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**Chlorhexidine gluconate vs Green tea mouthwash  
comparative effects on periodontal inflammation  
(Randomized clinical trial)**

**A Research Project**

**Submitted to the College of Dentistry, AL-Mustaqbal university in  
Partial Fulfillment of the Requirements for the B.D.S. Degree in  
Dentistry**

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿وَمَا تُوْفِيْقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ﴾

صَدَقَ اللَّهُ الْعَلِيِّ الْعَظِيمُ

## **Certification Of the Supervisor**

I certify that this project entitled “**Chlorhexidine gluconate vs Green tea mouthwash comparative effects on periodontal inflammation (Randomized clinical trial)**” Was prepared by fifth-year students (**Aya Falah Al-Gburi, Olla Ahmed Mohammed, Farah Abd Ulkareem Alkafaji, Zainab Akil Najm, Nabaa Dhyaa Baqer**) under my supervision at College of Dentistry / Al- Mustaqbal University in partial fulfillment of the graduation requirements for the Bachelor Degree in Dentistry.

**Supervisor Signature:**

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**Date:     /     / 2026**

## **Dedication & Acknowledgment**

*We're thankful to all of those who shared this journey with us.*

*From our parents and loved ones who supported us through this stage, to all of the faculty members, beginning with our dean Prof. Athraa Alhijazi who have inspired excellence within our college. We are dedicating this work to you.*

*We would also like to extend our deepest appreciation for Our supervisor Dr. Zaid M. Al. Alaboodi who has showed up for us during this research. We could've never been able to complete this without his guidance and for that we're truly grateful.*

*Finally, we wish to acknowledge all the volunteers who participated in our clinical trial. Their willingness, time and cooperation were essential in bringing this research to life.*

*This work stands as a testament to the collective effort of everyone who contributed to its completion, especially our team.*

## **Abstract**

**Background:** - Chlorhexidine gluconate mouthwash is widely regarded as the gold standard for chemical plaque control due to its broad-spectrum antibacterial action and substantivity, providing prolonged antimicrobial effects. However, its long-term use is associated with side effects like tooth staining, taste alterations, and potential mucosal irritation. In comparison, green tea, particularly its bioactive epigallocatechin gallate (EGCG), demonstrates significant antioxidant, anti-inflammatory, and antimicrobial properties. Clinical studies indicate that green tea mouthwash can effectively reduce plaque, gingival inflammation, and bleeding, with efficacy comparable to chlorhexidine in managing gingivitis. Its favorable safety profile and natural origin position it as a promising adjunctive or alternative therapy in periodontal care.

**Aim:** - To compare the efficacy and side effects of green tea mouthwash versus chlorhexidine gluconate mouthwash in reducing plaque and gingival inflammation in patients with gingivitis.

**Materials and Methods:** - A randomized clinical trial included 50 gingivitis patients, randomly assigned to a green tea mouthwash group and a chlorhexidine gluconate group. The Plaque Index (PI), Gingival Index (GI), and Bleeding on Probing (BOP) were assessed at baseline and following a two-week intervention period.

**Results:** - Both groups showed a significant reduction in plaque and gingival inflammation after two weeks. The chlorhexidine group demonstrated a slightly greater reduction in plaque

scores. However, the green tea group reported significantly fewer adverse effects, such as tooth staining.

**Conclusion:** - The study concludes that while chlorhexidine gluconate was more effective at reducing dental plaque, green tea mouthwash achieved comparable reductions in gingival inflammation and bleeding. Given its favorable side effect profile, green tea mouthwash serves as a suitable natural alternative for gingivitis management.

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## **Introduction**

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### **Introduction**

Periodontal health represents a fundamental component of both oral and systemic health, understanding the structure and function of the periodontium, as well as the diseases and risk factors that may compromise its integrity is essential for maintaining long-term oral health and preventing systemic complications.<sup>1</sup> The normal periodontium provides the support necessary to maintain teeth in function. It consists of four principal components: gingiva, periodontal ligament (PDL), cementum, and alveolar process. Each of these periodontal components is distinct in its location, tissue architecture, biochemical composition, and chemical composition, but all of these components function together as a single unit.<sup>2</sup>

The periodontal diseases are highly prevalent and can affect up to 90% of the worldwide population. Gingivitis, the mildest form of periodontal disease, is caused by the bacterial biofilm (dental plaque) that accumulates on teeth adjacent to the gingiva. However, gingivitis does not affect the underlying supporting structures of the teeth and is reversible.<sup>10</sup>

Periodontitis is a chronic inflammatory disease that progressively damages the periodontal tissues. The hallmark feature of the condition is the apical migration of the junctional epithelium, which leads to loss of attachment and the formation of periodontal pockets. As bacteria penetrate deeper into the tissues, the body activates an immune response to fight the infection. However, this defense mechanism unintentionally contributes to the destruction of the periodontium. As periodontitis progresses, it causes continued attachment loss, alveolar bone resorption, and, in severe cases, tooth loss. Key risk factors include poor oral

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hygiene, smoking, diabetes, advancing age, and genetic predisposition.<sup>11-</sup>

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Dental plaque is a soft deposit that accumulates on the teeth. It is a complex microbial community with as many as 400 distinct bacterial species. One of the most prevalent diseases of the oral cavity is periodontal disease which begins with gingivitis. The main cause of gingivitis is plaque accumulation.<sup>17</sup> Plaque control is one of the most important factors in preventing oral diseases. The accumulation of plaque is required for the development of caries and periodontal diseases. Therefore, maintaining good oral hygiene is the main goal of oral diseases prevention.<sup>18</sup>

After 20 years of use by the dental profession, chlorhexidine is recognized as the gold standard against which other antiplaque and gingivitis agents are measured. Chlorhexidine's antiplaque effect is a result of the dicationic nature of the chlorhexidine molecule, which affords the agent the property of persistence of antimicrobial effect at the tooth surface, through both bactericidal and bacteriostatic effects.<sup>23</sup>

The most common side effects include increase in staining of teeth and other oral surfaces including silicate and resin restorations due to continued use for long periods, moreover an increase in calculus formation<sup>23</sup>. Chlorhexidine also has a bitter taste which is difficult to mask completely.<sup>4</sup> Minor irritation and superficial desquamation of the oral mucosa<sup>23</sup> and parotid gland swelling and inflammation of the salivary glands (sialadenitis)<sup>23</sup>, for these reasons, the prolonged use of CHX should be avoided in normal periodontal patients. It is useful for short periods (up to two weeks) when oral hygiene may be difficult or impossible, such as during acute oral infections or following periodontal surgery.<sup>4</sup>

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Interestingly, green tea has been used as an adjunct in the treatment of plaque-induced gingivitis and showed to have desirable effects on clinical and biological parameters, providing a potentially natural and affordable alternative in the process. A number of clinical studies showed that applying green tea as a chewing gum or mouthwash improved plaque and bleeding scores, reduced salivary IL-1 $\beta$  levels and reduced volatile sulfur compound (VSC) levels effectively compared to placebo. In fact, chlorhexidine and green tea mouthwashes were found to be equally effective in reducing plaque and gingival inflammation. However, available reports are still lacking specific details regarding preparation of such custom-made natural remedies.<sup>32</sup>

A large number of researchers have confirmed that green tea possesses chemical ingredients that are closely related to human health. Tea polyphenols, caffeine, theanine, tea polysaccharides, and other components which are extracted and separated from green tea have pharmacological activities such as anti-cancer, anti-oxidation, protecting the nervous system, and lowering blood sugar. Green tea has been considered to be suitable for patients with hypertension, hyperlipidaemia, coronary heart disease, arteriosclerosis, and diabetes. However, it is important to keep in mind that “natural” does not mean perfectly safe. Although the toxic side effects of green tea are relatively small, it must be used with caution in pregnancy, children, and the elderly population.<sup>31</sup> Green tea contains polyphenols which are composed of catechins, such as Epigallocatechin-3-gallate, (EGCG) is the most abundant catechin and a major component that contributes to these effects.<sup>34</sup> EGCG has a greater effect on gram-positive bacteria than gram-negative bacteria. The incorporation of EGCG at increasing concentrations has been shown to decrease bacterial numbers.<sup>34</sup> Hence, polyphenols have the ability to

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interfere with biofilm formation. The previous literature reported that green tea extracts have short-term anti-plaque antibacterial capabilities.<sup>34</sup>

Studies have suggested that green tea mouthwash can effectively reduce the microbial pathogens, can be used as an adjunct to periodontal therapy in chronic periodontitis and, along with scaling and root planning for a period of two weeks, could improve the scores of various periodontal parameters.<sup>37</sup> Additionally, no evidence of toxic effects such as irritation, burn, vesicle or mucous disturbance was observed, and despite similar antibacterial effects of green tea mouth wash with the chemical chlorhexidine, they showed that the use of herbal green tea mouthwash was safer and more economical.<sup>37</sup>

On 2023 a randomized control trial was made to evaluate of the effectiveness of green tea mouth rinse on oral halitosis, tongue coating, and plaque accumulation.<sup>39</sup> It was found that under the limitations of the study, it can be concluded that 5% *Camellia sinensis* mouth rinse is as effective as commercially available 0.2% chlorhexidine mouth rinse in reducing plaque scores, tongue coating, and oral halitosis.<sup>39</sup> 0.5% green tea catechin has equivalent anti-plaque efficacy as 0.2% chlorhexidine gluconate and can be considered a potent alternative to prevent and treat gingival diseases.<sup>40</sup> Green Tea (*Camellia sinensis*) Demonstrates Substantial Potential as a natural, Sustainable, and Innovative Approach to Managing Periodontal disease.<sup>41</sup>

Its Bioactive Compounds, Particularly Epigallocatechin-3-Gallate (EGCG), Exhibit Potent Antioxidant, Anti-Inflammatory, and Antimicrobial Properties, Improving Oral Health Outcomes.<sup>41</sup>

### **Aims and Objectives**

#### **Aims:**

The main aim of this study is to evaluate and compare the antimicrobial efficacy and clinical performance of a chemical mouthwash containing Chlorhexidine versus a herbal mouthwash containing Green Tea extract in maintaining oral hygiene.

#### **Objectives:**

- To evaluate the clinical efficacy of each mouthwash in decreasing the buildup of dental plaque (Plaque Index).
- To examine the impact of each mouthwash on gingival health and their efficacy in diminishing gingival inflammation (Gingival Index).
- To evaluate the possible side effects (like tooth discoloration or change in taste) and the general acceptance/tolerance of patients for both mouthwashes.
- To assess whether Green Tea extract can act as a practical, efficient, and safe natural substitute for the chemical Chlorhexidine mouthwash in daily oral hygiene.

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## Chapter one: Review of literatures

### 1.1 Periodontal health

Periodontal health represents a fundamental component of both oral and systemic health, understanding the structure and function of the periodontium, as well as the diseases and risk factors that may compromise its integrity is essential for maintaining long-term oral health and preventing systemic complications.<sup>1</sup> In its pristine form, periodontal health would be defined as the absence of histological evidence of periodontal inflammation and no evidence of anatomical change to the periodontium. However, it must be recognized that in most (if not all) adults this is unlikely. Therefore, the term clinically healthy should be adopted to cover the absence of (or very significant reduction in) clinical periodontal inflammation on either an anatomically intact periodontium or a reduced periodontium.<sup>1</sup>

The normal periodontium provides the support necessary to maintain teeth in function. It consists of four principal components: gingiva, periodontal ligament (PDL), cementum, and alveolar process. Each of these periodontal components is distinct in its location, tissue architecture, biochemical composition, and chemical composition, but all of these components function together as a single unit.<sup>2</sup>

Gingiva, in an adult, normal gingiva covers the alveolar bone and tooth root to a level just coronal to the cemento-enamel junction. The gingiva is divided anatomically into marginal, attached, and interdental areas. Although each type of gingiva exhibits considerable variation in differentiation, histology, and thickness according to its functional demands, all types are specially structured to function appropriately against mechanical and microbial damage.<sup>2</sup>

The periodontal ligament is composed of a complex vascular and highly cellular connective tissue that surrounds the tooth root and connects it to the inner wall of the alveolar bone. It is continuous with the connective tissue of the gingiva, and it communicates with the marrow spaces through vascular channels in the bone. Although the average width of the periodontal ligament space is about 0.2 mm, considerable variation exists. The periodontal space is diminished around teeth that are not in function and in unerupted teeth, but it is increased in teeth that have been subjected to hyperfunction.<sup>2</sup> The most important elements of the periodontal ligament are the principal fibers, which are collagenous and arranged in bundles and which follow a wavy course when viewed in a longitudinal section. The terminal portions of the principal fibers that are inserted into cementum and bone are termed Sharpey fibers<sup>2</sup>.

Cementum is the calcified, avascular mesenchymal tissue that forms the outer covering of the anatomic root. The two main types of cementum are acellular (primary) and cellular (secondary) cementum.<sup>104</sup> Both consist of a calcified interfibrillar matrix and collagen fibrils.<sup>2</sup>

The alveolar process is the portion of the maxilla and mandible that forms and supports the tooth sockets (alveoli). It forms when the tooth erupts to provide the osseous attachment to the forming periodontal ligament; it disappears gradually after the tooth is lost. Because the alveolar processes develop and undergo remodeling with tooth formation and eruption, they are tooth-dependent bony structures.<sup>2</sup>

### 1.1.1 Indicators of clinical periodontal health

**Color:** The gingiva is the intra-oral tissue that is most frequently colored and most easily seen. Healthy gingiva can range in color from pale pink to bluish-purple. A wide range of colors exist, and they depend

on the level of melanogenesis, the degree of epithelial cornification, the depth of epithelialization, and the configuration of gingival vascularity.<sup>3</sup>

**Texture and consistency:** It is of firm texture, and often shows small depressions on the surface. The depressions, called “stippling”, give the appearance of orange peel. The gingiva is firmly attached to the underlying alveolar bone and cementum by connective tissue fibers, and is, therefore, comparatively immobile in relation to the underlying tissue.<sup>4</sup>

**Bleeding on probing (BOP):** BOP is usually measured as bleeding provoked by applying a probe to the bottom of a sulcus/pocket. Bleeding is an earlier sign of gingivitis than are the visual signs of inflammation (redness and swelling), from a clinical point of view, absence of BOP would indicate clinically healthy periodontal tissue.<sup>1</sup>

**Radiographic features of periodontal health:** Radiographic assessment forms a critical component of clinical assessment of the periodontium. Radiographic features of a normal, anatomically intact periodontium would include an intact lamina dura (both laterally and at the alveolar crest), no evidence of bone loss in furcation areas, and a 2 mm distance, on average, from the most coronal portion of the alveolar bone crest (AC) to the cemento-enamel junction (CEJ). The distance from the CEJ to AC in healthy individuals can vary between 1.0 and 3.0 mm.<sup>1</sup>

**Tooth mobility:** Clinicians often assess the status of a tooth by estimating its mobility. Because teeth are not ankylosed, or osseointegrated, as are implants, but are suspended in the alveolar bone by a network of collagenous fibers, they exhibit a degree of physiological mobility. This is usually assessed as the amplitude of crown displacement resulting from the application of a defined force.<sup>1</sup>

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### 1.1.2 Factors affecting periodontal health:

**Diabetes mellitus (DM):** The results of multiple studies demonstrated that DM and periodontal disease are bidirectionally associated. Studies shown that DM is a significant risk factor for periodontal/peri-implant disease. In addition to inflammation, which is the critical player in the connection between these diseases, other factors, such as microbiome alterations, may have a role, The reviewed studies suggest that the presence of chronic hyperglycemia is a more significant risk factor for periodontal and peri-implant diseases than a specific type of diabetes. Among DM patients, those with poor glycemic control have a higher prevalence and severity of periodontal disease, as evidenced by worse periodontal parameters and a greater risk of tooth loss.<sup>5</sup>

**Pregnancy:** The total viable microbial counts in pregnant women are known to be higher compared to non-pregnant women, especially in the first trimester of pregnancy. A balanced oral microbiome is vital for a healthy pregnancy, as perturbations in the oral microbiome composition can contribute to pregnancy complications. On the other hand, physiological changes and differences in hormonal levels during pregnancy, increase susceptibility to various oral diseases such as gingivitis and periodontitis. A growing body of evidence supports the link between the composition of the oral microbiome and adverse pregnancy outcomes such as preterm birth, preeclampsia, low birth weight among others.<sup>6</sup>

**Smoking:** Tobacco smoking has been implicated in periodontal pathology through various mechanisms, including perturbations of the inflammatory and host responses to putative periodontal pathogens, alterations in the subgingival microbial communities, and a compromised healing potential of the tissues leading to imbalance of tissue

homeostasis<sup>7</sup>, Tobacco use contributes to more mortality and morbidity globally than any other behavioral risk factor. Adverse effects do not spare the oral cavity, with many oral diseases more common, and treatments less successful<sup>8</sup>.

**Psychological state:** the majority of studies showed a positive relationship between stress/psychological factors and periodontal disease.<sup>9</sup>

## 1.2 Periodontal diseases

The periodontal diseases are highly prevalent and can affect up to 90% of the worldwide population. Gingivitis, the mildest form of periodontal disease, is caused by the bacterial biofilm (dental plaque) that accumulates on teeth adjacent to the gingiva. However, gingivitis does not affect the underlying supporting structures of the teeth and is reversible<sup>10</sup>

Periodontitis is a chronic inflammatory disease that progressively damages the periodontal tissues. The hallmark feature of the condition is the apical migration of the junctional epithelium, which leads to loss of attachment and the formation of periodontal pockets. As bacteria penetrate deeper into the tissues, the body activates an immune response to fight the infection. However, this defense mechanism unintentionally contributes to the destruction of the periodontium. As periodontitis progresses, it causes continued attachment loss, alveolar bone resorption, and, in severe cases, tooth loss. Key risk factors include poor oral hygiene, smoking, diabetes, advancing age, and genetic predisposition.<sup>11-</sup>

Gingivitis is caused by substances derived from microbial plaque accumulating at or near the gingival sulcus; all other suspected local and systemic etiologic factors either enhance plaque accumulation or retention, or enhance the susceptibility of the gingival tissue to microbial attack. Microbial species specifically associated with gingival health include *Streptococcus sanguis* and *Fusobacterium naviforme*. Bacteria involved in the etiology of gingivitis include specific species of *Streptococcus*, *Fusobacterium*, *Actinomyces*, *Veillonella*, and *Treponema* and possibly *Bacteroides*, *Capnocytophaga*, and *Eikenella*. Microbial colonization and participation are sequential, with the complexity of the associated flora increasing with time.<sup>14</sup> Periodontitis involves complex dynamic interactions among active herpesviruses, specific bacterial pathogens and destructive immune responses. Periodontal diagnostics is currently based on clinical rather than etiologic criteria, and provides limited therapeutic guidance.<sup>15</sup>

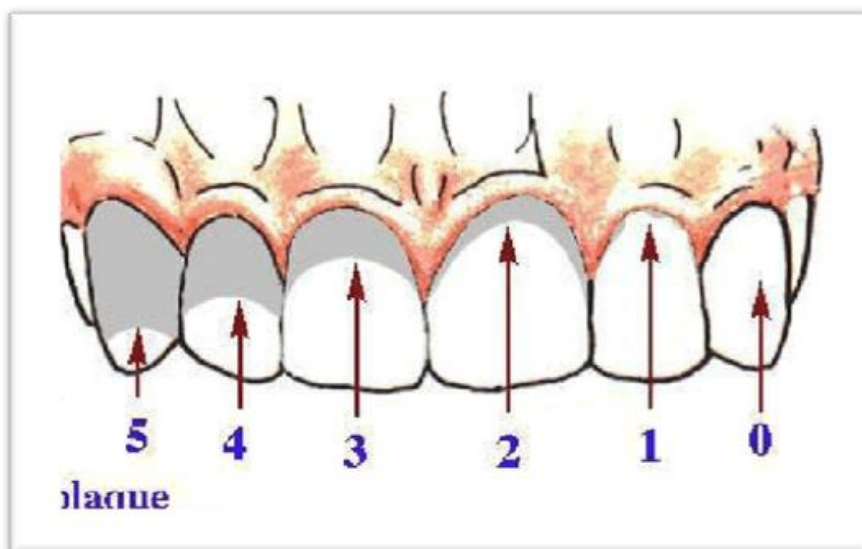
Diagnostic criteria used in clinical practice to discriminate between periodontal health, gingivitis, and periodontitis. Visual examination of the color and texture of the periodontal tissues, assessment of plaque deposits, periodontal probing assessments, and diagnostic imaging enable the collation of information to make a periodontal diagnosis, followed by an appropriate treatment plan. The periodontal probe is an essential diagnostic tool to assess probing pocket depth, clinical attachment level, bleeding on probing, and the degree of furcation involvement at multirooted teeth. When clinical signs and symptoms of periodontitis are identified, diagnostic imaging enables evaluation of the level and extent of bone destruction and bone defect morphology.<sup>16</sup>

### 1.2.1 Plaque index

Dental plaque is a soft deposit that accumulates on the teeth. It is a complex microbial community with as many as 400 distinct bacterial species. One of the most prevalent diseases of the oral cavity is periodontal disease which begins with gingivitis. The main cause of gingivitis is plaque accumulation.<sup>17</sup> Plaque control is one of the most important factors in preventing oral diseases. The accumulation of plaque is required for the development of caries and periodontal diseases. Therefore, maintaining good oral hygiene is the main goal of oral diseases prevention.<sup>18</sup> The Quigley-Hein plaque index modified by *Turesky et al.*, as shown in **(Fig.1.1)**, was used to evaluate plaque accumulation after the application of a plaque-disclosing agent.<sup>19</sup>

Plaque images were captured and analyzed, and plaque scores were recorded for the buccal surfaces of 20 teeth, including the maxillary and mandibular central and lateral incisors, canines, and premolars.<sup>19</sup>

- 0 No plaque.<sup>20</sup>
- 1 Separate fleck of plaque (up to one mm) at the cervical margin of the tooth.<sup>20</sup>
- 2 A thin continuous band of plaque wider than 1 mm but covering less than one-third of the crown of the tooth.<sup>20</sup>
- 3 A band of plaque wider than one mm but covering less than one-third of the crown of the tooth.<sup>20</sup>
- 4 Plaque covering at least one-third but less than two-thirds of the crown of the tooth.<sup>20</sup>
- 5 Plaque covering two-thirds or more of the crown of the tooth.<sup>20</sup>



**Fig. (1.1): Scoring criteria for plaque index Quigley Hein index (modified) 1970.<sup>20</sup>**

### 1.2.2 Gingival index

Dentists have developed numerous indices to assess the severity of gingivitis based on one or more of the following criteria: color of the gingiva (redness), gingival contour, bleeding presence, stippling, and crevicular fluid flow.<sup>21</sup> Most of the indices developed require both visual and invasive measures (probing of the gingiva with instruments) to assess gingival health status and reach a rating.<sup>21</sup> Exceptional is the Modified Gingival Index (MGI) which is completely noninvasive (i.e., exclusively visual). The MGI (**Fig. 1.2**) uses a rating score between 0 and 4, with 0 indicating a tooth with healthy gums and 4 the most severe inflammation with spontaneous bleeding.<sup>21</sup>

- 0 Normal None.
- 1 Mild inflammation Slight changes in color and texture, but not in all portions of gingival marginal or papillary.
- 2 Mild inflammation Slight changes in color and texture in all portions of gingival marginal or papillary.

- 3 Moderate Bright surface inflammation, erythema, edema, and/or hypertrophy of gingival marginal or papillary.
- 4 Severe inflammation Erythema, edema, and/or marginal gingival hypertrophy of the unit or spontaneous bleeding, papillary, congestion, or ulceration.



**Fig (1.2): Inflamed gingiva vs. Normal gingiva**

### **1.3 Chlorhexidine Gluconate (CHX)**

CHx, a bisbiguanide base, is a cationic antiseptic with broad-spectrum antibacterial activity (against Gram-positive and Gram-negative bacteria and certain mycetes). Consequently, it has been extensively studied in medical settings as an antiseptic compound. The International Union for Pure and Applied Chemistry (IUPAC) defines CHx as 1,1'-hexamethylene bis (5- [4 chlorophenyl] biguanide), having the chemical formula  $C_{22} Cl_2 N_{10} H_{30}$ . CHx has a symmetrical structure with 4 chlorophenyl rings and 2 biguanide groups linked by a central

hexamethylene bridge. The compound is a strong base, with cationic structure at physiological pH (positively charged). CHx is available with three formulations: digluconate, acetate (both water-soluble) and hydrochloride (poorly soluble in water).<sup>22</sup>

After 20 years of use by the dental profession, chlorhexidine is recognized as the gold standard against which other antiplaque and gingivitis agents are measured. Chlorhexidine's antiplaque effect is a result of the dicationic nature of the chlorhexidine molecule, which affords the agent the property of persistence of antimicrobial effect at the tooth surface, through both bactericidal and bacteriostatic effects.<sup>23</sup>

### **1.3.1 Mechanism of action**

Chlorhexidine is a broad-spectrum biocide effective against Gram positive bacteria, Gram negative bacteria and fungi. Chlorhexidine inactivates microorganisms with a broader spectrum than other antimicrobials (e.g. antibiotics) and has a quicker kill rate than other antimicrobials (e.g. povidone-iodine). Based on its concentration, it has an immediate bactericidal action and a prolonged bacteriostatic action due to adsorption onto the pellicle-coated enamel surface. Chlorhexidine kills by disrupting the cell membrane.<sup>23</sup>

### **1.3.2 Effect on bacteria**

Chlorhexidine is a positively charged molecule that binds to the negatively charged sites on the cell wall; it destabilizes the cell wall and interferes with osmosis. The bacterial uptake of the chlorhexidine is very rapid, typically working within 20 seconds. In low concentration, it affects the integrity of the cell wall. Once the cell wall is damaged, it crosses into the cell itself and attacks the cytoplasm membrane. Damage to the cytoplasm's delicate semi permeable membrane allows for leakage

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of components leading to cell death. In high concentration chlorhexidine solidifies the cytoplasm.<sup>23</sup>

### **1.3.3 Effect on biofilm**

Biofilms are a complex aggregation of microorganisms growing on a solid substrate. They can occur on organic (e.g. dental plaque) or inorganic surfaces. This matrix protects the cells within it and increases their resistance to antimicrobials. Many antimicrobial agents have a difficult time eliminating organisms in a bio film. Chlorhexidine has shown some ability to help inhibit adherence of microorganisms to a surface thereby preventing growth and development of bio films.<sup>23</sup>

### **1.3.4 Effects on other microbial organisms**

This includes bacterial spores and protozoa. It has also shown activity against enveloped viruses in vitro (e.g., herpes simplex virus, HIV, cytomegalovirus, influenza. But has substantially less activity against nonenveloped viruses (e.g., rotavirus, adenovirus, and enteroviruses).<sup>23</sup>

### **1.3.5 Effect on skin and mucous membrane**

In topical applications, chlorhexidine is shown to have the unique ability to bind to the proteins present in human tissues with limited systemic absorption. Protein bound chlorhexidine releases slowly leading to prolonged activity. This phenomenon is known as substantivity and allows for a longer duration of antimicrobial action against a broad spectrum of bacteria and fungi. In fact, its antimicrobial activity has been documented to last at least 48 hours on the skin. Unlike povidone-iodine, it is not affected by the presence of body fluids such as blood.<sup>23</sup>

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### 1.3.6 Effect on medical equipments

Chlorhexidine has also been applied to medical devices such as dental implants, vascular, catheters, needleless connectors and antimicrobial dressings to kill organisms and protect against microbial colonization and subsequently biofilm development.<sup>23</sup>

### 1.3.7 Deactivation

Chlorhexidine is deactivated by anionic compounds, including the anionic surfactants commonly used as detergents in toothpastes and mouthwashes, anionic thickeners such as carbomer. For this reason, chlorhexidine mouth rinses should be used at least 30 minutes after other dental products.<sup>23</sup> For best effectiveness, food, drink, smoking, and mouth rinses should be avoided for at least one hour after use. If it is not deactivated, chlorhexidine lasts longer in the mouth than other mouthwashes and this is partly why it is to be preferred over other treatments for gingivitis.<sup>23</sup>

### 1.3.8 Safety

Chlorhexidine is harmful in high concentrations, is used safely in low concentrations in many products, such as mouthwash and contact lens solution. However, numerous scientific papers have reported complications with low level exposure too. In the United Kingdom, the Medicines and Health Care Products Regulatory Agency (MHRA) has issued a patient safety alert on the risk of anaphylactic reactions from the use of medical devices and medicinal products containing chlorhexidine. Adequate and well-controlled studies in pregnant women have not been done, so this drug should be used during pregnancy only if clearly needed. Caution should be exercised when chlorhexidine is administered to a nursing woman.<sup>23</sup> Ingestion of 3-6ml of chlorhexidine by a small

child (~10 kg body weight) might result in gastric distress, including nausea, or signs of alcohol intoxication. Medical attention should be sought if more than 12ml of chlorhexidine is ingested by a small child or if signs of alcohol intoxication develop.<sup>23</sup>

### 1.3.9 Availability

Chlorhexidine is present in various forms such as oral rinses (0.2% and 0.12% concentration), skin cleansers, Gauze dressings, pre-operative skin preparation, surgical scrub, spray, rubbing agent, gel with and without combination of fluoride, soap, face wash, varnish, local drug delivery, chewing gums and in small quantities it is used as a preservative. As a mouth-rinse, chlorhexidine is sometimes marketed under the brand names Clohex, Foam Safe, Hexicleans, Peridex, and Perichlor.<sup>23</sup>

It is also available as a chlorhexidine-chip (PerioChip) in the UK, USA and in Germany. Quinoderm face wash is the brand name for its face wash.<sup>23</sup> Its spray products are mainly marketed under the brand name Corsodyl.<sup>23</sup> It is marketed as ethanol in Italy, Switzerland and other European countries, Chlorhexamed in Germany, Savacol in Australia and New Zealand, clohex in India, Perioxidina in Venezuela, chlorhex in UK.<sup>23</sup> As a skin cleanser, it is marketed under brand names such as Hibiclens, Savinox plus or Dexidin. Surgical hand wash is marketed under the brand name Hexigard. It is also used in some acne skin washes. It is also used as part of a treatment for athlete's foot. In some countries, it is available by prescription only.<sup>23</sup>

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**1.3.10 Chlorhexidine mouth wash Indications** <sup>23</sup>

- Antiplaque & antigingivitis agent.
- It is used to improve bad breath. Morning halitosis is reduced up to 90%.
- Improves gingival health for short periods in the absence of any mechanical oral hygiene procedure.
- It is used between dental visits as part of a professional program for the treatment of gingivitis.
- It may also be of some prophylactic value against oral candidial.
- It decreases the speed and degree to which recurrence of drug-induced gingival enlargement occurs.
- During the first postoperative week after a periodontal surgery, patient advised to use twice daily to maintain good oral hygiene.
- It may help to reduce the mucositis.
- There are oral pathologic conditions like oral cysts, dental traumas etc. in which the maintenance of oral hygiene is required for healing and regeneration of the oral tissues.

**1.3.11 Side effects****The most common side effects are:**

- An increase in staining of teeth and other oral surfaces including silicate and resin restorations due to continued use for long periods. This brownish discoloration of teeth and tongue are due to the fact that the disintegration of bacterial membranes leads to the denaturation of bacterial proteins.<sup>23</sup>
- Other discolorations might be caused by monosaccharides such as glucose and fructose that are dissolved in saliva and that react with the amine functions of bacterial proteins. (Maillard reaction)<sup>23</sup>

- An increase in calculus formation<sup>23</sup>
- Chlorhexidine also has a bitter taste which is difficult to mask completely.<sup>4</sup>
- Minor irritation and superficial desquamation of the oral mucosa.<sup>23</sup>
- Parotid gland swelling and inflammation of the salivary glands (sialadenitis).<sup>23</sup>
- Frequently reported oral mucosal symptoms are Stomatitis, Gingivitis, Glossitis, Ulcer, Dry mouth, Hypesthesia, Glossal edema, Paresthesia.<sup>23</sup>

Among the suggested mechanisms, precipitation of anionic dietary chromogens onto adsorbed cations has been considered as the most suitable (Addy & Moran 1995; Watts & Addy 2001). The intensity of staining seems correlate with the frequency of intake. To reduce the impact of this issue, can use CHX mouthwash containing ADS (Anti Discoloration System) has similar efficacy in microbial plaque control and reduction of BOP as CHX without ADS, with the advantage of lower stain formation on tooth surfaces in patients with chronic periodontitis<sup>24</sup>

**Possible side effect that's worth mentioning is allergic reaction:**

Chlorhexidine is a widely used and effective antiseptic agent. Although skin contact is usually well tolerated, it may cause both immediate and delayed hypersensitivity reactions<sup>25</sup>. Immunological reactions to chlorhexidine, including allergy (Type I hypersensitivity) and allergic contact dermatitis/stomatitis (Type IV hypersensitivity), have been recognized for many years. This potential safety issue, however, is not well known within dentistry<sup>26</sup>. For these reasons, the prolonged use of CHX should be avoided in normal periodontal patients. It is useful for short periods (up to two weeks) when oral hygiene may be difficult or

impossible, such as during acute oral infections or following periodontal surgery.<sup>4</sup>

### 1.3.12 Clinical Efficacy

- Chemical plaque control with mouthwashes as an adjunct to mechanical plaque control with a toothbrush and dental floss has been considered an effective method for controlling gingivitis. The anti-inflammatory effects of chemical plaque control benefit the oral tissues by reducing inflammation and bleeding.<sup>27</sup>
- CHX mouthwash with a 0.1% to 0.2% concentration demonstrates significant antiplaque effects when used daily over 2 weeks in the absence of mechanical cleaning and as a long-term adjunct to oral hygiene at 4- to 6-week and 6-month intervals.<sup>28</sup>
- There is high-quality evidence from studies that reported the Löe and Silness Gingival Index of a reduction in gingivitis in individuals with mild gingival inflammation on average (mean score of 1 on the 0 to 3 GI scale) that was not considered to be clinically relevant.<sup>29</sup>
- CHX mouth rinse adsorbed to the pellicle-coated enamel surface of the tooth surface, bacterial surface, oral mucosa and produces a persistent bacteriostatic action with slow sustained release into the oral cavity lasting 12 hours so it is used twice daily<sup>2,4</sup>.

### 1.3.13 Pharmacological considerations

CHX is frequently used as a mouth rinse (0.2% or 0.12% w/v). The compound can also be applied as a gel, spray, varnishes and has been incorporated into tooth paste, chewing gum, slow-release vehicles (perio chip), periodontal packs and sub- gingival irrigation.<sup>4</sup> When chlorhexidine is used as a mouthwash concurrently with fluoride-

containing toothpastes, interactions may occur that reduce the effectiveness of one or both products. This happens for several reasons: CHX, a cation, interacts and forms salts of low solubility and antibacterial activity with anions, such as sodium lauryl sulfate (SLS) and sodium monofluorophosphate (MFP). CHX and MFP are not compatible in clinically relevant concentrations *in vitro*.<sup>30</sup>

The Food and Drug Administration (FDA) suggests to use CHX (at 0.12% or 0.2% concentrations) as an oral rinse, applying 10-15 mL of product for about 30 seconds, or as local applications of gel or spray preparations, twice daily, for a limited period of time (1 month or 2 weeks).<sup>22</sup> The time that should elapse between brushing performed at home and the use of CHX mouthwash also remains a topic for debate. Some studies postulate that efficacy of CHX could be inhibited by certain anionic surfactants, particularly sodium lauryl sulphate (SLS), and the monofluoride phosphate, contained in commercial toothpastes, supposedly due to the multiple chemical reactions between these compounds.<sup>22</sup> It is thought that the first two compounds (being negatively charged) bind with CHX, thereby reducing its activity, and, furthermore, these ingredients may also compete for the binding sites of CHX, thereby causing an accelerated clearance of the molecule from oral tissues.<sup>22</sup>

Other studies suggested that a SLS-based mouthwash can deactivate CHX for up to 30 minutes after its use. More recent randomized clinical trials, however, have shown that the anti-plaque activity of CHX is not altered by the use, before or after CHX, of a toothpaste containing SLS.<sup>22</sup>

The most recent findings, therefore, do not suggest a reduced efficacy of CHX when used as a mouthwash in combination with a commercial toothpaste as part of a normal oral hygiene routine.<sup>22</sup>

On the contrary, brushing (with or without toothpaste) is essential to breaking up and removing the oral biofilm, exposing the bacteria to the anti-bacterial agent and making the tooth surface more favorable to CHX adhesion. Plaque removal prior to rinsing leads to an increased efficacy of CHX mouthwash and a reduction in its local adverse effects.<sup>22</sup> Therefore, the current recommendation is to use a CHX-based mouthwash, when necessary, after normal oral hygiene procedures (performed with or without tooth-paste).<sup>22</sup>

## 1.4 Green Tea

Tea has a long history, which originates from China and spreads all over the world by direct or indirect ways. Nowadays, tea has been consumed by 3 billion people worldwide, which is considered as one of the most popular non-alcoholic beverages. Tea can be classified in many types according to the diverse definition methods in different countries. In China, according to the degree of fermentation, tea is divided into six major tea lines: green tea, black tea, white tea, yellow tea, Oolong tea, and dark tea. Green tea was the first tea to be discovered, and it is a non-fermented tea. Green tea retains more natural substances in fresh leaves and has less vitamin loss, thus forming the characteristics of green tea as “clear soup with green leaves and strong flavor convergence”.<sup>31</sup>

Interestingly, green tea has been used as an adjunct in the treatment of plaque-induced gingivitis and showed to have desirable effects on clinical and biological parameters, providing a potentially natural and affordable alternative in the process. A number of clinical studies showed that applying green tea as a chewing gum or mouthwash improved plaque and bleeding scores, reduced salivary IL-1 $\beta$  levels and reduced volatile

sulfur compound (VSC) levels effectively compared to placebo. In fact, chlorhexidine and green tea mouthwashes were found to be equally effective in reducing plaque and gingival inflammation. However, available reports are still lacking specific details regarding preparation of such custom-made natural remedies.<sup>32</sup>

The main varieties of green tea are Longjing, Biluochun, Huangshanmaofeng, Xinyangmaojian, etc. A large number of researchers have confirmed that green tea possesses chemical ingredients that are closely related to human health. Tea polyphenols, caffeine, theanine, tea polysaccharides, and other components which are extracted and separated from green tea have pharmacological activities such as anti-cancer, anti-oxidation, protecting the nervous system, and lowering blood sugar. Green tea has been considered to be suitable for patients with hypertension, hyperlipidaemia, coronary heart disease, arteriosclerosis, and diabetes. However, it is important to keep in mind that “natural” does not mean perfectly safe. Although the toxic side effects of green tea are relatively small, it must be used with caution in pregnancy, children, and the elderly population<sup>31</sup>

### **1.4.1 Phytochemistry**

To understand the health benefits of green tea we must know more about the phytochemistry of it. The chemical structures of the main compounds that have been identified are listed below.<sup>31</sup>

#### **1.4.1.1 Tea Polyphenols**

Tea polyphenols is a general term for polyphenols in tea. There are about 30 kinds of compounds, mainly composed of catechins, flavonoids, anthocyanins, and phenolic acids. The highest content of tea polyphenols

in green tea is 20–30%, which can be used as an excellent natural antioxidant.<sup>31</sup>

#### 1.4.1.2 Catechins

The catechins in tea mainly include catechin (C), epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin Gallate (EGCG). A large number of studies have shown that catechins in green tea, especially EGCG, have anti-cancer, anti-viral, and anti-oxidant effects.<sup>31</sup>

#### 1.4.1.3 Flavonoids

Green tea is rich in flavonol glycosides, mainly including myricetin glycosides, quercetin glycosides, and behenyl glycosides. This sugar chain consists of monosaccharides, such as glucose, galactose, rhamnose, arabinose, etc., and disaccharides or trisaccharides. Anthocyanins are a class of water-soluble pigments and belong to flavonoids. The content of anthocyanins is not high in tea, but due to its obvious bitter taste, it has a great impact on tea quality.<sup>31</sup>

#### 1.4.1.4 Phenolic Acids

At present, there are few studies on phenolic acid compounds in green tea. The content of phenolic acids in green tea is relatively small, but it includes various ingredients such as gallic acid, chlorogenic acid, caffeic acid, p-coumaric acid, ellagic acid, quinic acid, and tea gallate.<sup>31</sup>

#### 1.4.1.5 Alkaloids

The alkaloids in tea are mainly purine alkaloids. Among them, the caffeine content is the most (2~5%). Secondly, it also contains a small amount of theophylline and theobromine. These three alkaloids are the main material basis for the refreshing effect of tea.<sup>31</sup>

#### 1.4.1.6 Amino Acids

The type and content of amino acids in tea is one of the most important substances affecting tea quality. Tea contains about 1% to 4% of amino acids. So far, 26 amino acids have been found in tea, including 20 protein amino acids and 6 non-protein amino acids. The highest content is theanine, glutamic acid, arginine, serine, and aspartic acid. Theanine and  $\gamma$ -aminobutyric acid are two important active amino acids in tea.<sup>31</sup>

They have notable protective effects on the nervous system, Theanine accounts for approximately 50% of all amino acids; however,  $\gamma$ -aminobutyric acid is low. Chen et al. used an amino acid analyzer to determine the content of free amino acids in several different teas and found that there was no significant difference in the amino acid composition of green tea and black tea<sup>31</sup>

#### 1.4.1.7 Carbohydrate

The reason why the tea soup is slightly sweet is that tea contains a small number of monosaccharides and disaccharides, such as glucose, fructose, galactose, sucrose, etc. Most carbohydrates in tea are polysaccharides, such as cellulose, starch, and pectin, which are insoluble in water.<sup>31</sup>

#### 1.4.1.8 Aromatic Ingredients

The substances that form the aroma of green tea are mainly volatile aromatic substances. Among the chemical components of green tea, the aroma components do not occupy much content, about 0.005% to 0.020%, but the types are quite complicated. There have been many reports on the analysis of volatile components in green tea, and at the same time, new components have been discovered and identified.<sup>31</sup>

### 1.4.1.9 Organic Acids Organic

acids in green tea, as a water-soluble substance, are one of the main components that affect the aroma and taste of tea soup. More than 40 organic acids have been isolated and identified from tea, including free organic acids in tea soup and more than 30 in aroma components. Volatile compounds such as acetic acid, butyric acid, and hexenoic acid are classified under the aromatic substance category.<sup>31</sup>

### 1.4.1.10 Mineral Elements

The inorganic compounds in tea are called ash, which is mainly composed of some mineral elements and their oxides. Ash content is one of the indexes for quality inspection of tea export. The most abundant mineral elements are P and K, followed by Ca, Mg, Fe, Mn, Al, S, Si, and trace elements such as Zn, Cu, and F, due to the valuable significance of mineral elements on the physiological function of tea plant and human body, it has aroused extensive attention of scientists.<sup>31</sup>

### 1.4.1.11 Others

In addition to the chemical components mentioned above, green tea also contains a certain number of vitamins, such as vitamin B, vitamin C, and vitamin E; enzymes, such as glucosidases and lipoxidases; and chlorophyll, which is a highly safe natural edible pigment.<sup>31</sup>

## 1.4.2 Pharmacological effects

### 1.4.2.1 Antioxidant Effects

- Green tea extract and components (polyphenols, theanine, caffeine) inhibit LDL lipid peroxidation, primarily through metal ion chelation (e.g., copper).<sup>31</sup>

- Catechins ranked by antioxidant ability: EGCG > ECG > EGC > EC.<sup>31</sup>
- Green tea exhibits strong antioxidant activity via:
  - o DPPH radical scavenging (very low IC<sub>50</sub> values, e.g., 0.005 µg/mL).
  - o TOSC assays, where ECG and EGCG are most effective.<sup>31</sup>
- Green tea polysaccharides (TLPS, TFPS, TSPS) also show dose-dependent superoxide scavenging, reaching up to 90% scavenging rate.<sup>31</sup>
- In vivo, green tea extract boosts antioxidant enzymes (e.g., SOD, catalase, GSH-Px) and reduces redox imbalance in aging mice brains—relevant to periodontal inflammation.<sup>31</sup>
- It can protect tissues (e.g., liver and brain) against oxidative damage caused by toxins like acetaminophen, suggesting systemic support in inflammatory conditions like periodontitis.<sup>31</sup>

#### 1.4.2.2 Antibacterial Effects

- EGCG is the most potent antibacterial component in green tea, with significant activity against *Porphyromonas gingivalis*, a major periodontal pathogen.<sup>31</sup>
- EGCG and green tea extract inhibit *P. gingivalis* with MIC values between 125–1000 µg/mL.<sup>31</sup>
- Mechanism: inhibiting bacterial adhesion and regulating bacterial gene expression, thus reducing biofilm formation.<sup>31</sup>
- Other catechins (ECG, EC) and caffeine have weaker effects.<sup>31</sup>
- Green tea extract shows broader antibacterial action against foodborne and skin pathogens—this general antimicrobial activity may support oral microbial balance.<sup>31</sup>
- Enhanced lipophilicity of green tea increases antibacterial potency.<sup>31</sup>

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**1.4.2.3 (Other Effects with Potential Periodontal Implications)**

While not specific to periodontology, the following effects may indirectly benefit periodontal health:

- Anti-inflammatory and immunomodulatory effects (e.g., suppression of IL-2 signaling, enhancement of regulatory T cells, COX-2 inhibition).<sup>31</sup>
- Neuroprotective and metabolic regulation via oxidative stress reduction—important in patients with systemic diseases (e.g., diabetes, Alzheimer’s) linked to periodontal risk.<sup>31</sup>
- Anti-diabetic effects, including improved insulin resistance and glucose metabolism, are relevant because diabetes is a key risk factor for periodontitis<sup>31</sup>
- Bone-protective properties in ovariectomized rats suggest potential to support alveolar bone preservation in periodontitis.<sup>31</sup>

Antiviral and detoxification effects may help modulate the systemic inflammatory burden associated with chronic periodontal infection.<sup>33</sup>

Polyphenols are thought to be responsible for the health benefits of herbal teas, particularly green tea, attributed to the presence of EGCG, one of the most active and abundant catechins in green tea. EGCG was the focal point of the scientists’ research as it can mimic some of the biological effects of green tea.<sup>33</sup>

Antioxidant, anti-inflammatory and anticarcinogenic properties of green tea are enhanced by the presence of higher amounts of (EGCG) epigallocatechin 3 gallate than black tea. Experimental trials on the physiologic effects of some polyphenolic tannins indicate that they may also be useful as anti-tumour and antibacterial agents for the reduction of

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serum lipids, reduction of blood pressure, modulation of immune responses and use in food preservation.<sup>33</sup>

### **Effects of green tea on periodontology**

Dental decay and periodontitis are perhaps the most common bacterial infections in dentistry.<sup>34</sup>

The data indicate that among the 200–300 species present in human dental plaque only a few may be considered as pathogens in caries and periodontitis, as there has been evidence implicating *Streptococci mutans* being responsible for a majority of human dental decay and periodontitis.<sup>34</sup>

Among the organisms present in the dental plaque, *S. mutans* often gets the most attention in dental-related studies because it has been previously shown to favour attachment to tooth enamel as plaque formation occurs through various mechanisms on the tooth surface and the morphology of the tooth surface dictates the composition of the plaque ecosystem. Among the tooth colonisers, the primary etiologic agent for dental caries is the *Streptococcus mutans* (*S. mutans*). Several studies have shown that high levels of *S. mutans* are at high risk for tooth decay and exacerbation of the periodontal disease.<sup>34</sup>

Studies have shown that *Camellia sinensis* has numerous medicinal advantages, such as anti-bacterial, anti-spore, anti-cariogenic, and anti-viral properties.<sup>34</sup>

Green tea contains polyphenols which are composed of catechins, such as Epigallocatechin-3-gallate, (EGCG) is the most abundant catechin and a major component that contributes to these effects.<sup>34</sup>

EGCG has a greater effect on gram-positive bacteria than gram-negative bacteria. The incorporation of EGCG at increasing concentrations has been shown to decrease bacterial numbers.<sup>34</sup>

Hence, polyphenols have the ability to interfere with biofilm formation. The previous literature reported that green tea extracts have short-term anti-plaque antibacterial capabilities.<sup>34</sup>

Therefore, in order to determine the EGCG's effect on *S. mutans*, Minimum inhibitory concentration (MIC) and disc diffusion tests were performed to observe the catechin effect on the growth the inhibition of *S. mutans*.<sup>34</sup>

In 2021 an in vitro study proved that green tea catechins showed antibacterial activity on streptococcus mutans. Green tea polyphenol EGCG was used to determine its effectiveness as an antimicrobial agent against bacterial growth.<sup>34</sup>

Different concentrations of EGCG were used to study the effect on *S. mutans* using the MIC and disc diffusion methods. EGCG was able to inhibit the growth at a concentration of 50–100 µg/mL and was able to kill *S. mutans* at a concentration of 100 µg/mL.<sup>34</sup>

Chlorhexidine (CHX) is considered the gold standard antimicrobial in dentistry yet there have been few studies which have compared the antimicrobial effect of EGCG and CHX. The result showed that both CHX and EGCG were effective in inhibiting microbial growth.<sup>34</sup>

In this study, the effect of EGCG showed inhibition against *Streptococcus mutans*. One more study compared the antimicrobial activity of EGCG with black, oolong and Pu-erh tea against *S. mutans* which showed antimicrobial activity against *Streptococcus mutans*.<sup>34</sup>

There is one study investigating EGCG as a potential anti-cariogenic agent which showed that EGCG can inhibit the growth of *S. mutans*. EGCG has been shown to interfere with the bacterial adhesion on the enamel thereby interfering and preventing the proliferation of *S. mutans* by suppressing the glucosyltransferase and amylase activity, thus, reducing the acid production in the dental plaque.<sup>34</sup>

Though there have been different methods used to evaluate the efficacy of EGCG against microorganisms, the results suggested that catechins is a stable substance and with antimicrobial properties capable to inhibit the *S. mutans*. This property can, therefore, be made use of in the preparation of mouthwashes or dentifrices for the prevention of dental caries and periodontal diseases.<sup>34</sup>

In 2025 a clinical trial study evaluated the clinical efficacy of green tea extract gel as local drug delivery for periodontitis and compared it with ornidazole gel as adjuncts to scaling and root planing (SRP) in patients with periodontitis.<sup>35</sup>

It recruited 20 patients (10 per group) aged 27-60 years diagnosed with periodontitis and presenting with bilateral probing pocket depths (PPDs) of 4-7 mm. The participants were selected based on specific inclusion and exclusion criteria.<sup>35</sup>

This study was conducted in the Department of Periodontology and Implantology, Adhiparasakthi Dental College and Hospital, Melmaruvathur, Tamil Nadu, India. It was approved by the Institutional Review Board (2020-MDS-BrI1-SIV-05/APDCH) and adhered to the guidelines outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants.<sup>35</sup>

The sample size was estimated to ensure adequate statistical power, considering factors such as expected effect size, population standard deviation, and confidence level.<sup>35</sup>

This study was structured into five phases: Initial screening, baseline clinical measurements, SRP and LDD, and maintenance with monthly re-evaluations. The gels were formulated, each containing 1% ornidazole (commercially available) and 1% green tea extract. The green tea extract was prepared from 100 g of dried and coarsely powdered green tea leaves using a maceration process.<sup>35</sup>

The gels were designed to target periodontal pathogens with ornidazole at a concentration of 250 mg and green tea extract at 250-500 µg/mL. A simple gel formulation method with a Carbopol gel base was used. Both green tea extract and commercially available ornidazole were prepared in gel form to minimize bias related to the application methods.<sup>35</sup>

The gels were stored in a cool, dry place, protected from direct sunlight. The key findings of this study revealed statistically significant enhancements in clinical periodontal parameters, such as a reduction in PI and PPD, as well as an improvement in CAL, after applying both green tea extract gel and ornidazole gel.<sup>35</sup>

Despite the study's inherent limitations, the observed clinical trends suggest that green tea extract gel may offer a comparable or potentially superior LDD approach compared to ornidazole gel. This could be attributed to its robust antioxidant and antibacterial properties.<sup>35</sup>

These results imply that green tea extract gel may be an effective adjunctive therapy to SRP in managing periodontitis, especially for patients seeking alternatives to conventional antimicrobial interventions.

However, additional research with larger groups, extended follow-up periods, and in-depth microbiological and biochemical assessments is needed to confirm these initial findings.<sup>35</sup>

In conclusion regular Matcha tea consumption for one month can reduce gingival inflammation, bleeding, plaque, and oxidative stress in patients with mild gingivitis. Dentists may recommend it as a supportive measure. Though further long-term placebo-controlled studies are needed.<sup>36</sup>

There's a study on the Journal of Family Medicine and Primary Care that reviewed the therapeutic effects of green tea as an antioxidant on oral health which states that green tea has been reported to be useful for prevention of periodontal disease progression.<sup>37</sup>

Several in vitro studies have shown that the growth of porphyromonas gingivalis, prevotella intermedia and prevotella nigrescens on human buccal epithelial cells is inhibited by the green tea component EGCG.<sup>37</sup>

These bacteria are heavily involved in the destruction of periodontal tissues and can lead to a reduction in periodontal tissue. In addition, the slow release of catechins into the periodontal tissues has been found to inhibit the production of toxic end metabolites of P. gingivalis.<sup>37</sup>

Studies have shown that the green tea catechin plays a key role in the prevention of oxidative stress. Overproduction of free radicals damages gingival tissues, periodontal ligaments, and alveolar bone in periodontal disease pathogenesis.

Green tea has potent antioxidant and anti-inflammatory properties and is believed to defend against inflammatory conditions by reducing the

production of pro-inflammatory cytokines particularly interleukin 8 (IL-8).<sup>37</sup>

Green tea products have been found to increase the total antioxidant capacity of gingival crevicular fluid, along with potent anti-inflammatory and antiplaque effects.<sup>37</sup>

Regular consumption of green tea can reduce gingival bleeding index, pocket depth and promote periodontal healing. Periodontal regeneration may be attributed to the presence of polyphenols by a decrease in expression of matrix metalloproteins (MMP 9), suppression of osteoclast differentiation, and induction of apoptosis in a dose-dependent manner.<sup>37</sup>

Recently, the use of green tea herbal mouthwash to improve periodontal health is becoming popular. Maroofian et al. prepared an herbal mouthwash using dried leaves of green tea plants which were grown in the North part of Iran.<sup>37</sup>

They extracted green tea polyphenols, one of the most therapeutic ingredients of the plant, in a safe and stable formula for use as a mouthwash.<sup>37</sup>

Studies have suggested that green tea mouthwash can effectively reduce the microbial pathogens, can be used as an adjunct to periodontal therapy in chronic periodontitis and, along with scaling and root planning for a period of two weeks, could improve the scores of various periodontal parameters.<sup>37</sup>

Additionally, no evidence of toxic effects such as irritation, burn, vesicle or mucous disturbance was observed, and despite similar antibacterial effects of green tea mouth wash with the chemical

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chlorhexidine, they showed that the use of herbal green tea mouthwash was safer and more economical.<sup>37</sup>

In another clinical trial, it was concluded that green tea mouthwash could improve the gingival health of patients with marginal gingivitis. Lagha et al. found the promising results of green tea catechins to protect the gingival epithelium against invasion by *P. gingivalis* and in reduction of periodontal disease progression.<sup>37</sup>

Additionally, several polyphenols of green tea have preventive effects on tooth decay. ECG, GCG and EGCG are most active among catechins and can strongly inhibit glucosyl transferase, thereby preventing adherence of bacteria to tooth enamel. EGCG has been reported to inhibit sugar transport and acid production by lactate dehydrogenase.<sup>37</sup>

It has been suggested that catechins on a daily basis can effectively reduce dental caries and that use of green tea extract herbal mouthwash reduces the acidity of saliva and inhibits bacterial colonisation.<sup>37</sup>

Studies have documented that daily intake of green tea for one month can increase the salivary pH beyond 5.5. Study conducted on forty healthy school children aged between 6 and 8 years has shown an increase in salivary pH from 6.15 to 7.65 after rinsing with green tea and reduced incidence of dental caries.<sup>37</sup>

Currently, use of green tea dark chocolate combination is gaining popularity for prevention of dental plaque and consequent dental caries; however, the role of green tea in the prevention and progression of dental caries is still unclear and requires more evidence-based trials to be carried out.<sup>37</sup>

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**Green tea as mouthwash:**

A 2020 systemic review on *Camellia Sinensis* Mouthwashes in Oral Care discussed that Anti-bacterial properties were the major focus of numerous pre-clinical studies on tea products.<sup>38</sup>

In a study for evaluation of antibacterial efficacy of an extemporaneous green tea-containing mouth rinse on oral pathogens including *Streptococcus mutans* (*S. mutans*), *Streptococcus sanguis*, *Enterococcus faecalis*, *Pseudomonas aerogenosa* and *Escherichia coli*, the herbal formulation showed considerable inhibitory effects on all microorganisms, although weaker than chlorhexidine (CHX).<sup>38</sup>

A study evaluating antibacterial effect of green tea extract on multi-drug resistant pathogens showed inhibitory effect on *Escherichia coli* and *Streptococcus aureus* and strong synergistic suppression against pathogens in combination of EGCG with gentamycin. This in vitro observation suggested that green tea has stronger inhibitory effect on gram-positive pathogens than gram-negative ones.<sup>38</sup>

A study was conducted in Laval University, Quebec, Canada on inhibitory effect of green tea extract on virulence markers of *Fusobacterium nucleatum*, a key factor in initiation and progression of periodontal diseases.<sup>38</sup>

The results indicated that treatment of pre-formed *Fusobacterium nucleatum* biofilm with green tea extract caused a time-dependent decrease in biofilm viability and decreased adherence of *Fusobacterium nucleatum* to oral epithelial cells.<sup>38</sup>

Anti-fungal property of green tea has been the subject of many in vitro studies, as well. Sitheeque et al. showed *Candida glabrata* is the

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most sensitive species of *Candida* to tea polyphenols followed by *Candida parapsilosis* and *Candida albicans* (*C. albicans*).<sup>38</sup>

Since being the most common fungal species found in oral cavity, anti-fungal activity of green tea is mostly evaluated against *C. albicans*. It is suggested that the EGCG found in green tea acts as an antifolate compound, which disturbs metabolism of folic acid in *C. albicans*. Another study showed that polyphenolic compounds found in green tea extract, caused 75% reduction in viable *C. albicans* cells during biofilm formation.<sup>38</sup>

This research proposed that polyphenols anti-fungal activity is exerted via reduction of proteasomal activity in *C. albicans* cells. Another study conducted by Yadegari et al. , demonstrated that inhibitory effect of EGCG against *C. albicans* is time dependent. The results also showed that EGCG could be effective on fluconazole-resistant *C. albicans*.<sup>38</sup>

It has also been stated that green tea aqueous extract can be useful against *C. albicans* colonies growing on acrylic resin and polyvinyl chloride surfaces used in prosthetic dentures and orthodontic appliances.<sup>38</sup>

In a study conducted by Mollashahi et al. , on tooth substrate of extracted premolar teeth, it was implied that green tea extract has the potential to be used as an irrigating agent in endodontic treatments due to its anti-fungal properties.<sup>38</sup>

However, the researchers of the study suggested evaluating its biocompatibility and safety before using it as an irrigating solution in clinical settings.<sup>38</sup>

Another study in the department of biotechnology in Graphic Era University, India, investigated synergistic activity of green tea extract and

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fluconazole, amphotericin B and copper sulphate as a combinational therapy against *C. albicans*.<sup>38</sup>

The results proved a synergic effect that can be efficient against *C. albicans* and implied that the combinational therapy does not show cytotoxic activity on healthy cells. Some in vivo experiments have studied green tea's anti-inflammatory function.<sup>38</sup>

An animal study on type 1 diabetic rats showed green tea extract minimizes expression of receptor activator of nuclear factor kappa-B ligand and tumor necrosis factor-alpha, consequently decelerating alveolar bone resorption compared to placebo group.<sup>38</sup>

Another animal observation on albino rats using green tea extract, illustrated a significant reduction in nicotine-induced damage, in terms of inflammatory cell infiltrates in buccal mucosa. Such observations proposed the potential benefits of tea mouthwash preparations in clinical application.<sup>38</sup>

However, there are some controversial findings. Regarding the wound healing, an animal study failed to show a significant effect for green tea formulation. They also mentioned that in a clinical trial on 30 healthy volunteers, gargling with two commercial tea extract solutions for 60 seconds resulted in significant decrease in microbial counts of expectorated oral rinses.<sup>38</sup>

Compared to a synthetic antiseptic mouthwash, those herbal oral rinses showed prolonged activity. In addition to teeth and oral cavity, the effect of mouthwashes on devices and surgical derbies has also been assessed. In another RCT, performed on 18 patients with unerupted maxillary third molars with extraction indication, researchers tried to

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evaluate the anti-microbial and anti-adherence activity of different mouthwashes on suture materials after the surgery.<sup>38</sup>

Participants were equally divided in three groups of *Camellia sinensis*, *Calendula officinalis*, or CHX mouthwash users for one week. Compared to no intervention, as a control, all solutions were effective to reduce the number of adhered microorganisms, but the only significant difference was observed for CHX.<sup>38</sup>

The same results was found in an RCT done by Prabakar and others, in which they showed that CHX and green tea mouthwashes are significantly effective against *S. mutans*, although this antibacterial effect was superior for CHX, again.<sup>38</sup>

Another RCT compared the efficacy of green tea and CHX mouthwashes against *S. mutans*, *Lactobacilli* spp., and *C. albicans* in children with severe early childhood caries. Thirty children aged 4-6 years were randomly divided into green tea and CHX groups and were asked to use the prescribed mouthwashes once daily, for two weeks.<sup>38</sup>

The results showed significant decrease in *S. mutans* and *Lactobacilli* spp. colonies but no decrease was detected in *C. albicans* in both groups. This study revealed that green tea mouthwash was more efficient against *S. mutans*, whilst CHX had higher efficiency against *Lactobacilli* spp. Regarding tolerability and acceptability, this research proved green tea mouthwash, to be tolerable than CHX in children.<sup>38</sup>

The same results for efficacy of green tea against *S. mutans* were reported in five other similar RCTs. However, this privilege was not a fixed rule in all clinical trials. Another clinical study showed green tea mouthwash could be as effective as nystatin in reducing candidal denture stomatitis symptoms.<sup>38</sup>

Then concluded *Camellia sinensis* mouthwashes have shown acceptable efficacy for management of various oral pathologies.

To our knowledge, this is the first review in medical literature, which involves all potential applications of green tea formulations in the form oral rinses, as an industrially standard medication in the setting of dentistry.<sup>38</sup>

Although there are several review articles about use of green tea in dentistry fields, none of them has the same comprehensiveness. Regarding our investigations, advantages of this herbal product has been demonstrated in the majority of studies.<sup>38</sup>

Therefore, some indications can be proposed for the tea mouthwashes with higher level of evidence including oral disinfection, dental plaque removal, and oral analgesia.<sup>38</sup>

An important and interesting issue in this context is the noticeable safety profile of these formulations, which is an outstanding advantage for this herbal mouthwash over synthetic chemical ones.<sup>38</sup>

On 2023 a randomized control trial was made to evaluate of the effectiveness of green tea mouth rinse on oral halitosis, tongue coating, and plaque accumulation.<sup>39</sup>

It was found that under the limitations of the study, it can be concluded that 5% *C. sinensis* mouth rinse is as effective as commercially available 0.2% chlorhexidine mouth rinse in reducing plaque scores, tongue coating, and oral halitosis.<sup>39</sup>

Larger sample size and long-term studies are recommended to validate the results of the present study. The long-term studies will help

us in assessing the acceptability of this indigenously prepared mouth rinse while providing opportunity for evaluating the long-term side effects.<sup>39</sup>

A different a triple-blind randomized controlled clinical trial on the adjunctive effect of green tea mouthwash prepared at different steeping temperatures on gingivitis in 2021.<sup>32</sup>

The conclusion was: Within the study limitations, it can be concluded that green tea-made mouthwashes significantly reduced plaque and gingivitis when used as adjuncts to mechanical plaque control.<sup>32</sup>

The green tea mouthwash prepared in warm water demonstrated significantly higher efficacy in lowering gingival inflammation after two weeks compared to that prepared in hot water followed by ice addition.<sup>32</sup>

Further large-scale studies with longer follow-up comparing such home-made products with available gold standards are required to determine their actual value as adjuncts to periodontal therapy.<sup>32</sup>

On another study that was published on 2023 under the title of “Clinical efficacy of green tea, aloe vera and chlorhexidine mouthwashes in the treatment of dental biofilm induced gingivitis: A multi-arm, double-blinded, randomized controlled clinical trial”.<sup>40</sup>

Where Sixty patients with generalized dental biofilm-induced gingivitis were randomly allocated to four study groups (n = 15 each) for treatment, namely Group GT, Group CHX, Group AV and Group CNT after scaling and polishing were administered to all the patients.<sup>40</sup>

Plaque index (PI), gingival index (GI) and sulcular bleeding index (SBI) were recorded at baseline, 14th and 21st day.<sup>40</sup>

It was discovered that green tea mouthwash displayed a significant reduction in plaque index, gingival index and sulcular bleeding index.

0.5% green tea catechin has equivalent anti-plaque efficacy as 0.2% chlorhexidine gluconate and can be considered a potent alternative to prevent and treat gingival diseases.<sup>40</sup>

A Novel Perspective was published in 2025 on Green Tea: The Traditional Plant's Potential in Managing Periodontal Diseases Has Concluded Green Tea (*Camellia sinensis*) Demonstrates Substantial Potential as a natural, Sustainable, and Innovative Approach to Managing Periodontal disease.<sup>41</sup>

Its Bioactive Compounds, Particularly Epigallocatechin-3-Gallate (EGCG), Exhibit Potent Antioxidant, Anti-Inflammatory, and Antimicrobial Properties, Improving Oral Health Outcomes.<sup>41</sup>

Studies have shown that Green Tea Consumption and Topical Applications Can Reduce Periodontal Pocket Depth (PPD), Inflammation, and Bleeding, supporting its role as an adjunct to Conventional Treatments such as Scaling and Root Planning (SRP).<sup>41</sup>

Clinical Trials and Systematic Reviews Suggest That Green Tea-Based Products—including Dentifrices, Mouthwashes, and Gels—Can Enhance Periodontal Therapy by Modulating Inflammatory Pathways, Inhibiting Bacterial Adhesion, and Reducing Oxidative Stress.<sup>41</sup>

These Benefits Position Green Tea as a Viable Alternative to Synthetic Antimicrobial Agents Like Chlorhexidine, Potentially Minimizing Side Effects such as Tooth Staining and Altered Taste Perception.<sup>41</sup>

However, while Green Tea Shows Promise, it has not yet demonstrated the same level of efficacy as established chemical treatments.<sup>41</sup>

Future Research Should Optimize Green Tea Formulations, Explore Advanced Delivery Systems Such as Nanoencapsulation, and Evaluate Its Long-Term Safety for Widespread Clinical USE. Investigating Its Synergistic Effects with Probiotics and Biomaterials May Expand Its Applications in Periodontal Therapy and Implantology.<sup>41</sup>

As Interest in Natural Alternatives Grows, Green Tea stands as a compelling candidate for Integration into Preventive and Therapeutic Oral Health Strategies, with the potential to benefit Both Individual Patients and Broader Public Health Initiatives.<sup>41</sup>

**Adverse Effects and Drug Interactions** Excessive consumption of green tea may cause sleep disturbances at night and decrease the bioavailability of iron from the diet.<sup>37</sup>

Aluminium present in green tea products can lead to neurological diseases; patients on Warfarin therapy should not take green tea due to the presence of vitamin K as a component, and it may increase the risk of bleeding in patients on aspirin therapy. Pregnant and lactating women should limit the consumption to 1–2 cups/day as it can increase the heart rhythm.<sup>37</sup>

## Chapter Two: Materials and Methods

### 2.1. Study Design

This study was a randomized, open-label, clinical trial conducted to compare the effectiveness of 0.12% Chlorhexidine (CHX) and Green Tea (GT) mouthwashes on periodontal health.

### 2.2. Study Sample

A total of 50 patients were involved in the study. They were randomly assigned into two equal groups:

- Group 1 (CHX Group): 25 patients used 0.12% Chlorhexidine mouthwash.
- Group 2 (GT Group): 25 patients used Green Tea mouthwash.



Fig (2.1): Types of mouthwashes used in the study (Listerine Green Tea and Chlorhexidine 0.12%).

### Exclusion Criteria

The initial sample included 70 potential patients. However, several individuals were excluded from the study based on the following criteria:

1. Systemic Diseases: some patients were excluded at the beginning because they had systemic conditions (such as Diabetes Mellitus) or were heavy smokers, which could interfere with periodontal healing and one of them was excluded during the study because her general health condition (systemic diseases) made it difficult to continue the clinical procedures.
2. Adverse Reactions: One participant in the Green Tea group was excluded after developing hypersensitivity (allergic reaction) to the green tea extract.
3. A total of 7 patients were excluded because they failed to attend the follow-up session after 14 days.

### 2.3. Clinical Procedures

All patients received professional scaling and polishing before starting the study. They were instructed to rinse with 10 ml of the assigned mouthwash for 30 seconds, twice daily, for a period of 14 days.



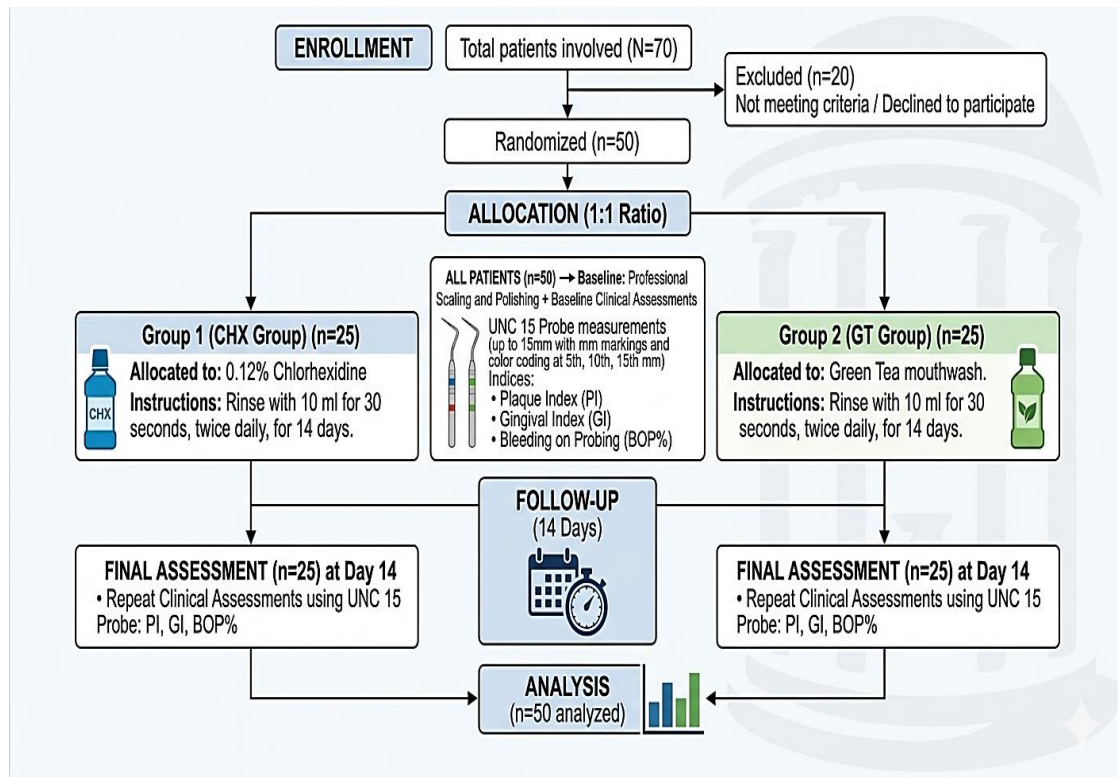
**Fig (2.2): Ultrasonic scaler handpiece**

## 2.4. Evaluation Parameters

Clinical assessments were performed twice: at the beginning (Before) and after 14 days (After) using the UNC 15 periodontal probe which is a precise diagnostic instrument developed by the University of North Carolina to measure periodontal pocket depths up to 15 mm long with millimeter markings at each millimeter and color coding at the fifth, tenth, and fifteenth millimeters.

The following indices were recorded:

- Plaque Index (PI): To measure the amount of dental plaque.
- Gingival Index (GI): To assess the severity of gingival inflammation.
- Bleeding on Probing (BOP%): To evaluate the percentage of bleeding sites in the gums.



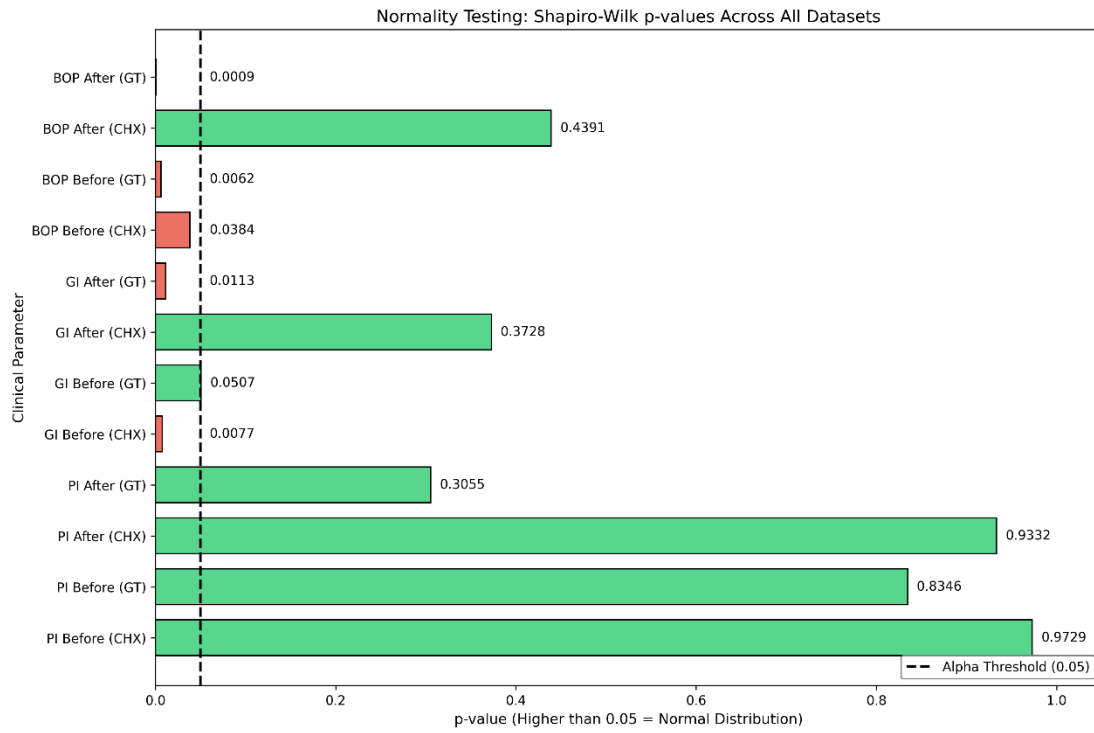
**Fig (2.3): Consort Diagram of the Parallel – Group Randomized Controlled Trial**



**Fig (2.4): Bleeding on Probing measurement**

## Chapter Three: Results

### 3.1 Normality test



**Fig (3.1): Shapiro-Wilk Normality Test**

This figure clearly separates the data points that follow a normal distribution from those that do not, which dictates whether you use parametric or non-parametric statistical tests.

#### Interpretation of the figure:

- Green bars ( $p > 0.05$ ): Show that the distribution of the data is normal. You use parametric tests (e.g., Paired t-test, Independent Samples t-test) for these datasets (such as the Plaque Index [PI]).
- Red bars ( $p < 0.05$ ): Show that the data is skewed or non-normal. We must use non-parametric tests (e.g., Wilcoxon, Mann-Whitney U) for these datasets (such as the majority of the Bleeding on Probing [BOP%] and Gingival Index [GI] data).
- Black Dashed Line: Shows the  $p = 0.05$  critical threshold.

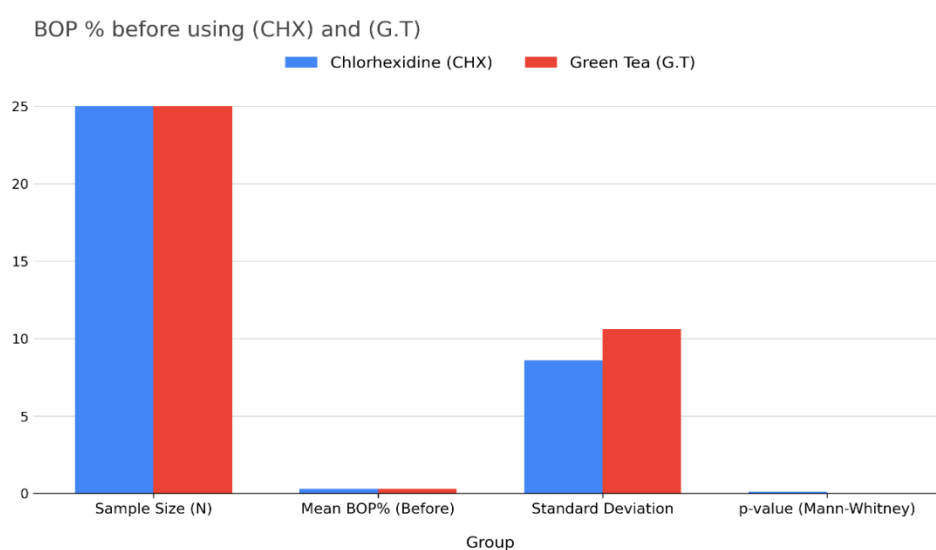
### 3.2 Bleeding on Probing

We usually use the Shapiro-Wilk Test to see whether the data follows a typical "bell curve" (Normal Distribution) before making comparisons.

- This test was previously conducted using the baseline BOP% data.
- The CHX group's p-value was 0.0384, while the Green Tea group's was 0.0062.
- The data is formally regarded as non-normal (or skewed) as both p-values were less than 0.05.
- Standard parametric tests, such as the Independent Samples t-test, cannot be applied to non-normal data because they lead to inaccurate results.

This is a statistical comparison of the two groups before treatment, based on the BOP% scores provided.

The Mann-Whitney U Test (the non-parametric counterpart of the independent t-test) is the most appropriate statistical analysis as we previously found that the baseline bleeding on probing data does not follow a normal distribution.



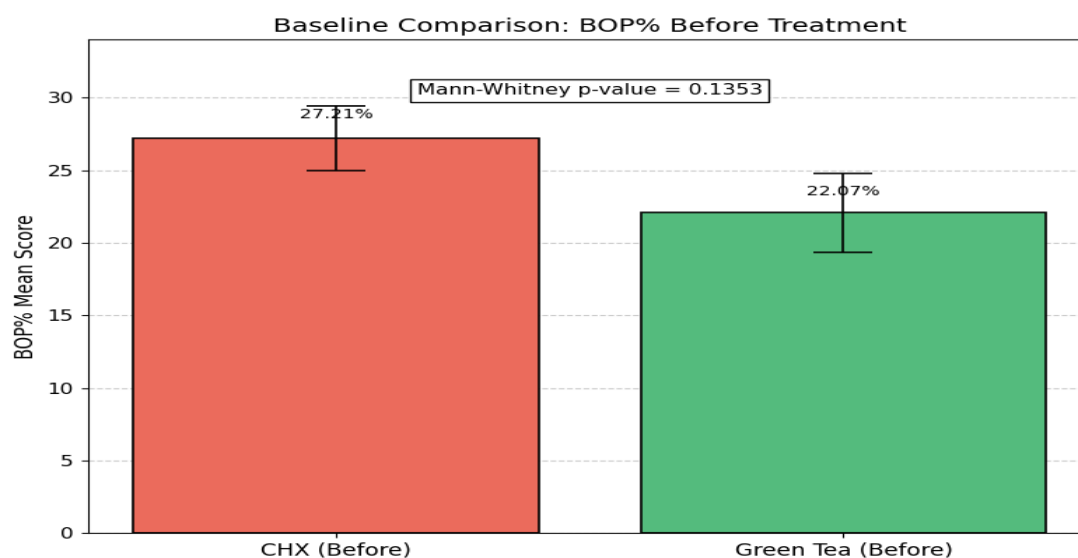
**Fig (3.2): “Comparison of Mean BOP% Values Between Chlorhexidine (CHX) and Green Tea (G.T) Groups at Baseline”**

**Table (3.1): Statistical Analysis Table: Baseline Comparison (Pre-Treatment)**

Group	Sample Size (N)	Mean BOP% (Before)	Standard Deviation	p-value (Mann-Whitney)	Significance
Chlorhexidine (CHX)	25	27.21%	8.47	0.1353	Not Significant
Green Tea (G.T)	25	22.07%	10.37		

### Interpretation of the Results

- The results showed that the Green Tea group began with a mean BOP of 22.07% and the CHX group with a mean BOP of 27.21%.
- The p-value: 0.1353 was the result of the Mann-Whitney U test.
- The difference between the two groups is not statistically significant because this value is higher than the conventional 0.05 threshold.
- This indicates that both patient groups had similar levels of gingival bleeding before receiving any mouthwash and the two groups were equally matched from the beginning so any changes that observe following the treatment are due to the mouthwashes and not an underlying discrepancy.



**Fig (3.3): Baseline Comparison of Bleeding on Probing (BOP%) Before Treatment**

The figure above represents the mean baseline scores. The error bars represent the standard error, and the visual overlap in their ranges further confirms the statistical finding that the starting points for these two groups are scientifically comparable.

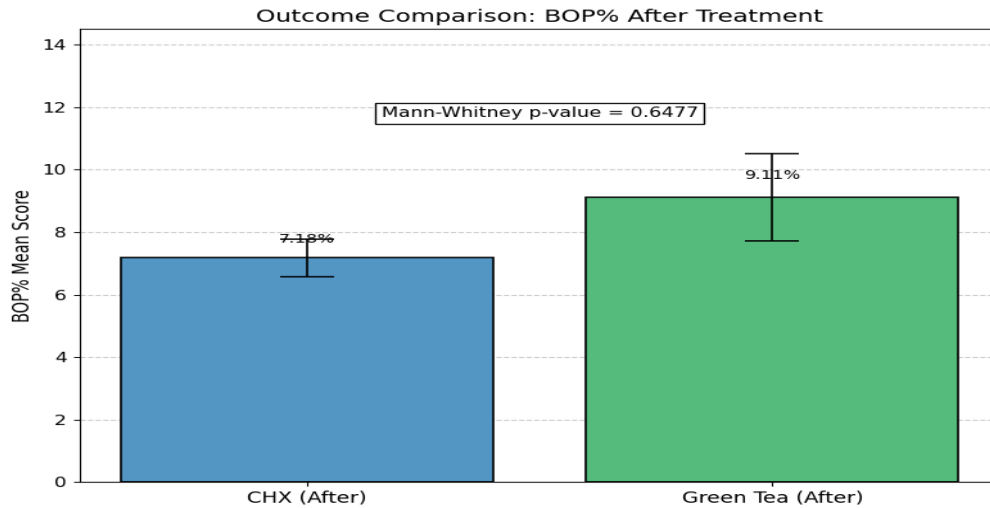
**Table (3.2): Statistical Analysis Table: Post-Treatment Outcome (After)**

Group	Sample Size (N)	Mean BOP% (After)	Standard Deviation	p-value (Mann-Whitney)	Significance
Chlorhexidine (CHX)	25	7.18%	2.12	<b>0.6477</b>	<b>Not Significant</b>
Green Tea (G.T)	25	9.11%	5.36		

### Interpretation of the Results

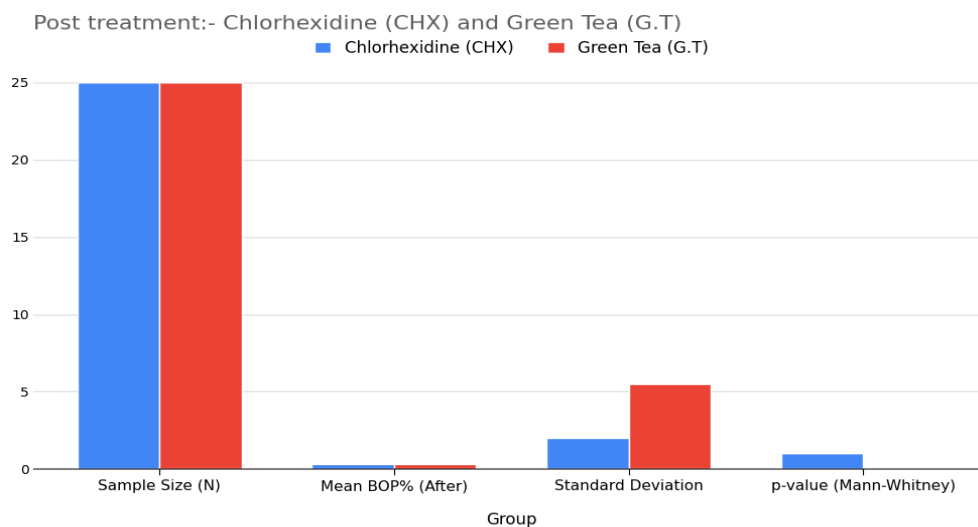
- The Final Means: The average bleeding score for the CHX group was 7.18%. The average score for the Green Tea group was 9.11% in the end.
- Variability (Std Dev): The Green Tea group's standard deviation is significantly larger (5.36 vs. 2.12), suggesting that patient reactions to the tea were somewhat more inconsistent (some had extremely low bleeding, while outliers like Patients 4 and 15 remained higher). CHX provided a more consistent reaction for all of the patients.
- Statistical Conclusion: A p-value of 0.6477 was obtained from the Mann-Whitney test.
- There is no statistically significant difference in bleeding decrease between the two mouthwashes at the end of the study because this number is significantly higher than the conventional 0.05 alpha threshold.

- Clinical Takeaway: Green tea is statistically as effective at controlling gingival bleeding, despite chlorhexidine's significantly narrower and lower mathematical average. This firmly supports using green tea as an alternative mouthwash for gingivitis.



**Fig (3.4): Outcome Analysis of (BOP) Scores Following the Use of CHX and Green Tea Mouthwashes.**

The figure above visualizes the final mean bleeding scores. The standard error bars illustrate the variability we discussed, specifically the wider spread in the Green Tea results. Despite this, the statistical overlap confirms the two treatments are comparable in clinical efficacy.

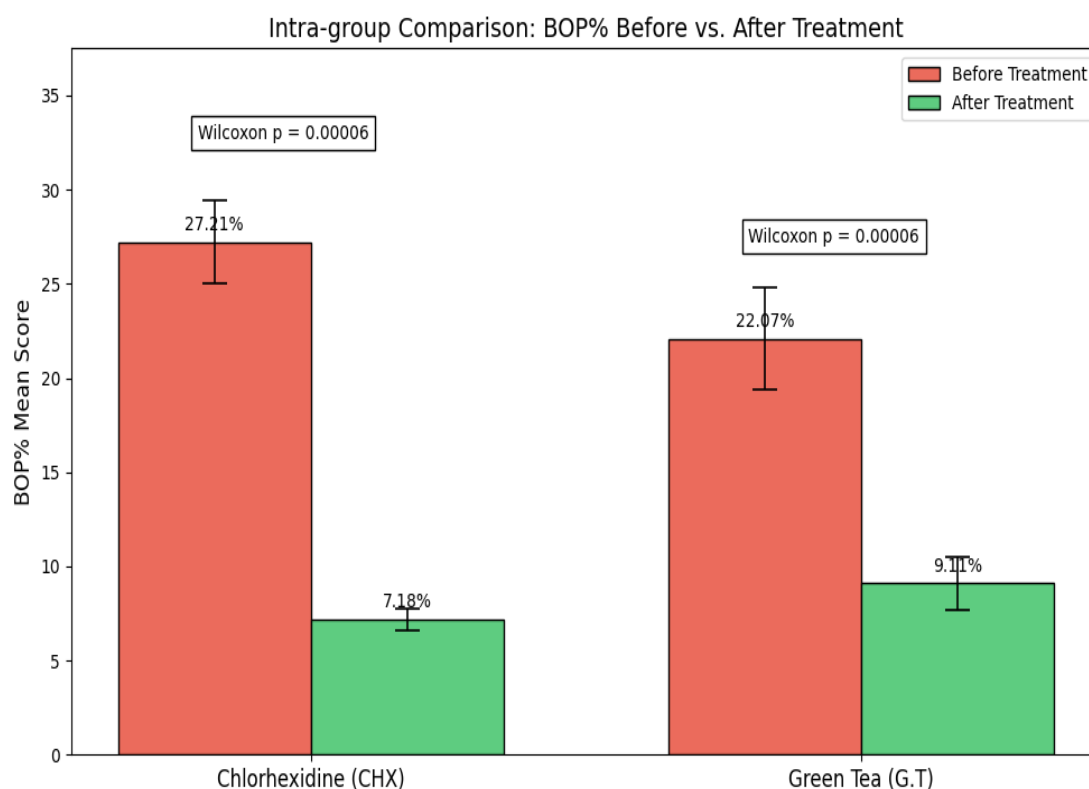


**Fig (3.5): Comparison of Mean BOP%, Standard Deviation, and Mann–Whitney p-value Between CHX and Green Tea Groups After Treatment**

Based on the data provided for **BOP% (After)** scores, here is the statistical comparison representing the clinical outcome between Chlorhexidine (CHX) and Green Tea (G.T) treatments.

Because we previously established that the Green Tea (After) dataset significantly violated the assumption of normal distribution, the most suitable analysis test for comparing these two independent, post-treatment groups is the **Mann-Whitney U Test**.

Based on the dataset for Bleeding on Probing (BOP%), here is the intra-group comparison analyzing the change in each patient *Before* and *After* using the mouthwashes.



**Fig (3.6): Within-group Comparison of Bleeding on Probing (BOP%) Before and After Treatment Using Wilcoxon Test in CHX and Green Tea Groups**

The figure above clearly shows the strong effect of both treatments.

- The high baseline bleeding scores before therapy are shown by the red bars.
- The considerably reduced bleeding scores after the therapy period are shown by the green bars.
- The standard error is represented by the error bars (black lines), which display the patient data's dispersion.

The statistical result that both mouthwashes are quite effective is clearly confirmed by the dramatic decline between the red and green bars for both groups.

### Selection of the Suitable Analysis Test

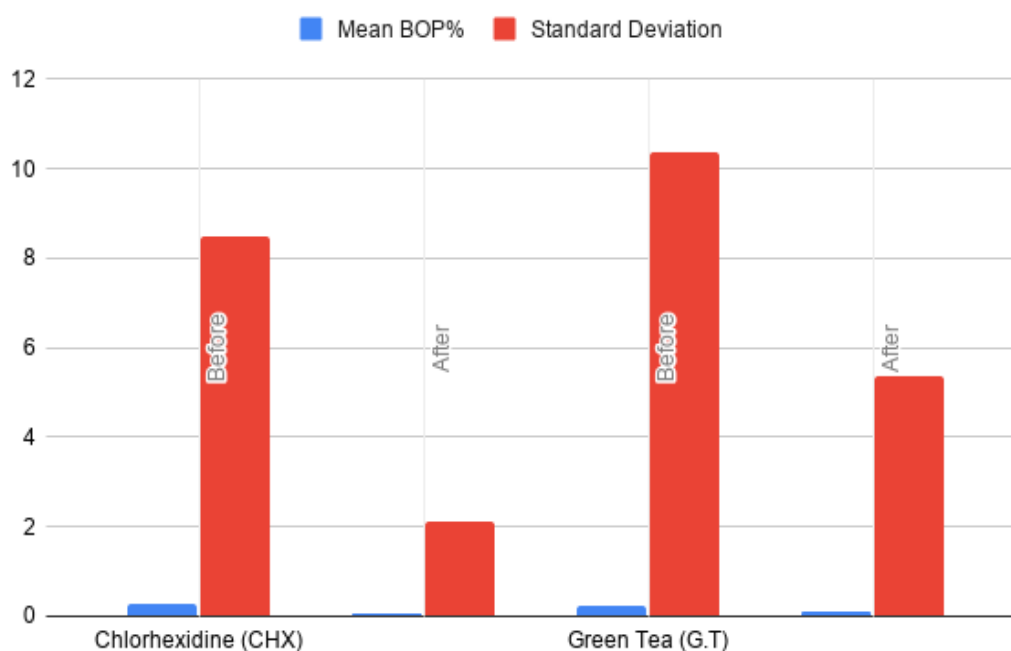
Because we are comparing the *same group of patients* at two different time points (Before and After), we must use a paired statistical test. Earlier, the Shapiro-Wilk test proved that the BOP% data does not follow a normal "bell curve" distribution. Therefore, the most suitable test is the **Wilcoxon Signed-Rank Test** (the non-parametric equivalent of the Paired t-test).

**Table (3.3): Statistical Analysis Table: BOP% (Before vs. After)**

Treatment Group	Timepoint	Mean BOP%	Standard Deviation	p-value (Wilcoxon Test)	Clinical Significance
<b>Chlorhexidine (CHX)</b>	Before	27.21%	8.47	p<0.0001	Extremely Significant
	After	7.18%	2.12		
<b>Green Tea (G.T)</b>	Before	22.07%	10.37	p<0.0001	Extremely Significant
	After	9.11%	5.36		

### Interpretation of the Results

- Efficiency of Chlorhexidine (CHX): The CHX group's mean bleeding scores significantly decreased, from 27.21% to 7.18%. A p-value of 0.00006 was obtained from the Wilcoxon test. This indicates that chlorhexidine is quite successful in stopping gingival bleeding because it is significantly below the 0.05 threshold.
- Green Tea (G.T) efficacy: The Green Tea group likewise experienced a significant decrease in bleeding, with a mean decrease from 22.07% to 9.11%. The identical highly significant p-value of 0.00006 was obtained by the Wilcoxon test. This demonstrates that the Green Tea mouthwash is a very successful way to stop gingival bleeding.



**Fig (3.7): Mean Bleeding on Probing (BOP%) and Standard Deviation values for Chlorhexidine (CHX) and Green Tea (G.T) groups before and after treatment.**

### 3.3 Plaque Index

#### Selection of the Suitable Analysis Test

First, we run the Shapiro-Wilk test to check for normal distribution

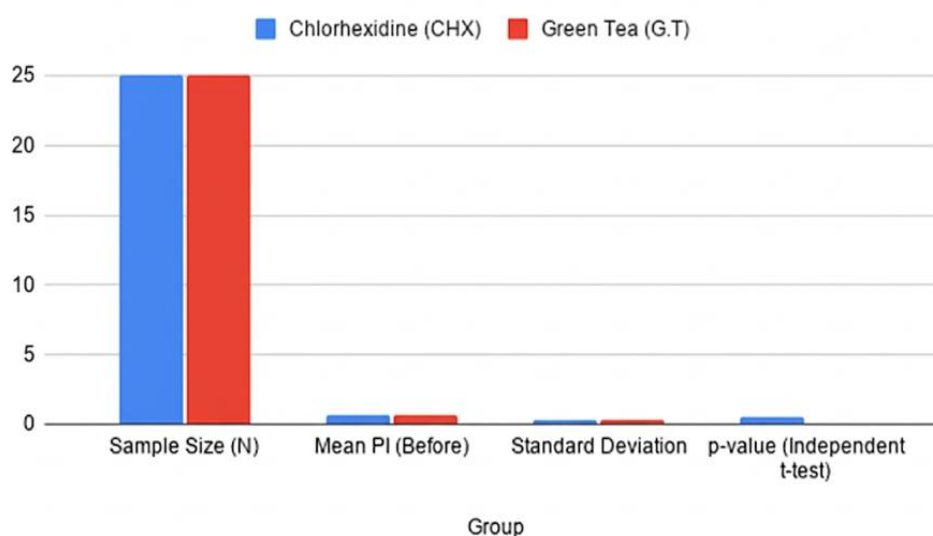
- The p-value obtained from the CHX data is 0.9729.
- The p-value for the Green Tea data is 0.8346.

The data is regularly distributed since both of these values are more than 0.05. The Independent Samples t-test is the appropriate and most effective statistical test to apply because we are comparing two different, independent groups (Chlorhexidine vs. Green Tea) before starting any treatment.

**Table (3.4): Statistical Analysis Table: Plaque Index (Baseline)**

Group	Sample Size (N)	Mean PI (Before)	Standard Deviation	p-value (Independent t-test)
Chlorhexidine (CHX)	25	0.6	0.24	<b>0.4708</b>
Green Tea (G.T)	25	0.53	0.23	

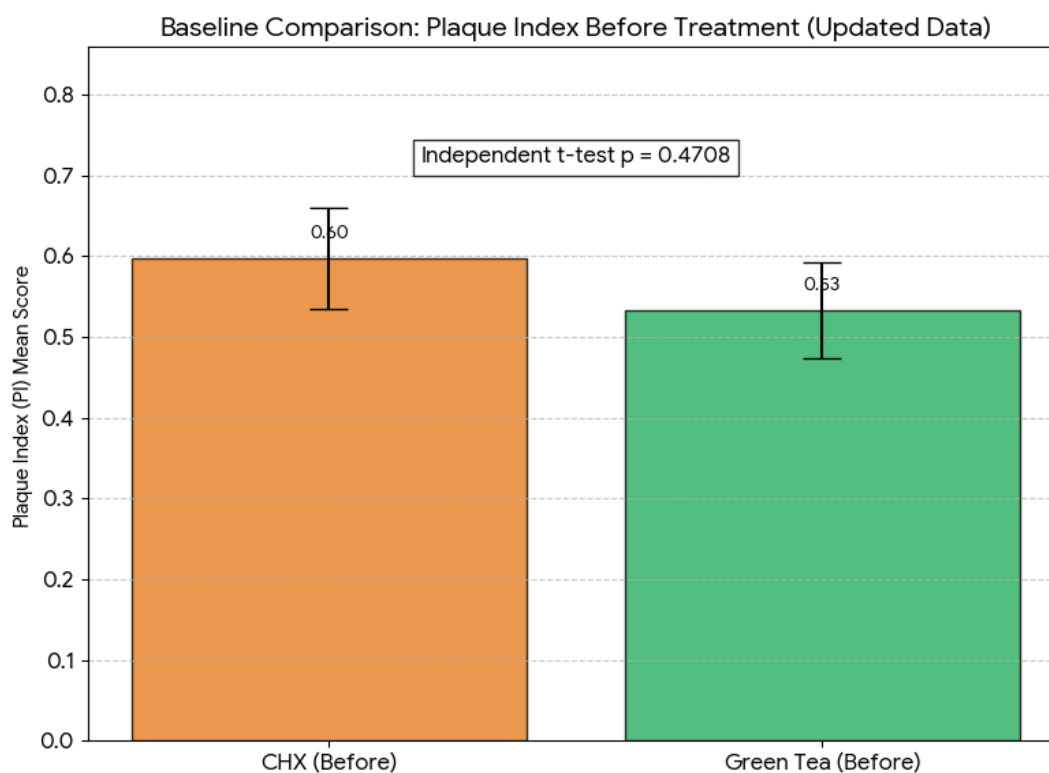
(Baseline) Chlorhexidine (CHX) and Green Tea (G.T)



**Fig (3.8): Comparison of Baseline Characteristics between Chlorhexidine (CHX) and Green Tea (G.T) Groups.**

### Interpretation of the Results

- The Baseline Means: The patients in the Chlorhexidine group had a mean Plaque Index of 0.60 before to using any mouthwash. The mean Plaque Index for the patients in the Green Tea group was 0.53.
- Statistical Conclusion: A p-value of 0.4708 was obtained from the Independent Samples t-test. There is no statistically significant difference between the two groups at baseline because this number is significantly higher than the threshold value of 0.05
- Both patient groups had statistically identical levels of plaque at the beginning of the clinical study, according to a p-value of 0.4708.



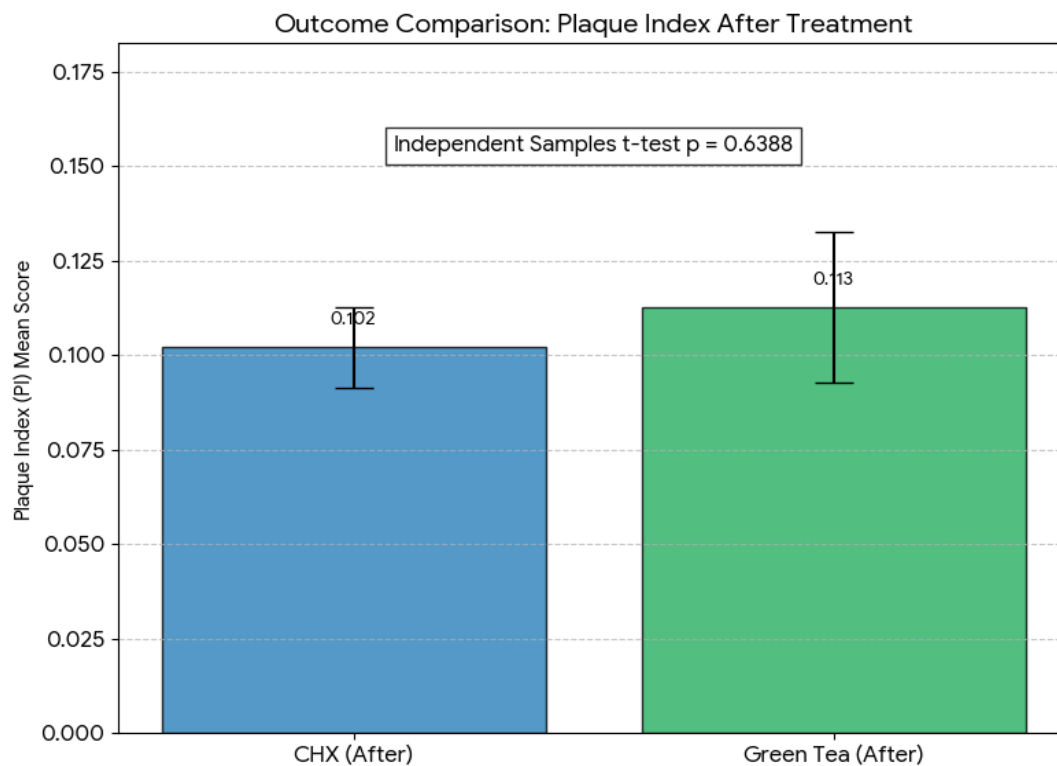
**Fig (3.9): Baseline Comparison of Mean Plaque Index (PI) Between Chlorhexidine (CHX) and Green Tea Groups.**

The figure above reflects our data, showing the baseline means for both groups. The overlapping standard error bars and the high p-value confirm that your test subjects were perfectly matched regarding plaque accumulation before the experiment began.

### Selection of the Suitable Analysis Test

First, we run the Shapiro-Wilk test to check if the final plaque scores follow a normal distribution.

- The post-treatment CHX data yields a p-value of **0.9332**.
- The post-treatment Green Tea data yields a p-value of **0.3055**



**Fig (3.10): Outcome Analysis of Plaque Index (PI) Scores Following the Use of CHX and Green Tea Mouthwashes.**

Because both of these values are well above the 0.05 threshold, the data is **normally distributed**. Since we are comparing two separate, independent patient groups at a single point in time (after the trial), the correct and most powerful statistical test to use is the **Independent Samples t-test**.

**Table (3.5): Statistical Analysis Table: Post-Treatment Plaque Index Outcome (After)**

Group	Sample Size (N)	Mean PI (After)	Standard Deviation	p-value (Independent t-test)	Clinical Significance
Chlorhexidine (CHX)	25	0.102	0.041	0.6388	Not Significant
Green Tea (G.T)	25	0.113	0.077		

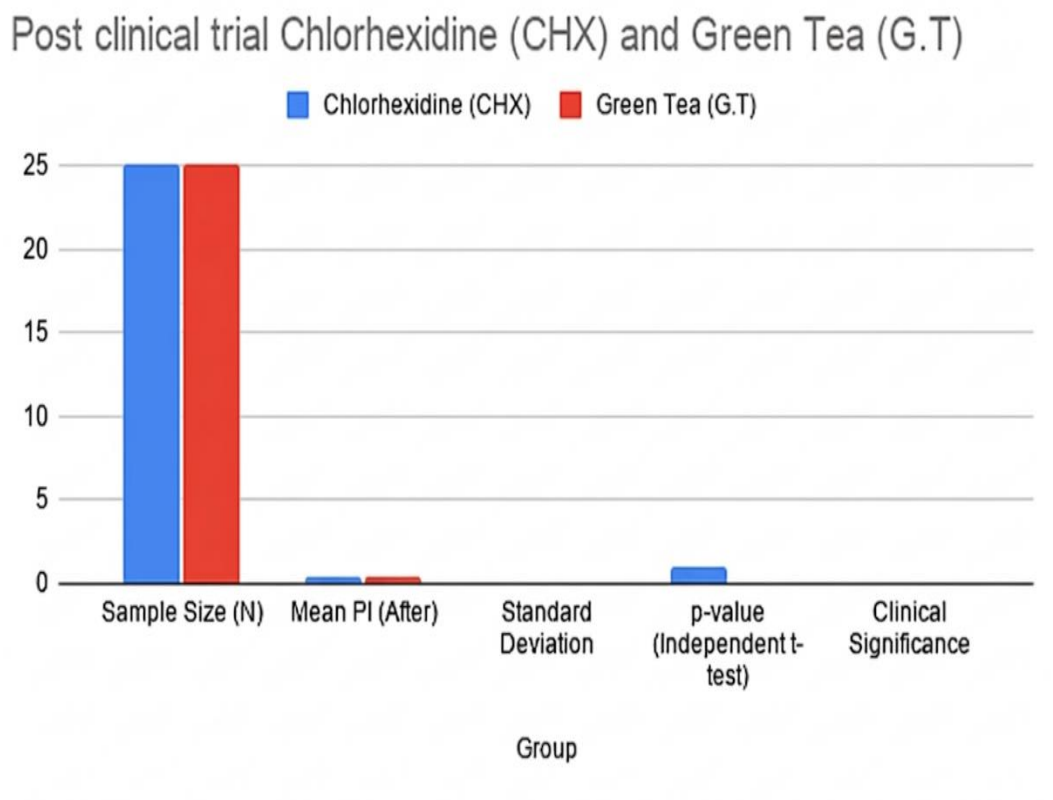
### Interpretation of the Results

- The Final Means: Patients in the Chlorhexidine group had an exceptionally low mean Plaque Index of 0.102 at the end of the study. Additionally, the mean Plaque Index of 0.113 was extremely low for the patients in the Green Tea group.
- Variability (Std Dev): The Green Tea group's standard deviation is somewhat higher than CHX's (0.077 vs. 0.041), indicating that patient responses varied significantly more. For example, the CHX group showed a tighter, more consistent response, while patients #2 (0.27) and #15 (0.25) in the G.T group still had some plaque.
- Statistical Conclusion: A p-value of 0.6388 was obtained using the Independent Samples t-test.
- There is no statistically significant difference between the two mouthwashes' ultimate plaque levels because this figure is far higher than the threshold of 0.05.

- **Clinical Takeaway:** Plaque levels were successfully reduced to about the same minimum by both mouthwashes. This finding shows scientific evidence that Green Tea mouthwash is equally as good at preventing or reducing plaque buildup as the gold standard, chlorhexidine.

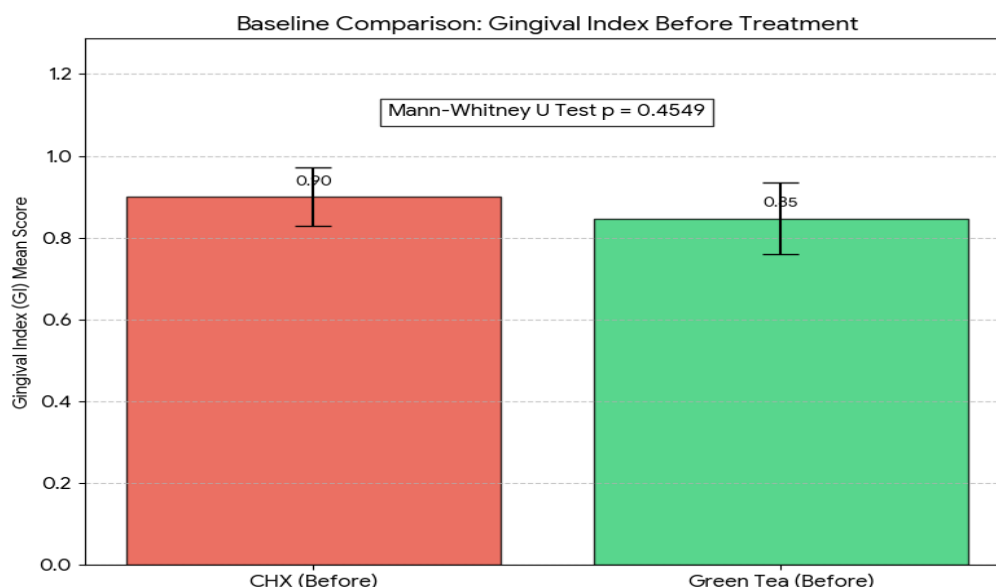
### Figure Representation

The chart above visualizes the final mean plaque scores. The error bars represent the standard error. The slight visual overlap and nearly identical bar heights firmly confirm the statistical finding: both treatments are comparably effective at controlling plaque.



**Fig (3.11): Post-Trial Distribution of Sample Size, Mean PI, and Statistical Significance between Treatment Groups.**

### 3.4 Gingival Index



**Fig (3.12): Baseline Gingival Index (GI) Distribution for Chlorhexidine (CHX) and Green Tea Groups Prior to Treatment.**

The chart above illustrates the baseline similarities in gingival inflammation between your two groups. The heavily overlapping standard error bars and the high p-value visual confirm that the groups were excellently randomized before treatment began.

#### Selection of the Suitable Analysis Test

First, we analyze the data distribution using the Shapiro-Wilk test to determine the correct statistical pathway.

- The baseline CHX data yields a p-value of **0.0077**. Because this is less than 0.05, the data is **non-normally distributed**.
- The baseline Green Tea data yields a p-value of **0.0507** (right on the edge, but technically normal).
- **The Rule:** When comparing two independent groups, if even one of the groups fails the normality test (like the CHX group did here), we must abandon parametric tests. Therefore, the statistically correct and

most suitable test to use is the non-parametric **Mann-Whitney U Test**.

**Table (3.6): Statistical Analysis Table: Gingival Index (Baseline)**

Group	Sample Size (N)	Mean GI (Before)	Standard Deviation	p-value (Mann-Whitney U test)	Clinical Significance
<b>Chlorhexidine (CHX)</b>	25	0.9	0.28	<b>0.4549</b>	<b>Not Significant</b>
<b>Green Tea (G.T)</b>	25	0.85	0.34		

### **Interpretation of the Results**

- The Baseline Means: Patients in the Chlorhexidine group had an average Gingival Index of 0.90 prior to receiving the mouthwash. The average of 0.85 was almost the same for the patients in the Green Tea group.
- Statistical Conclusion: A p-value of 0.4549 was obtained from the Mann-Whitney U Test. There is no statistically significant difference in gingival inflammation between the two groups at the beginning of the study because this value is far higher than the conventional 0.05 significance level.
- This result demonstrates that the test subjects were exactly matched in terms of their baseline gingival health, just like the updated Plaque Index data. Neither group had an unfair advantage at the beginning (i.e., reduced inflammation). Therefore, any reduction in inflammation seen after the study can be confidently attributed to the mouthwashes.

### Selection of the Suitable Analysis Test

As always, we begin by checking the distribution of the final data using the Shapiro-Wilk test.

- The post-treatment CHX data yields a p-value of **0.3728** (Normal distribution).
- The post-treatment Green Tea data yields a p-value of **0.0113**. Because this is less than 0.05, it indicates a **non-normal distribution**.

Since one of the groups failed the normality test, we must use the non-parametric alternative to compare independent groups. Therefore, the correct test to use is the **Mann-Whitney U Test**.

**Table (3.7): Statistical Analysis Table: Post-Treatment Gingival Index Outcome (After)**

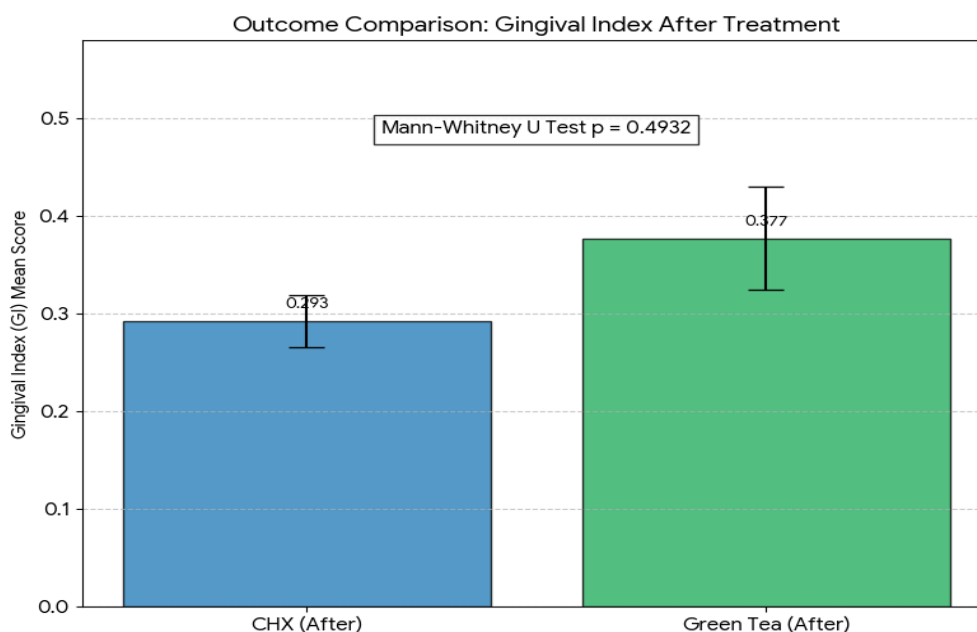
Group	Sample Size (N)	Mean GI (After)	Standard Deviation	p-value (Mann-Whitney U)	Clinical Significance
Chlorhexidine (CHX)	25	0.293	0.105	<b>0.4932</b>	<b>Not Significant</b>
Green Tea (G.T)	25	0.377	0.205		

### Interpretation of the Results

- The Final Means: Inflammation was greatly reduced by both treatments. The mean Gingival Index for the Chlorhexidine group was a very low 0.293. At the end, the Green Tea group had an outstanding mean Gingival Index of 0.377.
- Variability (Std Dev): The Green Tea group's standard deviation is marginally greater (0.205 vs. 0.105), which is consistent with the final plaque results. This suggests that although the general average was low, some members of the GT group (such as patients #4, #5,

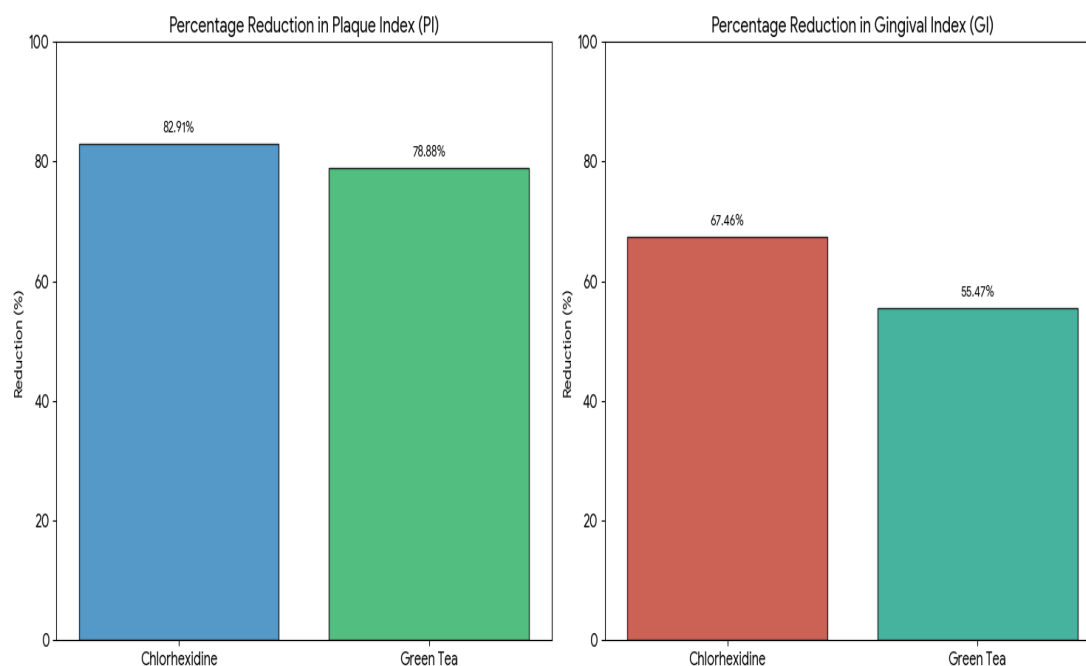
#7, and #15) experienced a less significant decrease in gingival inflammation than the group as a whole. The reaction from the CHX group was more consistent.

- **Statistical Conclusion:** A p-value of 0.4932 was obtained from the Mann-Whitney U test. The final levels of gingival inflammation between the two groups do not differ statistically significantly because this amount is much higher than the 0.05 threshold.
- **Clinical Takeaway:** It provides statistical evidence that green tea mouthwash reduces gingivitis and resolves gingival inflammation just as well as the chemical gold standard, chlorhexidine.



**Fig (3.13): Post-treatment Comparison of Mean Gingival Index (GI) Scores for Chlorhexidine (CHX) and Green Tea Groups.**

The chart above visualizes the final mean gingival inflammation scores. While the green bar is slightly taller, the overlapping error bars and the very high p-value visual confirm the statistical finding: the clinical outcomes are effectively identical between the two treatments.



**Fig (3.14): Comparative Percentage Reduction in Plaque Index (PI) and Gingival Index (GI) for Chlorhexidine and Green Tea Mouthwashes.**

The final calculations for the intra-group comparison (Before vs. After) show that both mouthwashes achieved highly significant reductions in clinical parameters. The choice of statistical test was based on the normality of the differences within each group.

**Table (3.8): Intra-group Comparison: Plaque Index (PI) Reduction**

Group	Mean (Before)	Mean (After)	%Reduction	p-value	Analysis Test
<b>Chlorhexidine (CHX)</b>	0.60	0.10	82.91%	< 0.0001	Paired t-test
<b>Green Tea (G.T)</b>	0.53	0.11	78.88%	< 0.0001	Paired t-test

**Chlorhexidine:** Demonstrated a massive **82.91% reduction** in plaque levels. The paired t-test confirms this change is extremely statistically significant ( $p < 0.0001$ ).

**Green Tea:** Achieved a comparable **78.88% reduction** in plaque. This reduction is also extremely significant ( $p < 0.0001$ ), proving Green Tea is highly effective as an anti-plaque agent.

**Table (3.9): Intra-group Comparison: Gingival Index (GI) Reduction**

Group	Mean (Before)	Mean (After)	% Reduction	p-value	Analysis Test
<b>Chlorhexidine (CHX)</b>	0.90	0.29	67.46%	0.00006	Wilcoxon Signed-Rank
<b>Green Tea (G.T)</b>	0.85	0.38	55.47%	0.000004	Paired t-test

**Chlorhexidine:** Resulted in a **67.46% reduction** in gingival inflammation. Because the differences in this group were non-normally distributed, the Wilcoxon Signed-Rank test was used, confirming a highly significant result ( $p = 0.00006$ ).

**Green Tea:** Achieved a **55.47% reduction** in gingival index scores. The paired t-test confirms this is a statistically significant clinical improvement ( $p < 0.0001$ ).

**As result conclusion** both Chlorhexidine and Green Tea mouthwashes produced noticeable and statistically significant improvements in oral health parameters. Chlorhexidine demonstrated marginally greater percentage reductions in gingival inflammation (67.46% vs. 55.47%) and plaque (82.91% vs. 78.88%), although the intra-group p-values for both treatments are much below the significance level. This demonstrates that both approaches are very successful therapeutic therapies for lowering gingivitis and plaque.

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## Chapter Four: Discussion

The primary objective of this study was to evaluate the clinical efficacy of a natural Green Tea mouthwash compared to the chemical "gold standard," Chlorhexidine. Based on the statistical analysis, both mouthwashes produced a highly significant reduction in dental plaque and gingival inflammation. Crucially, the final results showed **no statistically significant difference** between the two groups, suggesting that Green Tea is a viable, effective alternative to Chlorhexidine for the management of gingivitis.

### 4.1. Baseline Equality and Randomization

The statistical analysis of baseline (Before) data for both PI ( $p = 0.4708$ ) and GI ( $p = 0.4549$ ) confirmed that there were no significant differences between the groups at the start of the trial. This ensures that the subsequent improvements recorded were due to the therapeutic effects of the mouthwashes rather than initial differences in oral hygiene or inflammatory status.

### 4.2. Anti-Plaque Efficacy (PI)

Both groups achieved dramatic reductions in plaque scores, with Chlorhexidine showing an **82.91%** reduction and Green Tea achieving **78.88%** ( $p < 0.0001$  for both). The comparison of post-treatment scores yielded a p-value of **0.6388**, indicating that Green Tea matched the anti-plaque performance of CHX.

- **Mechanism:** The effectiveness of Green Tea is attributed to its high concentration of **catechins**, particularly *epigallocatechin*

*gallate (EGCG)*. These polyphenols inhibit the growth and adherence of *Streptococcus mutans* to the tooth surface by hindering the glycosyltransferase enzyme, which is essential for plaque biofilm formation (Kaur, 2014).

- **Literature Correlation:** Our results align with a study by **Priya et al. (2015)**, which found that 0.5% Green Tea mouthwash was equally effective as 0.2% CHX in reducing plaque index scores over a similar trial period.

### 4.3. Anti-Gingivitis and Anti-Inflammatory Effects (GI)

The Gingival Index scores decreased significantly in both groups: **67.46%** for CHX and **55.47%** for Green Tea. While CHX showed a slightly higher percentage reduction, the statistical comparison of the final "After" scores ( $p = 0.4932$ ) confirms that this difference was not significant.

- **Mechanism:** Green tea catechins exert a potent anti-inflammatory effect by reducing the expression of pro-inflammatory cytokines and matrix metalloproteinases (MMPs) in the gingival tissues. This biological action helps in resolving gingival swelling and bleeding (Deshpande et al., 2021).
- **Literature Correlation:** Our findings support the conclusions of **Deshpande et al. (2021)** and **Chatterjee et al. (2012)**, who reported that herbal mouthwashes can achieve anti-gingivitis outcomes comparable to CHX without the associated side effects.

#### 4.4. Clinical Implications

While Chlorhexidine is highly effective, its long-term use is often limited by side effects such as extrinsic tooth staining, taste alteration, and mucosal irritation. Green Tea mouthwash offers a major clinical advantage: it provides comparable therapeutic benefits with **no reported staining or taste disturbances**, leading to better long-term patient compliance (Balapanane et al., 2017).

## **Chapter Five: Conclusions and Suggestions**

### **5.1 Conclusion**

In conclusion, this study demonstrates that both Green Tea and 0.12% Chlorhexidine (CHX) mouthwashes have a significant positive impact on periodontal health. After 14 days of regular use, both groups showed a marked reduction in plaque accumulation and gingival inflammation. While both were effective, Chlorhexidine (CHX) exhibited a slightly higher potency in improving gingival health and controlling plaque compared to Green Tea with notable disadvantage of CHX tendency to cause extrinsic teeth staining, a side effect that was completely absent in the Green Tea group.

## 5.2 Suggestions

- Future studies are recommended to evaluate the effect of chlorhexidine and green tea mouthwashes on oral microbiome diversity rather than only plaque and gingival indices.
- It is recommended to compare different concentrations of chlorhexidine with green tea extract.
- Studies are recommended to investigate the combined use of chlorhexidine and green tea for possible synergistic effects.
- Further research is recommended to evaluate the effect of both mouthwashes on salivary pH and buffering capacity.

### References

1. Priya, B., Anitha, V., et al. (2015). Efficacy of chlorhexidine and green tea mouthwashes in the management of dental plaque-induced gingivitis: A comparative clinical study. *Contemporary Clinical Dentistry*, 6(4), 505–509.
2. Kaur, H. (2014). Comparative evaluation of the antiplaque effectiveness of green tea catechin mouthwash with chlorhexidine gluconate. *Journal of Indian Society of Periodontology*, 18(2), 178–182.
3. Deshpande, A., et al. (2021). Effect of green tea, ginger plus green tea, and chlorhexidine mouthwash on plaque-induced gingivitis: A randomized clinical trial. *Journal of the International Society of Preventive & Community Dentistry*, 11(4), 438–445.
4. Chatterjee, A., et al. (2012). Comparative evaluation of the efficacy of a herbal mouthwash and chlorhexidine on plaque and gingival inflammation. *Journal of Indian Society of Periodontology*, 16(4), 533–537.
5. Balapanane, S. C., et al. (2017). Comparison of the effectiveness of 0.5% green tea extract, 0.2% chlorhexidine, and 0.05% sodium fluoride mouthwashes on plaque and gingivitis: A randomized controlled trial. *Journal of Oral Biology and Craniofacial*
6. Lang N P., Bartold P M. Periodontal health. *J Periodontol* 2018;89.
7. Newman MG, Klokkevold PR, Elangovan S, Kapila Y, eds. Newman and Carranza's Clinical Periodontology and Implantology. 14th ed. Elsevier; 2023.
8. Koppolu P, Almutairi H, Yousef SA, Ansary N, Noushad M, Vishal MB, et al. Relationship of skin complexion with gingival tissue color

## References

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- and hyperpigmentation. A multi-ethnic comparative study. *BMC Oral Health* 2024;24:451.
9. Lang NP, Berglundh T, Giannobile W V, Sanz M, eds. *Lindhe's Clinical Periodontology and Implant Dentistry*. 7th Edition. Wiley-Blackwell (John Wiley & Sons); 2021.
  10. Enteghad S, Shirban F, Nikbakht MH, Bagherniya M, Sahebkar A. Relationship Between Diabetes Mellitus and Periodontal/Peri-Implant Disease: A Contemporaneous Review. *Int Dent J* 2024;74:426–45.
  11. Saadaoui M, Singh P, Al Khodor S. Oral microbiome and pregnancy: A bidirectional relationship. *J Reprod Immunol* 2021;145:103293.
  12. Apatzidou D A. The role of cigarette smoking in periodontal disease and treatment outcomes of dental implant therapy. *Periodontol* 2000 2022;90:45–61.
  13. Chaffee B W, Couch E T, Vora M V, Holliday R S. Oral and periodontal implications of tobacco and nicotine products. *Periodontol* 2000 2021;87:241–53.
  14. Peruzzo D C., Benatti B B., Ambrosano G M.B., Nogueira-Filho G R., Sallum EA., Casati M Z., et al. A Systematic Review of Stress and Psychological Factors as Possible Risk Factors for Periodontal Disease. *J Periodontol* 2007;78:1491–504.
  15. Pihlstrom B L, Michalowicz B S, Johnson N W. Periodontal diseases. *The Lancet* 2005;366:1809–20.
  16. Pihlstrom B, Michalowicz B, Johnson N. Periodontal diseases. *Lancet* 2005;366:1809–20.
  17. Kinane D, Stathopoulou P, Papapanou P. Periodontal diseases. *Nat Rev Primers* 2017;3:17038.
  18. Highfield J. Diagnosis and classification of periodontal disease. *Aust Dent J* 2009;54 Suppl 1:S11-26.
  19. Page R. Gingivitis. *J clin periodontol* 1986;13:345–59.

## References

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20. Slots J. Periodontitis: facts, fallacies and the future. *Periodontol* 2000 2017;75:7–23.
21. Heitz-Mayfield L. Conventional diagnostic criteria for periodontal diseases (plaque-induced gingivitis and periodontitis). *Periodontol* 2000 2024;95:10–9.
22. Chinger G, Hadidjah D, Rusminah N. Comparison effectiveness between cetylpyridinium chloride and triclosan mouthwash on plaque. *Padjadjaran Journal of Dentistry* 2012;24.
23. Soldo M, Matijević J, Malčić Ivanišević A, Čuković-Bagić I, Marks L, Nikolov Borić D, et al. Impact of oral hygiene instructions on plaque index in adolescents. *Cent Eur J* 2020;28:103–7.
24. Jeong J, Kim K, Gu Y, Yoon D, Zhang M, Wang L, et al. Deep learning for automated dental plaque index assessment: validation against expert evaluations. *BMC Oral Health* 2025;25:1000.
25. Chinger G, Hadidjah D, Rusminah N. Comparison effectiveness between cetylpyridinium chloride and triclosan mouthwash on plaque. *Padjadjaran Journal of Dentistry* 2012;24.
26. Tobias G, Spanier A. Modified Gingival Index (MGI) Classification Using Dental Selfies. *Applied Sciences* 2020;10:8923.
27. Elena V, Luisa T, Elena L, Massimo C. Chlorhexidine (CHX) in dentistry: state of the art. *Minerva Stomatol* 2012;61:399–419.
28. Paavai I, Arulpari M, Medona M, Abirami T. CHLORHEXIDINE-A MIRACLE MOLECULE. *Int J Curr Res Rev* 2013;5:26–30.
29. Yaghobee S, Dorkoosh F A, Kouhestani F, Mozafari G, AslRoosta H. Comparison of 0.2% chlorhexidine mouthwash with and without anti-discoloration system in patients with chronic periodontitis: A randomized controlled clinical trial. *Journal of Advanced Periodontology & Implant Dentistry* 2019;11:63–8.

## References

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30. Vu M, Rajgopal B H, Cahill J, Toholka R, Nixon R. Immediate hypersensitivity to chlorhexidine. *Australasian Journal of Dermatology* 2018;59:55–6.
31. Pemberton M N, Gibson J. Chlorhexidine and hypersensitivity reactions in dentistry. *Br Dent J* 2012;213:547–50.
32. Boyapati R, Peeta J, Dhulipalla R, Kolaparthi L, Adurty C, Cheruvu R N S. Comparative evaluation of the efficacy of probiotic, Aloe vera, povidine-iodine, and chlorhexidine mouthwashes in the treatment of gingival inflammation: A randomized controlled trial. *Dent Med Probl* 2024;61:181–9.
33. Poppolo D F, Ouanounou A. Chlorhexidine in Dentistry: Pharmacology, Uses, and Adverse Effects. *Int Dent J* 2022;72:269–77.
34. James P, Worthington H V, Parnell C, Harding M, Lamont T, Cheung A, et al. Chlorhexidine mouthrinse as an adjunctive treatment for gingival health. *Cochrane Database of Systematic Reviews* 2017;2021.
35. Wiegand A, Stock A, Attin R, Werner C, Attin T. Impact of the acid flow rate on dentin erosion. *J Dent* 2007;35:21–7.
36. Zhao T, Li C, Wang S, Song X. Green Tea (*Camellia sinensis*): A Review of Its Phytochemistry, Pharmacology, and Toxicology. *Molecules* 2022;27:3909.
37. Fadel H T, AlRehaili A M, AlShanqiti M M, Alraddadi A A, Albolowi A M. Adjunctive Effect of Green Tea Mouthwash Prepared at Different Steeping Temperatures on Gingivitis: A Triple-Blind Randomized Controlled Clinical Trial. *Dent J (Basel)* 2021;9:139.
38. Vyas T, Nagi R, Bhatia A, Bains S K. Therapeutic effects of green tea as an antioxidant on oral health- A review. *J Family Med Prim Care* 2021;10:3998–4001.

## References

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39. Hattarki S A, Bogar C, Bhat K G. Green Tea Catechins showed Antibacterial Activity on Streptococcus Mutans –An In Vitro Study. *Indian Journal of Dental Research* 2021;32:226–9.
40. Rengaraj S, Thilagar S S, Yadalam P K, Pampani P, Mani E, Ardila C M. Evaluation of the clinical efficacy of green tea extract gel as local drug delivery for periodontitis. *World J Exp Med* 2025;15.
41. Abood R S, Al-Taweel F B H, Akram H M, Abdulbaqi H R. Does Daily Intake of Matcha Tea Enhance The Periodontal Health of Patients With Localised Gingivitis: A Control Study. *Oral Health Prev Dent* 2025;23:535–41.
42. Vyas T, Nagi R, Bhatia A, Bains S K. Therapeutic effects of green tea as an antioxidant on oral health- A review. *J Family Med Prim Care* 2021;10:3998–4001.
43. Tafazoli A, Tafazoli Moghadam E. Camellia Sinensis Mouthwashes in Oral Care: a Systematic Review. *J Dent (Shiraz)* 2020;21:249–62.
44. Sharma P, Chandrashekar B R, Mruthunjaya K, Bhaskar V. Evaluation of the effectiveness of green tea mouth rinse on oral halitosis, tongue coating, and plaque accumulation in comparison with 0.2% chlorhexidine mouth rinse – A double-blind randomized control trial. *J Indian Soc Periodontol* 2023;27:308–14.
45. Andhare M G, Shetty S, Vivekanandan, Shett RM, Rahman B, Shetty S R, et al. Clinical efficacy of green tea, aloe vera and chlorhexidine mouthwashes in the treatment of dental biofilm induced gingivitis: A multi-arm, double-blinded, randomized controlled clinical trial. *Int J Dent Hyg* 2024;22:504–13.
46. Paczkowska-Walendowska M, Grzegorzewski J, Kwiatek J, Leśna M, Cielecka-Piontek J. Green Tea: A Novel Perspective on the Traditional Plant's Potential in Managing Periodontal Diseases. *Pharmaceuticals (Basel)* 2025;18.

## Appendices

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**Al-Mustaqbal University**  
**College of Dentistry**  
**Dental teaching clinics**  
**Periodontics clinic**  
**2025-2026**



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4<sup>th</sup> Student name:

group:

Date:

Patient name:

Age:

Gender:

Job:

Address:

mouthwash:

The patient telephone:

The student telephone:

---

Medical history:

Systemic Disease (if exists):

medication:

Sensitivity to certain substance (allergies):

---

dental history:

Pervious dental treatment:

Teeth brushing: Yes / No frequency:

Dental aids:

(for female) is the patient pregnant: Yes / No

Plaque index

Gingival index

---

**0** No plaque

**0** No swelling

**1** Thin visible plaque, difficult to identify

**1** Mild swelling, no bleeding after gentle probing

**2** Thick visible plaque, easily detected

**2** Moderate to severe gingival swelling, bleeding after air drying

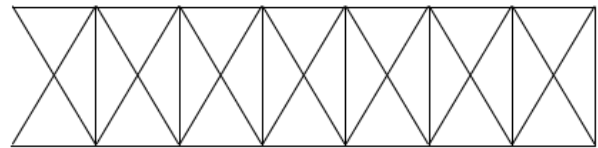
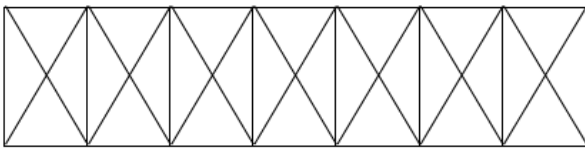
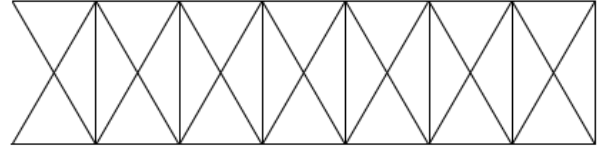
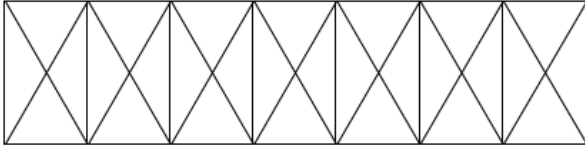
**3** Presence of plaque filling the interproximal region

**3** Severe inflammation; redness and edema. Ulceration. Spontaneous bleeding tendency

# Appendices

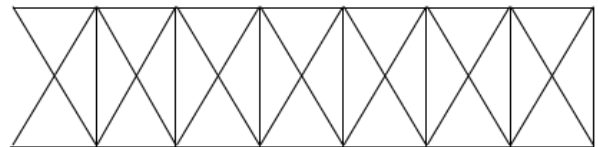
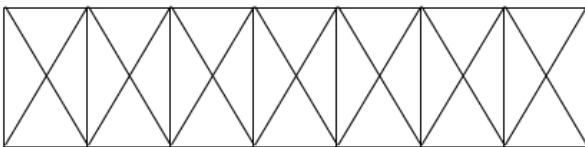
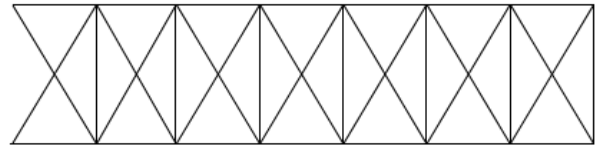
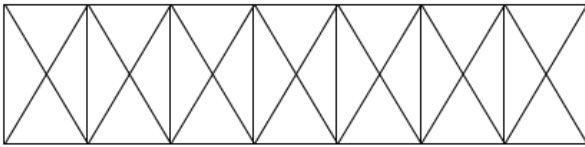
## First visit

Plaque index:



Total score:

Gingival index:



$$\text{BOP \%} = \frac{\text{Bleeding sites}}{(\text{Number of available teeth} \times 6)} \times 100$$

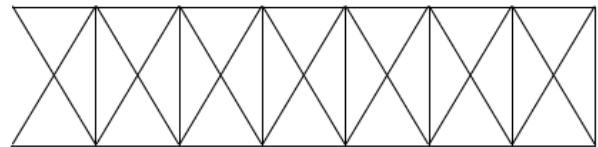
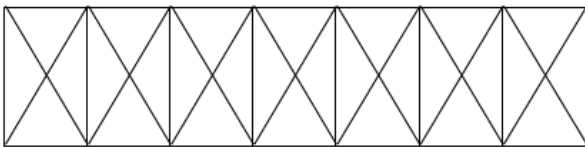
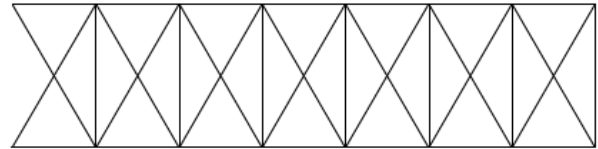
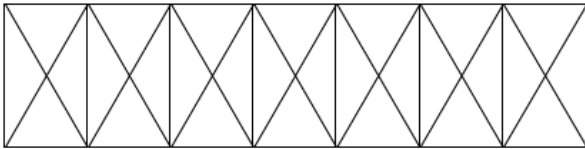
BOP (%):

Max.	17	16	15	14	13	12	11	21	22	23	24	25	26	27
Facial														
Palatal														
Lingual														
Facial														
Mand.	47	46	45	44	43	42	41	31	32	33	34	35	36	37

# Appendices

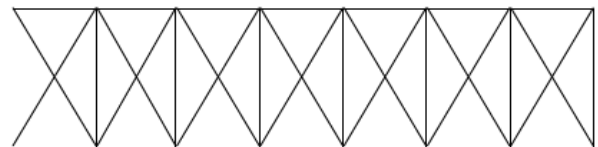
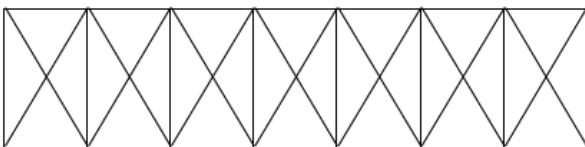
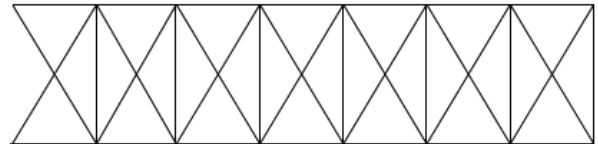
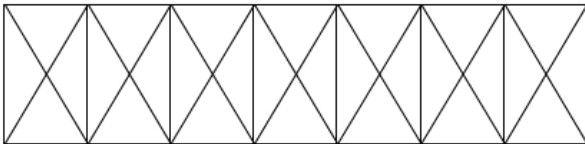
## second visit

Plaque index:



Total score:

Gingival index:



$$\text{BOP \%} = \text{Bleeding sites} / (\text{Number of available teeth} * 6) = ? * 100$$

BOP (%):

Max.	17	16	15	14	13	12	11	21	22	23	24	25	26	27
Facial														
Palatal														
Lingual														
Facial														
Mand.	47	46	45	44	43	42	41	31	32	33	34	35	36	37

### الموافقة الخاصة بالعلاج

1. أؤكد موافقتي على خطة العلاج المخصصة لي حيث أني قرأت وفهمت ووافقت على

فقرات الموضحة في خطة العلاج ضمن بحث تخرج الطالب

2. أؤكد انه اتاحت الفرصة الكاملة لاستفسار حول نوع وطريقة العلاج وقد تم إجابة كل

استفساراتي

3. أؤكد بأنني اخضع للعلاج بمحض ارادتي ولي كامل الحق بالانسحاب باي وقت بدون

تبعات قانونية

4. اسمح للطالب بأخذ الاشعة السينية المطلوبة والتقاط الصور الخاصة بالعلاج ويكون

العلاج تحت اشراف الطبيب المختص

اسم المريض والتوقيع

اسم الطالب والتوقيع