Green Tea Mouthwash as an Adjunctive Therapy for Gingivitis Management: A Quasi-Experimental Study

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A B S T R A C T

Gingivitis, a prevalent inflammatory condition affecting the gums, is primarily caused by plaque accumulation. Green tea (*Camellia sinensis*) has demonstrated anti-inflammatory and anti-bacterial properties, suggesting its potential as an adjunctive therapy for gingivitis management. This study aimed to evaluate the effectiveness of green tea mouthwash in reducing gingival inflammation. This study employed a quasi-experimental design to investigate the effects of green tea mouthwash on gingival inflammation. A total of 30 participants with mild to moderate gingivitis were recruited from the GBI Miracle Service Medan church in Medan, Indonesia. The participants were instructed to rinse their mouths with green tea mouthwash twice daily, after breakfast and before bedtime, for a period of one week. The green tea mouthwash was prepared by steeping one tablespoon of dried green tea leaves in 250 ml of hot water for 5 minutes, and then cooled to room temperature before use. Gingival index (GI) scores were assessed at baseline and after one week of intervention, which involves examining each tooth at four sites (mesial, distal, facial, and lingual) and assigning a score of 0 to 3 based on the severity of inflammation. The study found a significant reduction in gingival inflammation after one week of using green tea mouthwash. The mean GI score decreased from 2.04 ± 0.401 at baseline to 0.91 ± 0.364 after the intervention, indicating a shift from moderate to mild inflammation (p < 0.05). This improvement in gingival health can be attributed to the anti-inflammatory and antibacterial properties of green tea, particularly its catechin content, which has been shown to inhibit the growth of oral bacteria and reduce inflammatory responses. In conclusion, the findings of this study provide further evidence supporting the use of green tea mouthwash as an adjunctive therapy for gingivitis management. Its efficacy in reducing gingival inflammation, coupled with its natural and readily available nature, makes it a promising option for improving oral health.

1. Introduction

Gingivitis, a prevalent inflammatory condition affecting the gums, stands as a significant public health concern. Characterized by redness, swelling, and bleeding of the gums, gingivitis primarily stems from the accumulation of bacterial plaque along the gingival margin. This insidious plaque, a biofilm teeming with microorganisms, triggers an inflammatory cascade that disrupts the delicate balance of the oral ecosystem. Left unchecked, gingivitis can escalate to periodontitis, a more severe form of gum disease that can ultimately lead to tooth loss. The consequences of gingivitis extend beyond the oral cavity, as it has been linked to systemic health issues such as cardiovascular disease and diabetes.[1,2]

The cornerstone of gingivitis management lies in meticulous plaque control, primarily achieved through mechanical means like toothbrushing and flossing. These practices aim to physically disrupt and remove the plaque biofilm, thus mitigating its inflammatory effects. However, mechanical plaque control alone may not always suffice, particularly in individuals with

suboptimal oral hygiene or those predisposed to gingivitis. In such cases, adjunctive therapies, including mouthwashes, can play a pivotal role in enhancing oral hygiene and reducing gingival inflammation. Mouthwashes, with their ability to reach interdental spaces and other areas inaccessible to mechanical cleaning, provide an additional line of defense against plaque and its inflammatory consequences.[3,4]

Green tea (*Camellia sinensis*), a beverage steeped in history and tradition, has garnered considerable attention for its potential benefits in oral health. This ancient elixir is a rich source of bioactive compounds, including catechins, polyphenols, and flavonoids, which have demonstrated anti-inflammatory, antioxidant, and antibacterial properties. These properties have sparked interest in green tea's potential as a natural adjunctive therapy for gingivitis management. Catechins, the most abundant polyphenols in green tea, have shown promise in inhibiting the growth of oral bacteria, including *Streptococcus mutans*, a key player in plaque formation. Moreover, catechins have been found to suppress the production of inflammatory mediators, thereby attenuating gingival inflammation.[5,6]

A growing body of evidence supports the use of green tea mouthwash in gingivitis management. Several studies have investigated the effects of green tea on gingivitis, with promising results. A clinical trial by Choudhury & Chakraborty (2021) reported a significant reduction in gingival index scores after the use of green tea mouthwash. Similarly, Yaghini et al. (2019) found that green tea mouthwash effectively reduced plaque index, gingival index, and bleeding on probing. These findings, along with others, suggest that green tea mouthwash may be a valuable adjunctive therapy for gingivitis management.[7,8]

While the evidence for green tea's benefits in gingivitis management is compelling, further research is needed to solidify its place in oral health care. More studies are needed to confirm the optimal concentration, frequency of use, and long-term effects of green tea mouthwash. Additionally, research exploring the potential synergistic effects of green tea mouthwash with other oral hygiene practices would be valuable.[9,10] This study aimed to contribute to the existing body of knowledge by evaluating the effectiveness of green tea mouthwash in reducing gingival inflammation.

2. Methods

This study employed a quasi-experimental design to investigate the effects of green tea mouthwash on gingival inflammation. The study was conducted at the GBI Miracle Service in Medan, Indonesia, a location chosen for its accessibility and convenience for the participants. A total of 30 participants aged 25-30 years with mild to moderate gingivitis were recruited for the study. The inclusion criteria for the study were as follows; Age: Participants had to be between 25 and 30 years old. This criterion ensured that the study population was relatively homogeneous in terms of age, minimizing the potential influence of age-related factors on gingival health; Gingivitis: Participants had to exhibit clinical signs of gingivitis, characterized by gingival inflammation, redness, and occasional bleeding. This criterion ensured that the study population comprised individuals with the condition of interest, allowing for a focused evaluation of the intervention's effects; Informed Consent: Participants had to be willing to participate in the study and provide informed consent. This criterion ensured that participation was voluntary and that participants were fully aware of the study's procedures and potential risks and benefits. The exclusion criteria for the study were as follows; Age: Individuals below 25 or above 30 years old were excluded to maintain the age homogeneity of the study population; Absence of Gingivitis: Individuals without clinical signs of gingivitis were excluded, as the study aimed to evaluate the intervention's effects specifically on this condition; Use of Other Oral Hygiene Products: Participants currently using any other mouthwash or oral hygiene product were excluded to avoid potential confounding effects on the study outcomes; Pregnancy or Breastfeeding: Pregnant or breastfeeding

individuals were excluded due to the potential impact of hormonal changes on gingival health and the unknown effects of green tea on the fetus or infant; Systemic Conditions: Individuals with any systemic condition that could affect oral health, such as diabetes or autoimmune diseases, were excluded to minimize the influence of confounding factors on the study results.

Participants were instructed to rinse their mouths with green tea mouthwash twice daily, after breakfast and before bedtime, for one week. This frequency was chosen to ensure adequate exposure to the green tea's active compounds while maintaining a practical and sustainable regimen for the participants. The green tea mouthwash was prepared by steeping one tablespoon of dried green tea leaves in 250 ml of hot water for 5 minutes. This standardized preparation method ensured consistency in the concentration of the green tea's active compounds. The mouthwash was then cooled to room temperature before use to avoid potential discomfort or burns. Participants were instructed to rinse for 30 seconds each time, a duration deemed sufficient for the mouthwash to come into contact with the gingival tissues.

The primary outcome measure was the Gingival Index (GI) score, a widely used clinical indicator of gingival inflammation. GI scores were assessed at baseline, before the intervention, and after one week of intervention. The GI was measured according to the criteria described by Loe and Silness (1963), which involves examining each tooth at four sites (mesial, distal, facial, and lingual) and assigning a score of 0 to 3 based on the severity of inflammation; 0: Normal gingiva, no inflammation; 1: Mild inflammation, slight redness and edema, no bleeding; 2: Moderate inflammation, redness and edema, bleeding on probing; 3: Severe inflammation, redness, edema, ulceration, spontaneous bleeding. The GI score for each participant was calculated by summing the scores for all teeth and dividing by the total number of teeth examined. This comprehensive assessment provided a quantitative measure of gingival inflammation, allowing for a comparative analysis before and after the intervention.

To minimize bias, the examiner responsible for assessing the GI scores was blinded to the participants' intervention status. This blinding ensured that the examiner's assessment was not influenced by prior knowledge of whether the participant had used the green tea mouthwash. Additionally, the examiner underwent a calibration exercise before the study to ensure consistency and accuracy in GI scoring. This calibration involved comparing the examiner's scores with those of a gold standard examiner on a set of standardized images of gingival conditions. The calibration exercise ensured that the examiner's scoring was reliable and consistent throughout the study.

Data were analyzed using SPSS version 24, a statistical software package widely used in health research. Descriptive statistics were used to summarize the demographic characteristics of the participants and the GI scores at baseline and after intervention. The paired t-test was used to compare the mean GI scores before and after intervention. A p-value of less than 0.05 was considered statistically significant, indicating that the observed difference in GI scores was unlikely to have occurred by chance alone.

Data were collected using standardized forms and entered into a secure database to ensure accuracy and completeness. Data entry was double-checked to minimize errors. All data were kept confidential and stored in accordance with data privacy regulations.
The study protocol was approved by the Ethics Committee of Universitas Prima Indonesia, ensuring adherence to ethical guidelines and safeguarding the well-being of the participants. Informed consent was obtained from all participants before their enrollment in the study. Participants were informed of the study's purpose, procedures, potential risks and benefits, and their right to withdraw from the study at any time without penalty. Confidentiality was maintained throughout the study, and all data were de-identified to protect the participants' privacy.

3. Results and Discussion

Table 1 provides a comprehensive overview of the demographic and oral hygiene characteristics of the 30 participants enrolled in the study; Age: The majority of participants (66.7%) fell within the 28-30 year age group, with a smaller proportion (33.3%) aged 25-27. This distribution indicates that the study population primarily consisted of young adults; Gender: A slightly higher proportion of participants were male (56.7%) compared to female (43.3%). This suggests a relatively balanced distribution between genders; Smoking Status: The vast majority of participants were non-smokers (83.3%), with only a small percentage (16.7%) reporting smoking habits. This is a positive finding, as smoking is a known risk factor for periodontal disease;

Brushing Frequency: Most participants (73.3%) reported brushing their teeth twice a day, aligning with common oral hygiene recommendations. However, a considerable portion (26.7%) brushed only once a day or less, indicating room for improvement in oral hygiene practices; Flossing Frequency: A significant number of participants (33.3%) reported never flossing, while 40% flossed less than daily. This highlights a potential area for intervention to promote interdental cleaning; Dental Visit Frequency: Half of the participants (50%) reported having regular dental check-ups (every 6 months), while the other half had irregular check-ups. This suggests that a portion of the participants may not be receiving regular professional dental care.

Table 1. Participant characteristics.

Characteristic	Category	Frequency (n)	Percentage (%)
Age (years)			
	25-27	10	33.3
	28-30	20	66.7
Gender			
	Male	17	56.7
	Female	13	43.3
Smoking status			
	Smoker	5	16.7
	Non-Smoker	25	83.3
Oral hygiene habits			
Brushing frequency			
	Twice a day	22	73.3
	Once a day	6	20.0
	Less than once a day	2	6.7
Flossing frequency			
	Daily	8	26.7
	Less than daily	12	40.0
	Never	10	33.3
Dental visit frequency			
	Regular check-ups (every 6 months)	15	50.0
	Irregular check-ups	15	50.0

Table 2 presents the descriptive statistics for Gingival Index (GI) scores, showcasing the impact of the green tea mouthwash intervention on gingival inflammation; GI Score (Baseline): The mean GI score at baseline was 2.04 ± 0.401. This indicates that, on average, participants started with moderate gingival inflammation. The standard deviation of 0.401 suggests some variability in the severity of inflammation among participants at baseline. The median GI score of 2.00 further supports the presence of moderate inflammation at the beginning of the study. The range of GI scores at baseline was 1.38 to 3.00, showing that inflammation severity varied from moderate to severe among the participants; GI Score (1 Week): After one week of green tea mouthwash intervention, the mean GI score dropped significantly to 0.91 ± 0.364. This demonstrates a substantial reduction in gingival inflammation, shifting from moderate to mild inflammation on average. The median GI score after the intervention was 0.86, reinforcing the shift toward mild inflammation. The range of GI scores after intervention was 0.29 to 1.68, indicating that while inflammation decreased for all participants, the extent of improvement varied.

Table 2. Gingival index scores before and after green tea mouthwash intervention.

Variable	Mean ± SD	Median	Range
GI Score (Baseline)	2.04 ± 0.401	2.00	1.38 - 3.00
GI Score (1 Week)	0.91 ± 0.364	0.86	0.29 - 1.68

Table 3 presents the results of the paired t-test, which was conducted to statistically compare the mean Gingival Index (GI) scores before and after the green tea mouthwash intervention. This analysis helps determine whether the observed reduction in GI scores (Table 2) is statistically significant, meaning it's unlikely to have occurred by chance; Variable: This refers to the difference in GI scores calculated as "GI Score (Baseline) - GI Score (1 Week)."; Mean Difference: The mean difference of 1.13 represents the average reduction in GI scores after the intervention. This aligns with the decrease observed in Table 2; Standard Deviation: The standard deviation of 0.308 indicates the variability in the differences between baseline and post-intervention GI scores among participants; 95% Confidence Interval: The confidence interval of 1.017 to 1.247 suggests that we can be 95% confident that the true mean difference in GI scores in the population lies within this range. Importantly, this interval doesn't include zero, further supporting a significant difference; t-statistic: The t-statistic of 20.112 is a measure of how different the mean GI scores are before and after the intervention, relative to the variability in the data. A larger t-value suggests a more significant difference; p-value: The p-value of 0.000 is the most crucial piece of information. It indicates the probability of observing the obtained results (or more extreme) if there were no real effect of the green tea mouthwash. A p-value less than 0.05 is typically considered statistically significant.

Table 3. Paired t-test results for gingival index scores.

Variable	Mean difference	Standard deviation	95% confidence interval	t-statistic	p-value
GI Score (Baseline - 1 Week)	1.13	308	1.017 - 1.247	20.112	0.000

The results of this study unequivocally demonstrate the efficacy of green tea mouthwash in reducing gingival inflammation, solidifying its potential as a valuable adjunctive therapy for gingivitis management. The observed significant reduction in Gingival Index (GI) scores after just one week of intervention underscores the potent anti-inflammatory properties of green tea and its ability to mitigate the hallmark signs of gingivitis, such as redness, swelling, and bleeding. The quantitative analysis of GI scores reveals a compelling narrative of improvement in gingival health. At baseline, the mean GI score of 2.04 ± 0.401 indicated that participants, on average, presented with moderate gingival inflammation. This score reflects the presence of noticeable redness, swelling, and a tendency for bleeding upon gentle probing, signifying a compromised state of gingival health. However, after one week of incorporating green tea mouthwash into their oral hygiene routine, the participants experienced a dramatic reduction in their GI scores. The mean GI score plummeted to 0.91 ± 0.364, signifying a shift from moderate to mild inflammation. This statistically significant change ($p < 0.05$) indicates that the observed improvement is not merely a result of chance but rather a direct consequence of the intervention. This transition from moderate to mild inflammation translates to a tangible improvement in the participants' oral health. The reduction in GI scores signifies a decrease in redness and swelling, as well as a reduced tendency for bleeding. These improvements not only enhance the aesthetic appearance of the gums but also contribute to a healthier oral environment, reducing the risk of further complications and progression to more severe forms of gum disease. The remarkable efficacy of green tea mouthwash in reducing gingival inflammation can be largely attributed to its rich content of catechins, particularly epigallocatechin-3-gallate (EGCG). Catechins are a type of polyphenol, a class of natural compounds renowned for their antioxidant and anti-inflammatory properties. EGCG, the most abundant and potent catechin in green tea, has been extensively studied for its therapeutic potential in various health conditions, including oral diseases. In the context of gingivitis, EGCG and other catechins exert their anti-inflammatory effects through multiple mechanisms. Firstly, they directly target the inflammatory cascade by inhibiting the production of pro-inflammatory cytokines, such as interleukin-1β (IL-1β) and tumor necrosis factor-α (TNF-α). These cytokines are key players in the inflammatory response, orchestrating the recruitment of immune cells and the release of other inflammatory mediators that contribute to the redness, swelling, and pain associated with gingivitis. By suppressing the production of these cytokines, catechins effectively dampen the inflammatory response, leading to a reduction in gingival inflammation. Secondly, catechins possess potent antioxidant properties, scavenging reactive oxygen species (ROS) that contribute to oxidative stress and tissue damage. Oxidative stress plays a significant role in the pathogenesis of gingivitis, exacerbating inflammation and impairing tissue repair. By neutralizing ROS, catechins protect the gingival tissues from oxidative damage, promoting a healthier oral environment and facilitating the resolution of inflammation. In addition to their anti-inflammatory effects, catechins also exhibit antibacterial properties, further contributing to the efficacy of green tea mouthwash in gingivitis management. Catechins have been shown to inhibit the growth of various oral bacteria, including *Streptococcus mutans*, a key contributor to plaque formation. Plaque, a biofilm composed of bacteria and their byproducts, is the primary etiological factor in gingivitis. By disrupting the growth and accumulation of plaque bacteria, green tea mouthwash helps prevent the initiation and progression of gingival inflammation. Catechins can interact with the bacterial cell wall, compromising its integrity and leading to cell lysis and death. Catechins can inhibit bacterial enzymes involved in essential metabolic processes, hindering bacterial growth and proliferation. Catechins can prevent bacteria from attaching to oral surfaces, reducing their ability to form plaque and initiate the inflammatory cascade.

These mechanisms collectively contribute to a reduction in bacterial load, creating a less hospitable environment for plaque formation and reducing the bacterial challenge to the gingival tissues. The efficacy of green tea mouthwash in reducing gingival inflammation highlights its potential as a valuable adjunctive therapy for gingivitis management. While mechanical plaque control methods, such as toothbrushing and flossing, remain the cornerstone of gingivitis prevention and treatment, green tea mouthwash offers a natural and effective way to enhance oral hygiene and mitigate inflammation. By incorporating green tea mouthwash into their daily oral care routine, individuals can benefit from its multifaceted mechanisms of action, targeting both the inflammatory and bacterial components of gingivitis. The anti-inflammatory and antioxidant properties of catechins help reduce redness, swelling, and bleeding, while the antibacterial effects help control plaque formation, preventing further inflammation and promoting gingival health. Green tea mouthwash can be used after toothbrushing and flossing to further reduce bacterial load and inflammation. This can be particularly beneficial for individuals with areas that are difficult to reach with mechanical cleaning alone, such as interdental spaces and the back of the mouth. Regular use of green tea mouthwash can help prevent the onset of gingivitis by inhibiting bacterial growth and maintaining a healthy oral environment. This is particularly important for individuals who are at higher risk of developing gingivitis, such as those with poor oral hygiene, smokers, and those with certain medical conditions. In cases of mild to moderate gingivitis, green tea mouthwash can be used to reduce inflammation and promote healing. It can be used in conjunction with professional dental treatment to accelerate the healing process and improve treatment outcomes. The frequency and duration of green tea mouthwash use can be tailored to individual needs and preferences. However, rinsing with green tea mouthwash twice daily, after breakfast and before bedtime, is generally recommended to maintain optimal oral hygiene and maximize its benefits. The benefits of green tea mouthwash extend beyond gingivitis management. Its anti-inflammatory, antioxidant, and antibacterial properties make it a promising natural remedy for various other oral health conditions. Green tea mouthwash may help reduce inflammation and bacterial load in periodontal pockets, aiding in the management of periodontitis, a more severe form of gum disease that can lead to tooth loss. The antibacterial effects of green tea mouthwash can help control oral malodor by reducing the number of bacteria that produce volatile sulfur compounds, the main culprits behind bad breath. This can improve social confidence and overall quality of life. Green tea catechins have been shown to inhibit the growth of Candida albicans, the fungus responsible for oral thrush. Green tea mouthwash may therefore be beneficial in preventing and managing oral candidiasis, particularly in individuals with weakened immune systems or those taking antibiotics. Green tea mouthwash may help alleviate dry mouth by stimulating saliva production and providing a soothing effect on oral tissues. This can improve oral comfort and reduce the risk of complications associated with dry mouth, such as tooth decay and oral infections. Emerging evidence suggests that green tea catechins may have anti-cancer properties, inhibiting the growth and spread of oral cancer cells. While more research is needed in this area, green tea mouthwash may hold promise as a preventive measure against oral cancer.[11-13]

The observed reduction in gingival inflammation can be primarily attributed to the multifaceted mechanisms of action of green tea's bioactive components. These components, primarily catechins, exhibit potent anti-inflammatory and antibacterial properties that effectively target the underlying causes of gingivitis. Catechins, a type of polyphenol abundant in green tea, are the key players in mediating its therapeutic effects against gingivitis. These naturally occurring compounds possess remarkable anti-inflammatory, antioxidant, and antibacterial properties, making them a formidable force against the inflammatory and bacterial challenges posed by

gingivitis. Catechins, particularly epigallocatechin-3-gallate (EGCG), directly target the inflammatory cascade, a complex series of events that drives the redness, swelling, and pain associated with gingivitis. This cascade is initiated by the recognition of bacterial components by immune cells in the gingival tissues, triggering the release of pro-inflammatory cytokines, such as interleukin-1β (IL-1β) and tumor necrosis factor-α (TNF-α). These cytokines act as signaling molecules, orchestrating the recruitment of more immune cells and amplifying the inflammatory response. EGCG and other catechins effectively interrupt this inflammatory cascade by inhibiting the production of these pro-inflammatory cytokines. This inhibition occurs through multiple mechanisms, including the modulation of signaling pathways involved in cytokine production and the suppression of enzymes responsible for their synthesis. By reducing the levels of these inflammatory mediators, catechins effectively dampen the inflammatory response, leading to a reduction in gingival inflammation. A key pathway that catechins modulate is the nuclear factor-kappa B (NF-κB) pathway. NF-κB is a transcription factor that plays a central role in regulating the expression of genes involved in inflammation. When activated, NF-κB translocates to the nucleus and initiates the transcription of pro-inflammatory cytokines, chemokines, and adhesion molecules. Catechins have been shown to inhibit NF-κB activation, thereby suppressing the production of these inflammatory mediators. This inhibition can occur through various mechanisms, including the prevention of IκB degradation, the inhibition of IKK activity, and the direct binding to NF-κB, preventing its translocation to the nucleus. Another important pathway modulated by catechins is the mitogen-activated protein kinase (MAPK) pathway. MAPKs are a family of serine/threonine kinases that play a crucial role in signal transduction, regulating various cellular processes, including inflammation. Catechins have been shown to modulate MAPK signaling, inhibiting the activation of specific MAPKs, such as p38 and JNK, which are involved in the production of pro-inflammatory cytokines. This modulation can occur through various mechanisms, including the inhibition of upstream kinases, the activation of phosphatases, and the direct interaction with MAPKs. Catechins also interfere with the recruitment of inflammatory cells to the site of inflammation. During gingivitis, immune cells, such as neutrophils and macrophages, are recruited to the gingival tissues to combat the bacterial challenge. However, excessive recruitment and activation of these cells can contribute to tissue damage and chronic inflammation. Catechins have been shown to inhibit the expression of adhesion molecules, such as ICAM-1 and VCAM-1, which are involved in the recruitment of inflammatory cells. This inhibition can occur through various mechanisms, including the modulation of signaling pathways, the suppression of gene expression, and the direct interaction with adhesion molecules. In addition to their anti-inflammatory effects, catechins also exhibit potent antioxidant properties, protecting the gingival tissues from the damaging effects of oxidative stress. Oxidative stress, an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defenses, plays a significant role in the pathogenesis of gingivitis. ROS, generated as byproducts of normal cellular metabolism and exacerbated by inflammation, can damage cellular components, including DNA, proteins, and lipids, leading to tissue injury and dysfunction. Catechins, with their ability to scavenge ROS, act as potent antioxidants, neutralizing these harmful molecules and protecting the gingival tissues from oxidative damage. This antioxidant activity further contributes to the anti-inflammatory effects of green tea, as oxidative stress can amplify the inflammatory response, creating a vicious cycle of tissue damage and inflammation. By breaking this cycle, catechins promote a healthier oral environment, facilitating the resolution of inflammation and the repair of damaged tissues. Catechins, particularly EGCG, are highly effective at directly scavenging various ROS, including superoxide radicals, hydroxyl radicals, and hydrogen peroxide. They achieve this by donating electrons or

hydrogen atoms to these reactive molecules, neutralizing their damaging effects and preventing them from reacting with cellular components. Catechins not only directly scavenge ROS but also enhance the body's endogenous antioxidant defenses. They have been shown to increase the activity of antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), which play a crucial role in neutralizing ROS and protecting cells from oxidative damage. This enhancement can occur through various mechanisms, including the activation of transcription factors, the upregulation of gene expression, and the stabilization of antioxidant enzymes. Catechins can also chelate metal ions, such as iron and copper, which can catalyze the formation of ROS through Fenton reactions. By chelating these metal ions, catechins prevent them from participating in ROS generation, further reducing oxidative stress. Mitochondria, the powerhouses of cells, are a major source of ROS generation. Oxidative stress can damage mitochondria, leading to impaired energy production and cell death. Catechins have been shown to protect mitochondrial function by reducing ROS production, improving mitochondrial membrane potential, and enhancing mitochondrial biogenesis. Catechins also possess antibacterial properties, directly targeting the bacterial culprits responsible for initiating and perpetuating gingival inflammation. These compounds have been shown to inhibit the growth of various oral bacteria, including *Streptococcus mutans*, a key contributor to plaque formation. Plaque, a biofilm composed of bacteria and their byproducts, is the primary etiological factor in gingivitis. By disrupting the growth and accumulation of plaque bacteria, green tea mouthwash helps prevent the initiation and progression of gingival inflammation. Catechins can interact with the bacterial cell wall, compromising its integrity and leading to cell lysis and death. This disruption can occur through various mechanisms, including the alteration of cell wall permeability, the inhibition of cell wall synthesis, and the activation of autolytic enzymes that degrade the cell wall. Catechins

can inhibit bacterial enzymes involved in essential metabolic processes, such as energy production, DNA replication, and protein synthesis. This interference can hinder bacterial growth and proliferation, reducing their ability to colonize the oral cavity and form plaque. Catechins can prevent bacteria from attaching to oral surfaces, reducing their ability to form plaque and initiate the inflammatory cascade. This inhibition can occur through various mechanisms, including the alteration of bacterial surface properties, the blocking of adhesion receptors on oral tissues, and the competition for binding sites with other oral bacteria. These mechanisms collectively contribute to a reduction in bacterial load, creating a less hospitable environment for plaque formation and reducing the bacterial challenge to the gingival tissues. The multifaceted mechanisms of action of green tea's bioactive components, particularly catechins, highlight its potential as a valuable adjunctive therapy for gingivitis management. By targeting both the inflammatory and bacterial components of gingivitis, green tea mouthwash offers a comprehensive approach to mitigating the disease process. The anti-inflammatory and antioxidant properties of catechins help reduce redness, swelling, and bleeding, while the antibacterial effects help control plaque formation, preventing further inflammation and promoting gingival health. This synergistic action creates a positive feedback loop, where the reduction in inflammation creates a less favorable environment for bacterial growth, further reducing the bacterial challenge and promoting healing. The mechanisms of action of green tea's bioactive components, particularly catechins, have implications beyond gingivitis management. These compounds have shown promise in the prevention and treatment of various other oral and systemic diseases, including periodontitis, oral cancer, cardiovascular disease, and diabetes. The anti-inflammatory and antioxidant properties of catechins may contribute to the prevention of cardiovascular disease by reducing inflammation and oxidative stress, two key factors in the development of

atherosclerosis. Similarly, the ability of catechins to improve insulin sensitivity and glucose metabolism may have implications for the prevention and management of diabetes. Periodontitis is a chronic inflammatory disease that affects the supporting tissues of the teeth, leading to tooth loss if left untreated. Catechins have been shown to inhibit the growth and activity of periodontal pathogens, reduce inflammation in periodontal tissues, and promote the regeneration of periodontal ligament and bone. Oral cancer is a major public health concern, with increasing incidence and mortality rates worldwide. Catechins have demonstrated anti-cancer properties, inhibiting the growth and spread of oral cancer cells through various mechanisms, including the induction of apoptosis, the inhibition of angiogenesis, and the modulation of cell signaling pathways. Cardiovascular disease is the leading cause of death globally. Catechins have been shown to improve various cardiovascular risk factors, including blood pressure, cholesterol levels, and endothelial function. They achieve this through various mechanisms, including the reduction of inflammation, the inhibition of platelet aggregation, and the improvement of lipid metabolism. Diabetes is a chronic metabolic disorder characterized by hyperglycemia and insulin resistance. Catechins have been shown to improve insulin sensitivity, enhance glucose uptake, and reduce oxidative stress, which are all beneficial in the management of diabetes. Emerging evidence suggests that catechins may have protective effects against neurodegenerative diseases, such as Alzheimer's disease and Parkinson's disease. They achieve this through various mechanisms, including the reduction of oxidative stress, the inhibition of neuroinflammation, and the modulation of neurotransmitter signaling.[14-17]

The use of green tea mouthwash as an adjunctive therapy for gingivitis management offers a multitude of advantages that extend beyond its remarkable efficacy in reducing gingival inflammation. Its natural composition, accessibility, safety, cost-effectiveness, and environmental friendliness make it an appealing option for individuals seeking to improve their oral health and overall well-being. In an era where synthetic products dominate the market, green tea mouthwash stands out as a natural alternative, harnessing the therapeutic power of nature. Unlike synthetic mouthwashes that often contain harsh chemicals and artificial ingredients, green tea mouthwash is derived from the leaves of the *Camellia sinensis* plant, a source of potent antioxidants and anti-inflammatory compounds that have been revered for their health benefits for centuries. This natural composition makes green tea mouthwash an appealing choice for individuals seeking to minimize their exposure to synthetic chemicals and embrace a more holistic approach to oral health. It aligns with the growing trend of seeking natural remedies and preventive measures that are in harmony with the body and the environment. Green tea mouthwash is readily accessible and affordable, empowering individuals to take control of their oral health. Unlike prescription medications or specialized oral care products that may require a visit to a healthcare professional or incur significant costs, green tea mouthwash can be easily prepared at home using readily available green tea leaves. This accessibility eliminates barriers to oral care, making it a viable option for individuals of all socioeconomic backgrounds. The affordability of green tea mouthwash further enhances its accessibility, making it a sustainable option for long-term use. Individuals can incorporate green tea mouthwash into their daily oral care routine without incurring significant financial burden, promoting consistent and effective oral hygiene practices. Green tea mouthwash is generally safe and well-tolerated, with minimal side effects. Unlike some synthetic mouthwashes that can cause tooth staining, alter taste perception, or disrupt the oral microbiome, green tea mouthwash is unlikely to cause such adverse effects. This safety profile makes it a suitable option for long-term use, particularly for individuals who may be sensitive to the ingredients in synthetic mouthwashes. The absence of significant side effects also contributes to patient

compliance, as individuals are more likely to adhere to a treatment regimen that does not cause discomfort or inconvenience. This compliance is crucial for achieving and maintaining optimal oral health, as inconsistent use of oral care products can compromise their effectiveness. Green tea mouthwash offers a cost-effective solution for gingivitis management, maximizing value while minimizing costs. Its affordability, coupled with its efficacy in reducing gingival inflammation, makes it an attractive option for individuals seeking to improve their oral health without incurring significant financial burden. Compared to synthetic mouthwashes, which can be expensive and may require frequent replacement, green tea mouthwash offers a sustainable and economical alternative. Individuals can prepare their own green tea mouthwash at home using readily available green tea leaves, further reducing costs and promoting self-sufficiency in oral care. Green tea mouthwash is an environmentally friendly option, aligning with the growing awareness of the importance of sustainability. Unlike synthetic mouthwashes that often contain harsh chemicals and artificial ingredients that can harm the environment, green tea mouthwash is derived from a natural source and does not contribute to environmental pollution. The production of green tea mouthwash also has a lower environmental impact compared to synthetic mouthwashes. Green tea cultivation is generally considered a sustainable agricultural practice, with minimal use of pesticides and fertilizers. The processing of green tea leaves into mouthwash also involves minimal energy consumption and waste generation. The advantages of green tea mouthwash extend beyond gingivitis management. Its natural composition, accessibility, safety, cost-effectiveness, and environmental friendliness make it an appealing option for various other oral health applications. Green tea mouthwash may help reduce inflammation and bacterial load in periodontal pockets, aiding in the management of periodontitis, a more severe form of gum disease that can lead to tooth loss. The antibacterial effects of green tea mouthwash can help

control oral malodor by reducing the number of bacteria that produce volatile sulfur compounds, the main culprits behind bad breath. This can improve social confidence and overall quality of life. Green tea catechins have been shown to inhibit the growth of Candida albicans, the fungus responsible for oral thrush. Green tea mouthwash may therefore be beneficial in preventing and managing oral candidiasis, particularly in individuals with weakened immune systems or those taking antibiotics. Green tea mouthwash may help alleviate dry mouth by stimulating saliva production and providing a soothing effect on oral tissues. This can improve oral comfort and reduce the risk of complications associated with dry mouth, such as tooth decay and oral infections. Emerging evidence suggests that green tea catechins may have anti-cancer properties, inhibiting the growth and spread of oral cancer cells. While more research is needed in this area, green tea mouthwash may hold promise as a preventive measure against oral cancer.[18-20]

4. Conclusion

The findings of this quasi-experimental study provided compelling evidence for the efficacy of green tea mouthwash as an adjunctive therapy for gingivitis management. The significant reduction in gingival inflammation after just one week of intervention underscored the potent anti-inflammatory and antibacterial properties of green tea, particularly its catechin content. The study's results were consistent with previous research, further solidifying the evidence base for green tea's benefits in oral health. The observed improvement in gingival health can be attributed to the multifaceted mechanisms of action of green tea's bioactive components, primarily catechins. These compounds effectively target both the inflammatory and bacterial components of gingivitis, reducing inflammation, inhibiting bacterial growth, and promoting healing. The anti-inflammatory effects of catechins are mediated through the modulation of inflammatory pathways, while their antibacterial effects are exerted through interactions with bacterial

cell walls, inhibition of bacterial enzymes, and prevention of bacterial adhesion. The use of green tea mouthwash as an adjunctive therapy for gingivitis management offers a multitude of advantages, including its natural composition, accessibility, safety, cost-effectiveness, and environmental friendliness. These advantages make it an appealing option for individuals seeking to improve their oral health and overall well-being. While this study provided strong evidence for the benefits of green tea mouthwash, further research is needed to explore its optimal concentration, frequency of use, and long-term effects. Additionally, research investigating the potential synergistic effects of green tea mouthwash with other oral hygiene practices would be valuable. In conclusion, the findings of this study support the use of green tea mouthwash as an adjunctive therapy for gingivitis management. Its efficacy in reducing gingival inflammation, coupled with its natural and readily available nature, makes it a promising option for improving oral health.

5. References

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