 1 shows a summary of the final articles.

### Type of Studies and Sample Size

Among the 12 final studies, one article was a triple blind RCT (24), 8 studies were double blind RCT, one study was single blind RCT (25), and one study was open label RCT (26). One RCT study was not separable in this way due to the lack of blinding (27). Three studies had a crossover design in which, by time interval, the interventions rotated between the studies' subjects (25,27,28). Additionally, 535 individuals were enrolled in the studies. Considering the rotation in crossover studies, the groups

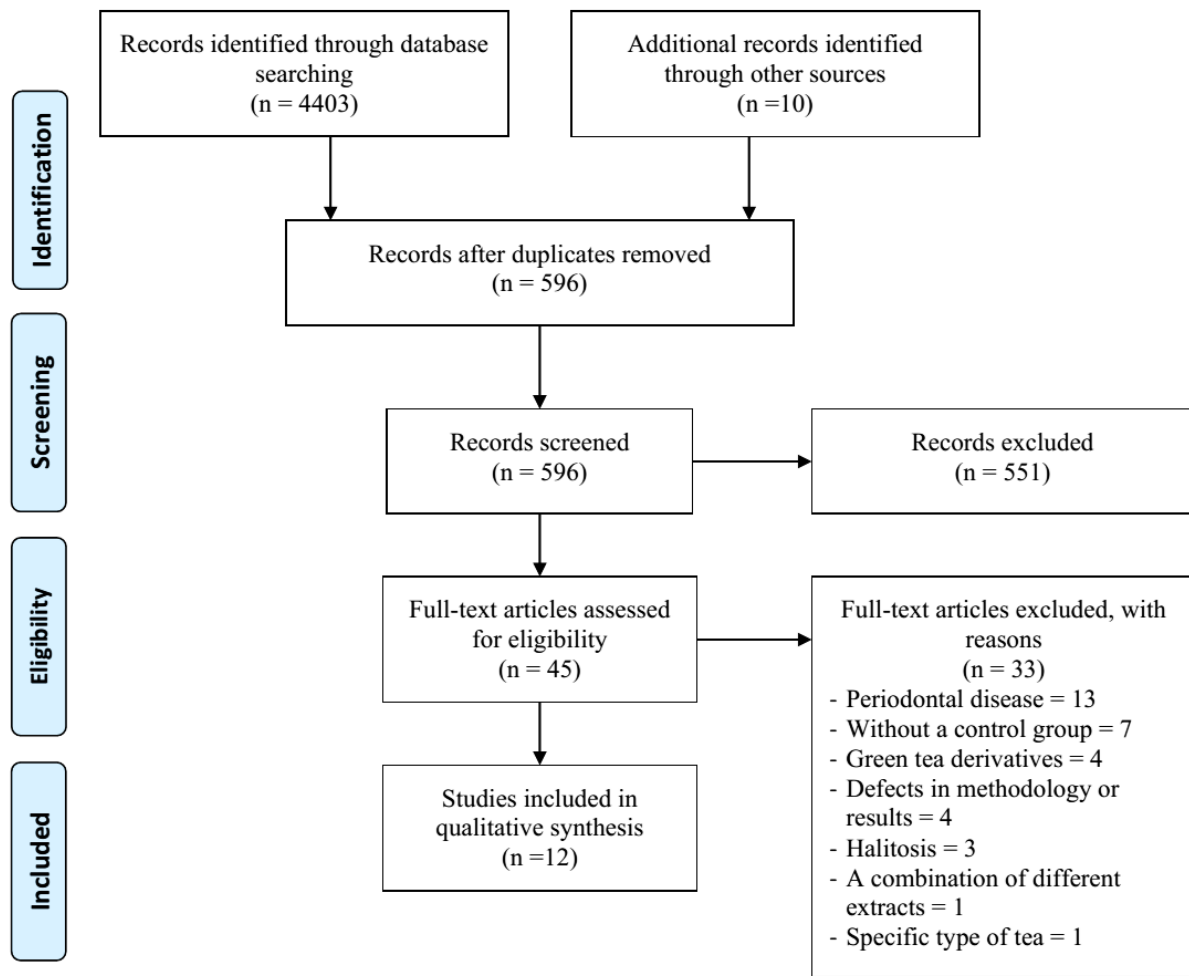


Figure 1. PRISMA 2009 Flow Diagram of Literature Search and Study Selection.

included: GT extract (n=246), placebo such as water (n=157), sodium fluoride (n=55) (28-30), CHX (n=69) (25,28,30-33), neem extract (n=10) (31), combination of CHX and sodium fluoride (n=25) (32), and probiotic (n=13) (30). Participants in seven studies were adults and in five studies, they were under 18 years (26,29,32-34).

### GT Compounds

The studies were conducted in Brazil, Egypt, India, Iran, Italy, and Saudi Arabia. The type of GT leaf used in the studies was not mentioned.

In 9 studies, aqueous GT extract was used, and in one study, the alcoholic extract was used (29). In two studies, it was not clear whether the GT extract was aqueous or alcoholic (28,30). Additionally, diluted aqueous solution of GT was used in 11 studies and GT extract in combination with toothpaste was used in one study (30). GT concentration in six studies varied between 0.5% and 2%. In four studies, the final concentration of GT was not exactly mentioned, but in their report, the amounts of dried GT leaves in boiling water were 2 g/180 mL (27), 2 g/100 mL (25), 1.6 g/40 mL (35), and 1 g/100 mL (34). In two studies, GT concentration was not calculable (30,33).

### Study Groups

Positive control groups in the studies included CHX

(25,28,30-33), sodium fluoride (28-30,32), neem extract (31) and probiotics (30). In the negative control group, water, sugar, and fluoride-free toothpaste were used. In 5 studies, there were only positive control groups and the GT group was compared with them (29-33). In six studies, the placebo group was compared with the GT group (24,26-28,34,35). In two studies, the placebo and positive control groups were compared with the GT group (25,28).

### Efficacy Assessment of GT

Seven studies investigated the effect of interventions on *S. mutans* and lactobacilli, one study examined the effect of GT on plaque pH (26), two studies examined the effect of GT on dental and gingival plaque index (24,31) and two studies examined dental erosion (27,28).

### Length of Studies

Intervention duration in the studies can be summarized as few hours (25,26), five days (27,28), one week (35), two weeks (29,32,33), three weeks (31) and one month (24,30,34).

### Effectiveness

In all of the studies, GT showed a significantly better effect than placebo and a similar effect or superiority over

**Table 1.** A summary of the Final Articles

Efficacy of Green Tea	Type of assessment	Groups	N	Type of Study	Reference
E	<i>S. mutans</i>	GT, 1 g/100 mL Placebo	2×20	RCT	(34)
E	<i>S. mutans</i> <i>Lactobacillus</i>	GT, - CHX, 0.12% Placebo	3×14	RCT	(33)
E	<i>S. mutans</i> <i>Lactobacillus</i>	GT, - CHX, 0.12% Probiotic Sodium fluoride	4×13	RCT	(30)
E	<i>S. mutans</i> <i>Lactobacillus</i>	GT, 0.5% CHX, 0.12% CHX, 0.12% + sodium fluoride	24 24 23	RCT	(32)
E	<i>S. mutans</i>	GT, 2 g/100 mL CHX, 0.12% Placebo	3×10	RCT (crossover)	(25)
E	<i>S. mutans</i> <i>Lactobacillus</i>	GT, 0.5% Sodium fluoride	2×30	RCT	(29)
E	<i>S. mutans</i> <i>Lactobacillus</i>	GT, 1.6 g/40 mL placebo	2×33	RCT	(35)
E	Plaque index Gingival index	GT, 2% Placebo	50 52	RCT	(24)
E	Plaque index Gingival index pH index OHIS	GT, 0.5% Neem, 2% CHX gluconate, 0.2%	3×10	RCT	(31)
E	Plaque pH	Sugar + GT, 2% Sucrose Milk + sugar	3×10	RCT	(26)
E	Dentin erosion	GT, 0.61% CHX, 0.12% Sodium fluoride Placebo	12	RCT (crossover)	(28)
E	Dentin erosion	GT, 0.61% Placebo	10	RCT (crossover)	(27)

Abbreviations: RCT, randomized clinical trial; GT, green tea; CHX, chlorhexidine; *S. mutans*, *Streptococcus mutans*; OHIS, oral hygiene index score; E, effective.

positive control groups. The following is a summary of GT effectiveness results.

#### Anti-bacterial effect

In a study by Ferrazzano et al, participants in the GT group were asked to use GT mouthwash three times a day for a week. The control group used placebo mouthwash. Colonies of *S. mutans* and lactobacilli were counted in saliva. In the GT group, the levels of *S. mutans* and lactobacilli were significantly reduced. In this study, colony reduction was not mentioned separately and instead Odds ratio (OR) was reported. At the end of the fourth day, the ORs were recorded as 3.12 and 4.02 for *S. mutans* and lactobacilli, respectively, and at the end of the seventh day, these values were 3.12 and 4.02, respectively (35).

Neturi et al compared GT mouthwash with CHX and placebo. In their study, mouthwashes were given to subjects and they were asked to rinse their mouths with them (10 mL) for one minute. Before and 5 minutes after mouthwash, dental plaque was obtained for *S. mutans* colony count. This process was repeated one and two weeks later and each group used all mouthwashes alternately in

three phases. Based on the results, the colony count in all phases of the study was significantly reduced in the CHX group (17.2-17.9%) and the GT group (16.1-17.4%) in comparison with the placebo group (-0.6 - + 0.6%). There was no significant difference between GT and CHX groups (25).

Salama and Alsughier divided 40 children into two groups: GT and placebo mouthwashes. The mouthwash was used twice daily for 4 weeks. Salivary *S. mutans* colonies were assessed at baseline, 2 and 4 weeks after the start of the study. The results showed a statistically significant reduction in the *S. mutans* count two weeks (23.2% vs. 4.5%) and four weeks (55.4% vs. 10%) after the intervention compared with placebo (34).

In the study by Ali et al, 42 children were divided into three groups: CHX, GT, and placebo mouthwashes. Subjects were asked to use 5 mL of mouthwash for two weeks (twice a day for one minute). At the end of the study, two mL of saliva was taken from the subjects and examined for *S. mutans* and lactobacilli. Based on the results, CHX and GT significantly reduced the bacterial colony of both types when compared to placebo. CHX and GT groups

were not significantly different from each other. The rates of reductions in *S. mutans* and lactobacilli colonies were 50% and 46.6% in the GT group, 51.8% and 45.9% in the CHX group, and 0.3% and 1.4% in the placebo group, respectively (33).

Tehrani et al divided 60 children (6-12 years old) into groups of 0.5% GT and 0.05% sodium fluoride mouthwashes. Subjects used mouthwash twice a day for 2 weeks and at the end of the study, the colony counts of *S. mutans* and lactobacilli obtained from saliva samples were examined. Both interventions significantly reduced bacterial count without significant differences. In GT and sodium fluoride groups, the rates of reduction were 97.8% and 99.4% in *S. mutans* colonies and 72.1% and 56% in lactobacilli colonies, respectively. For each type of bacteria, no difference was observed between the two groups (29). Hegde and Kamath divided 75 children into three groups of CHX, CHX + sodium fluoride, and GT mouthwashes. Children used mouthwash daily for two weeks. First, 2 mL of saliva was collected and the number of *S. mutans* and lactobacilli colonies was counted before and after the study. The three groups showed a significant decrease in bacterial colony counts. By comparison, the combined and GT groups were not significantly different from each other. CHX alone had significantly better results than the other two groups (54.7% vs. 41.1% and 42%). The rates of reduction in lactobacilli count were reported to be 56.7%, 43.2%, and 37.1% in CHX, GT, and the combined groups, respectively, but no difference was observed among the groups (32).

In the study conducted by Prabakar et al, 42 subjects were divided into four groups of participants using toothpastes containing GT, sodium fluoride, CHX, and probiotic. The number of *S. mutans* and lactobacilli colonies in saliva and dental plaque was counted after 15 and 30 days of the interventions. Based on the results, all the interventions reduced the colony counts, but none of the groups were significantly different from each other (30).

#### *Anti-erosive Effect*

Kato et al compared the effect of GT mouthwash with water on dental erosion and dental erosion + abrasion. The participants used GT extract or water in two crossover phases. Each phase lasted five days and the interval between phases was seven days. They attached samples of bovine teeth to orthodontic appliance. During each phase, the instruments were placed in the mouth for 24 hours and were taken out of the mouth four times a day after food consumption. Then, the bovine teeth were subjected to Coca-Cola (erosion), and in some samples, the teeth were subjected to Coca-Cola and toothbrush (erosion + abrasion). After each challenge, people placed the appliance in their mouths and rinsed their mouths with mouthwashes for one minute. The amount of dentin loss was higher in the erosion + abrasion group than in the erosion group alone. GT significantly reduced erosion (39.8%) and abrasion (26.8%) when compared with

placebo (27). Magalhães et al similar to Kato et al evaluated 12 volunteers in four phases (each phase lasted five days). Study groups included 250 ppm sodium fluoride, 0.12% CHX, 0.61% GT, and deionized water. Based on the results, the erosion + abrasion group had a lower enamel thickness when compared with the erosion group. All positive control groups showed decreased erosion and abrasion and this decrease was higher in the GT, the CHX, and the sodium fluoride groups, respectively, but no significant difference was observed between them. In the GT group, the rates of reductions in abrasion + erosion and erosion were 37.5% and 45%; these values were 33.3% and 40% in the CHX group, and 29.2% and 30% in the sodium fluoride group (28).

#### *Anti-plaque Effect*

Sarin et al divided 102 adults into two groups of 2% GT and placebo mouthwashes. The participants used mouthwash twice a day for 28 days. In intragroup comparison, only the GT group showed a significant decrease in plaque and gingival index. Compared with the placebo group, plaque index (48.1% vs. 12.5%) and gingival index (44.7% vs. 3.4%) showed a more significant decrease in the GT group (24). Balappanavar et al compared 0.5% GT mouthwash with neem extract and CHX mouthwashes. GT and neem were used daily for three weeks and CHX was used for two weeks. The participants were monitored before, immediately after the first wash, and every week until the end of each intervention by measuring the plaque index, gingival index, and oral health status. The plaque index had the highest to the lowest decrease in the GT, neem, and CHX groups, respectively, to the extent that the downward trend in the GT group was higher than that in the other two groups. The gingival index in all three groups showed a similar improvement. The highest reduction in the gingival index was observed in the GT group. Oral health and hygiene in the GT and neem groups had an upward trend and this index in the CHX group had an alternating trend. The best oral hygiene score was recorded for the GT group, followed by neem and CHX groups. The comparison between the groups at the end of the second week showed that the plaque index in the GT group was significantly higher compared to the other groups and there was no significant difference in terms of other indices (31).

#### *pH Modulation Effect*

In other part of their study, Balappanavar et al compared the pH of saliva after using 0.5% GT, neem, and CHX mouthwashes. The pH at the beginning of the study was about 5 in all three groups and at the end of the study, it was about 6.3 in all three groups, which showed a similar upward trend. By comparing the groups at the end of the second week, it was revealed that there was no significant difference in pH level. At the end of the third week, the GT group had a significantly higher pH than the neem group ( $6.44 \pm 0.39$  vs.  $6.28 \pm 0.44$ ) (31).

Additionally, Talreja et al reported that at all times after the intervention (5, 10, 20, and 30 minutes), the pH of plaque in the GT group (6.69-6.93) was significantly higher compared to the milk + sugar group (6.45-6.50) and the sucrose group (6.01-6.16). In addition, the pH in the milk + sugar group was higher compared to the sucrose group, significantly (26).

### Quality of Studies and Bias

The quality score of the studies varied between 62.5 and 90.6%. Lack of randomization and blinding process, as well as lack of access to study protocol were the main reasons for the decrease in the quality score of the articles. Among the studies, lack of randomization, blinding process, and follow-up period were the main causes of bias in the studies. Table 2 shows the quality and risk of bias distribution in the studies.

### Discussion

Findings of the above-mentioned 12 RCT studies showed that GT extract as a mouthwash or in combination with toothpaste can modulate factors related to tooth aging and caries including dental erosion and abrasion, salivary acidity, oral bacterial flora, and dental plaque, and they also demonstrated that GT did not have a placebo effect. GT also showed a similar anti-cryogenic effect to standard mouthwashes including CHX and sodium fluoride.

Tea is available in black, oolong (fermented), and green (without fermentation). Catechins 30%, other polyphenols 8%, minerals 10%, proteins and amino acids 9%, carbohydrates 7%, tannins 3%, and caffeine 3% are the main components of the dry leaf of GT (36). Polyphenols such as Epicatechin, Epicatechin-3-gallate, Epigallocatechin, and Epigallocatechin-3-gallate are the most important components of GT. The catechins in GT appear to have the main protective effects on tissue health (37,38). The amount of active catechins of GT decreased significantly by fermentation (37).

In seven studies, GT had a reducing effect on the colonies of *S. mutans* and lactobacilli in samples prepared from saliva and dental plaque (25,29,30,32-35) and in two studies, it decreased dental plaque (24,31). In cross-

sectional studies, in the dental plaques accompanied by significant dental caries, *S. mutans* was a common dental plaque microflora, and only the lack or a lower load of this bacterium has reduced the incidence and severity of dental caries (39,40). Although dental plaque is polymicrobial, *S. mutans* enhance the presence of other bacteria in dental plaque (41). *S. mutans* break down carbohydrates by producing lactic acid and enzymes. With the fermentation and accumulation of sucrose by *S. mutans*, an insoluble extracellular polymer called glucan is produced, which forms the biofilm and dental plaque base and stabilizes the presence of bacteria in the plaque (42). Various species of lactobacilli are present in the oral cavity and gastrointestinal tract. The main source of *Lactobacillus* is dairy. In epidemiological studies, *Lactobacillus* has a high prevalence in people with dental caries (43). *Lactobacillus* has the ability to produce acid, break down sugar, and produce glucan in some species (43). It seems that GT with a concentration of 2 mg/mL prevents the formation of dental plaque completely and has an anti-bacterial effect on different species of oral microflora (44). The catechins in GT have a significant anti-bacterial effect. EGCG reduces acid production by *S. mutans*, inhibits the growth of *S. mutans*, and reduces the viability of the *S. mutans* colonies. In addition, it reduces the metabolic activity and virulence of *S. mutans* by inhibiting the activity of ATPase and lactate dehydrogenase (45). EGCG has been proven to reduce glucan production by *S. mutans* (46), thereby reducing the ability of *S. mutans* to bind to the surrounding environment (47). GT reduces the hydrolysis of starch by salivary amylase and thus reduces the availability of broken sugars to bacteria. GT inhibits bacterial amylase too (48).

In two reviewed studies, the use of GT mouthwash reduced dental erosion and abrasion up to 45% (27,28). In the laboratory, the immersion of the bovine teeth samples in the Coca-Cola, Kuat guarana, Sprite, and light Coca-Cola beverages in combination with 1.2% GT extract reduced dental erosion by 15-40% compared with the control group (49). In another laboratory study, after immersing samples of human coronary dentin in citric acid and then washing them with CHX, water, or GT, the lowest amount

**Table 2.** The Quality and Risk of Bias Assessment of the RCT Studies Based on Modified CONSORT 2010 Statement and Cochrane Risk of Bias Tool

Study	(29)	(35)	(31)	(24)	(25)	(32)	(26)	(30)	(34)	(28)	(33)	(27)
<b>Quality</b>												
No. positive items	28/32	23/33	24/32	25/32	22/32	23/32	21/30	29/32	23/32	26/32	22/32	20/32
%	87.5	69.7	75	78.1	68.8	71.9	70	90.6	71.9	81.3	68.8	62.5
<b>Bias</b>												
Random sequence generation	L	H	H	L	L	L	L	L	H	H	H	H
Allocation concealment	L	H	H	L	U	L	L	L	H	H	U	L
Blinding of participants and personnel	L	U	U	L	H	U	H	L	L	L	H	H
Blinding of outcome assessment	L	U	U	U	U	L	L	L	L	L	L	L
Incomplete outcome data	L	L	L	L	L	L	L	L	L	L	L	L
Other (follow-up)	H	H	H	H	H	H	H	H	H	H	H	H

H, high; U, uncertain; L, low.

of erosion was observed in the GT group and CHX, respectively. Loss of dentin hardness was also lowest in the CHX and GT groups, respectively (50). The effectiveness of GT in reducing dental erosion can be affected by its anti-bacterial effect, pH modulation and also modulation in the secretion of Matrix metalloproteinases (MMPs). In cases where the tooth is exposed to endogenous or exogenous acids acutely, the role of acidity modulation and MMPs seems to be more significant. In acidic environments, the secretion of MMPs from the tissue and bacteria increases, which causes damage to collagen in the tooth tissue, a greater tooth permeability, decreased tooth strength, and increased erosion (51). GT decreases MMPs 3, 8 and 9 (52). A similar effect has been observed for CHX on the reduction of MMPs 2, 8, and 9 in the laboratory model (53). GT can also improve the eroded texture and increase the microhardness of eroded dentin with erosion (54).

Fluoride reduces demineralization and increases remineralization in a dynamic process (55) and has a protective effect on the development of erosion and tooth decay. Depending on the type of the GT and the method of extraction, there were different concentrations of fluoride in GT extract. Generally, the minimum and maximum concentrations of fluoride in the GT infusions were 0.16 mg/L and 3.29 mg/L, respectively (56). GT had a similar effect to fluoride in reducing bacterial colonization (29,30,32) and modulating dental erosion (28) in four reviewed studies. In two reviewed studies that measured the concentration of fluoride in GT, its levels were 1.4 and 0.39 ppm, compared to 221 and 250 ppm of fluoride in the fluoride mouthwash group (28,29). In these studies, the amount of GT extract fluoride was close to city water fluoride amount (about 0.7 ppm) (57) and the concentration of fluoride in 15 types of GT extract (56). Accordingly, it seems that the anti-erosive effects of GT and fluoride are due to the presence of other compounds in GT (54), which needs further studies to be confirmed. No significant side effect was found in the available literature for GT mouthwash and it seems to be safe. Among the reviewed studies, two studies evaluated the possible clinical side effects of GT extract. CHX, GT, and neem mouthwashes were reported to be acceptable to 80%, 78%, and 60% of the people, respectively (31). In addition, the color and bitterness of GT had a repulsive effect, but no side effects were recorded (31). In the study by Tehrani et al, GT extract was acceptable for participants and had no side effects (29). A pilot study, which evaluated the side effects of GT and CHX mouthwashes in two groups of 18 individuals for two weeks, showed that the mild to moderate burning sensation and dry mouth were the most common side effects in the GT group, but there was no significant difference between the groups in terms of side effects (58). The limitations of the reviewed studies included short-term interventions (one month or less), failure to follow up and evaluate the stability of the effects of interventions, failure to evaluate possible local and systemic complications of GT in most studies, and failure

to evaluate GT with concentrations greater than 2%. These limitations can be reduced in future studies.

In summary, the review of 12 articles showed that the use of mouthwash and toothpaste containing GT extract has anti-bacterial, anti-plaque, and, anti-erosive effects comparable to sodium fluoride and CHX mouthwashes and can be a preventative agent against tooth erosion and decay. For a better summary, more RCT studies with larger sample size are needed. Using different concentrations of GT extract with and without combination with fluoride can show a better view of its effects on tooth decay and erosion.

#### Authors' Contribution

FK and SP screened the titles and selected the qualified articles. NM was the plan supervisor. SFS was the main author. FK was the corresponding author.

#### Conflict of Interest Disclosures

The authors declare that there is no conflict of interest.

#### Ethical Statement

Not applicable.

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