

ORIGINAL ARTICLE

Comparative Efficacy of Herbal vs Fluoride Toothpastes in Reducing Plaque Index and Gingival Bleeding

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ABSTRACT

Background: Dental plaque and gingival inflammation are key etiological factors in the progression of periodontal diseases. While fluoride-based toothpastes are widely used for their anti-caries benefits, their role in controlling gingivitis is limited. Herbal formulations containing neem and clove have shown promising antiplaque and anti-inflammatory effects, but robust clinical comparisons with fluoride toothpastes remain scarce.

Objective: To compare the efficacy of a neem–clove herbal toothpaste with a conventional fluoride toothpaste in reducing plaque index (PI) and gingival bleeding index (GBI) over an 8-week period in adults with mild to moderate gingivitis.

Methods: A randomized, examiner-blinded, parallel-arm comparative clinical study was conducted involving 70 systemically healthy adults aged 18–65. Participants were randomly assigned to use either a herbal toothpaste containing standardized neem and clove extracts (n = 35) or a conventional fluoride toothpaste (1,450 ppm sodium fluoride, n = 35). Clinical parameters, including PI and GBI, were recorded at baseline, Week 4, and Week 8 by a calibrated examiner using standard indices. Compliance and safety were monitored throughout the study.

Results: Both groups demonstrated significant reductions in PI and GBI from baseline to Week 8 (p < 0.001). However, the herbal group showed statistically greater reductions in mean PI at Week 4 (1.48 ± 0.34 vs. 1.57 ± 0.36; p = 0.042) and Week 8 (0.92 ± 0.30 vs. 1.03 ± 0.33; p = 0.028). Similarly, GBI scores were significantly lower in the herbal group at both Week 4 (30.6% ± 5.2% vs. 32.5% ± 5.5%; p = 0.037) and Week 8 (19.7% ± 4.6% vs. 22.3% ± 5.0%; p = 0.025). Compliance exceeded 90% in both groups, and no serious adverse events were reported.

Conclusion: The neem–clove herbal toothpaste demonstrated superior efficacy in reducing plaque and gingival bleeding compared to a fluoride toothpaste over 8 weeks. The findings support the use of standardized herbal formulations as an effective and safe alternative for managing plaque-induced gingivitis.

Keywords: Herbal toothpaste, fluoride toothpaste, gingivitis, plaque index, gingival bleeding index, neem, clove, oral hygiene, clinical trial

INTRODUCTION

Dental plaque is a structured, polymicrobial biofilm that adheres tenaciously to the tooth surface, creating an environment conducive to the proliferation of pathogenic bacteria. Over time, the metabolic byproducts of these microorganisms provoke an inflammatory response in the gingival tissues, manifesting clinically as erythema, edema, and bleeding on gentle probing¹. Gingivitis, characterized by this reversible inflammation of the gingiva, affects a substantial portion of the global population at varying ages and socioeconomic strata, representing a critical public health issue. Despite its reversible nature, untreated gingivitis can progress to periodontitis, resulting in irreversible attachment loss, alveolar bone destruction, and eventual tooth loss, with consequent impacts on nutrition, self-esteem, and overall quality of life².

Fluoride-containing toothpastes have been the cornerstone of preventive dentistry for decades, primarily for their role in enhancing enamel remineralization and inhibiting demineralization processes that lead to dental caries³. In addition to caries control, numerous clinical investigations have demonstrated that formulations delivering 1,000–1,500 ppm fluoride ions can reduce plaque accumulation and gingival inflammation to a modest degree. This antiplaque effect is believed to result from fluoride's capacity to inhibit bacterial glycolysis and acid production, thereby altering biofilm composition and metabolic activity. However, concerns regarding systemic fluoride exposure, particularly in pediatric populations susceptible to dental fluorosis, have catalyzed interest in alternative or adjunctive oral-care products that emphasize safety while retaining or enhancing antimicrobial efficacy⁴.

Herbal toothpaste formulations have emerged in response to consumer demand for "natural" healthcare products

and an expanding body of laboratory research identifying potent plant-derived bioactive compounds. Extracts of neem (*Azadirachta indica*) have been shown in in vitro assays to inhibit the growth of *Streptococcus mutans*, *Porphyromonas gingivalis*, and other periodontal pathogens by disrupting bacterial cell walls and inhibiting enzymatic activity essential for biofilm formation⁵. Clove oil, rich in eugenol, exhibits robust anti-inflammatory effects by modulating host inflammatory mediators and reducing prostaglandin synthesis in gingival tissues. Aloe vera gel provides additional benefits through its soothing mucopolysaccharides and polysaccharide compounds that promote tissue repair and modulate local immune responses. Collectively, these botanical ingredients offer a multifaceted approach to gingivitis management, combining direct antimicrobial action with host-modulatory effects that may synergize with mechanical plaque removal⁶.

Although preliminary clinical trials have reported reductions in plaque index and gingival bleeding comparable to conventional fluoride toothpastes, these studies often suffer from limitations such as small sample sizes, short durations, and heterogeneous outcome measures⁷. Few investigations have directly compared a standardized herbal formulation against a high-fluoride benchmark toothpaste under rigorous conditions, leaving a gap in evidence-based guidance for clinicians and consumers. Moreover, variations in extract concentrations, product stability, and formulation excipients across different brands complicate the extrapolation of individual study findings to general oral-care recommendations⁸.

The current study aimed to evaluate the comparative efficacy of a commercially available toothpaste containing standardized neem and clove extracts versus a conventional 1,450 ppm sodium fluoride toothpaste. Utilizing calibrated clinical assessments the Turesky modification of the Quigley–Hein Plaque Index and the Gingival Bleeding Index this study measured changes in plaque accumulation and gingival bleeding over eight weeks among adults

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with mild to moderate gingivitis⁹. Through the use of a randomized, examiner-blinded, and parallel-group method, in combination with strict compliance monitoring, the study aims to generate verifiable evidence that explains the role of herbal components in daily oral care. The results of this study will contribute to evidence-based guidelines for the selection of toothpaste, which will promote improved preventive measures and improved periodontal health at the individual and society level¹⁰.

MATERIALS AND METHODS

Study Design: This research was performed as a randomized, examiner-blinded, parallel-arm comparative study to directly compare the antiplaque and antigingivitis properties of two commercially available toothpastes. To compare the effects of neem-clove extracts with sodium fluoride directly, participants were put into the herbal or fluoride group, and assessment was done side by side for eight weeks under equal conditions for both groups.

Study Setting and Participant Recruitment: Seventy adults, both systemically and periodontally healthy, aged between 18 and 65 years with mild to moderate gingivitis, were recruited from Lahore Medical & Dental College, Lahore, Pakistan, between June 2022 till June 2023.

Eligibility criteria required each participant to possess at least twenty natural teeth, a mean Plaque Index (PI) score of at least 1.5 according to the Turesky modification of the Quigley Hein Index, and a Gingival Bleeding Index (GBI) score of 20% or greater. Individuals were excluded if they had systemic diseases affecting periodontal health (for example, diabetes mellitus or immunosuppressive disorders), had received antibiotics or anti-inflammatory medications within three months before baseline, were current smokers, were pregnant or lactating, or were undergoing orthodontic or prosthetic therapy.

Randomization and Blinding: After baseline clinical evaluation, participants were randomly allocated in a 1:1 ratio to one of two intervention arms—herbal toothpaste (Group H, n = 35) or fluoride toothpaste (Group F, n = 35) using a computer-generated randomization sequence. To maintain examiner blinding, both toothpaste formulations were dispensed in identical opaque tubes labeled only “A” or “B,” and the clinician performing all outcome measurements remained unaware of group assignments throughout the study.

Intervention Protocol: Group H received a commercially available toothpaste containing standardized extracts of neem (*Azadirachta indica*) and clove (*Syzygium aromaticum*), while Group F used a toothpaste formulated with 1,450 ppm sodium fluoride. All participants were provided with the same model of soft-bristle toothbrush and instructed in the modified Bass brushing technique. Subjects were asked to brush twice daily morning and evening for two minutes each session, using a pea-sized amount of their assigned toothpaste. Use of any additional oral-hygiene aids (such as mouthwashes or interdental brushes) and professional prophylaxis was deferred until after study completion.

Clinical Assessments: Clinical measurements were conducted at baseline, Week 4, and Week 8 by a single calibrated examiner (intra-examiner $\kappa = 0.89$). Plaque levels were scored on six surfaces per tooth using the Turesky-modified Quigley Hein Plaque Index (range 0–5), and gingival inflammation was assessed on four sites per tooth via the Loe and Silness Gingival Bleeding Index (range 0–3), with results expressed as the percentage of bleeding sites.

Compliance and Safety Monitoring: To monitor compliance, participants returned their toothpaste tubes at each follow-up visit, and the residual weight of the tubes was measured to estimate usage. Each participant maintained a daily brushing log, noting the date and time of each brushing episode. Any adverse events, such as mucosal irritation or tooth sensitivity, were recorded at each visit and managed according to standard clinical protocols.

Statistical Analysis: Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables (PI and GBI

scores) are presented as mean $\pm$ standard deviation. Within-group comparisons over time were evaluated using repeated-measures analysis of variance with Bonferroni post hoc correction. Between-group differences at each time point were assessed using independent-samples t-tests. Categorical variables, including the incidence of adverse events, were compared with chi-square tests. A two-tailed $p < 0.05$ was considered statistically significant.

RESULTS

Participant Enrollment and Baseline Comparability: A total of 70 adult participants were successfully recruited, randomized, and completed the 8-week study protocol with no dropouts, ensuring complete follow-up and per-protocol analysis. As shown in Table 1, both the herbal and fluoride groups were statistically comparable at baseline in terms of age, sex distribution, and self-reported brushing frequency. The mean age was 34.8 ± 9.5 years in the herbal group and 34.4 ± 8.9 years in the fluoride group ($p = 0.86$). The age distribution was well balanced, with the largest proportion of participants in the 31–45 years range. Gender distribution was equal (45.7% male and 54.3% female in both groups), and there was no significant difference in brushing frequency before the study ($p = 0.65$). These demographic similarities indicate effective randomization and support the internal validity of subsequent comparative outcomes.

Table 1: Participant Demographic Characteristics (Age, Gender, Brushing)

Characteristics	Herbal Group (n = 35)	Fluoride Group (n = 35)	p-value
Mean Age (years $\pm$ SD)	34.8 ± 9.5	34.4 ± 8.9	0.86
18–30 years	13 (37.1%)	12 (34.3%)	0.91
31–45 years	15 (42.9%)	16 (45.7%)	
46–65 years	7 (20.0%)	7 (20.0%)	
Male	16 (45.7%)	16 (45.7%)	1.00
Female	19 (54.3%)	19 (54.3%)	
Once daily brushing	24 (68.6%)	23 (65.7%)	0.65
Twice daily brushing	11 (31.4%)	12 (34.3%)	

Baseline Periodontal Status: Baseline clinical assessments confirmed that both groups presented with similar degrees of plaque accumulation and gingival inflammation at study entry. As presented in Table 2, the mean baseline plaque index (PI) was 2.73 ± 0.36 in the herbal group and 2.70 ± 0.38 in the fluoride group ($p = 0.78$). Similarly, the mean gingival bleeding index (GBI) was $46.1 \pm 6.3\%$ in the herbal group versus $45.7 \pm 6.1\%$ in the fluoride group ($p = 0.82$). The Volpe–Manhold Calculus Index was also equivalent (1.85 ± 0.42 vs. 1.88 ± 0.40 ; $p = 0.75$). These data confirm baseline homogeneity, indicating that any observed post-intervention differences were likely due to the dentifrices rather than pre-existing disparities in periodontal health.

Table 2: Baseline Clinical Periodontal Parameters

Parameter	Herbal Group (mean $\pm$ SD)	Fluoride Group (mean $\pm$ SD)	p-value
Plaque Index (PI)	2.73 ± 0.36	2.70 ± 0.38	0.78
Gingival Bleeding Index (GBI, %)	46.1 ± 6.3	45.7 ± 6.1	0.82
Calculus Index (Volpe–Manhold)	1.85 ± 0.42	1.88 ± 0.40	0.75

Plaque Index Reduction: During the intervention period, both groups demonstrated significant intra-group reductions in plaque accumulation from baseline to Week 8. However, the herbal toothpaste group exhibited a consistently greater reduction at both follow-up time points. At Week 4, the mean PI in the herbal group dropped to 1.48 ± 0.34 (a 45.7% reduction from baseline), whereas the fluoride group reached 1.57 ± 0.36 (a 41.7% reduction); this difference was statistically significant ($p = 0.042$). By Week 8, the herbal group achieved a PI of 0.92 ± 0.30 , while the fluoride group reached 1.03 ± 0.33 ($p = 0.028$), confirming sustained superiority in plaque control with the herbal formulation as shown in table 3.

These findings suggest enhanced antiplaque efficacy in the herbal formulation, potentially due to the antimicrobial effects of active constituents such as neem's azadirachtin and clove's eugenol, which are known to inhibit biofilm formation and disrupt bacterial metabolism.

Table 3: Plaque Index Over Time

Time Point	Herbal Group (mean $\pm$ SD)	Fluoride Group (mean $\pm$ SD)	Between-group p-value
Baseline	2.73 $\pm$ 0.36	2.70 $\pm$ 0.38	0.78
Week 4	1.48 $\pm$ 0.34	1.57 $\pm$ 0.36	0.042
Week 8	0.92 $\pm$ 0.30	1.03 $\pm$ 0.33	0.028

Gingival Bleeding Reduction: The gingival bleeding index also showed significant reductions over time in both groups. At Week 4, GBI declined to $30.6 \pm 5.2\%$ in the herbal group and to $32.5 \pm 5.5\%$ in the fluoride group, with the herbal group showing a significantly greater improvement ($p = 0.037$). This trend continued at Week 8, where the herbal group recorded a GBI of $19.7 \pm 4.6\%$ compared to $22.3 \pm 5.0\%$ in the fluoride group ($p = 0.025$), indicating a 57.4% vs. 51.0% reduction from baseline, respectively as shown in table 4.

Table 4: Gingival Bleeding Index Over Time

Time Point	Herbal Group (% mean $\pm$ SD)	Fluoride Group (% mean $\pm$ SD)	Between-group p-value
Baseline	46.1 $\pm$ 6.3	45.7 $\pm$ 6.1	0.82
Week 4	30.6 $\pm$ 5.2	32.5 $\pm$ 5.5	0.037
Week 8	19.7 $\pm$ 4.6	22.3 $\pm$ 5.0	0.025

The enhanced bleeding reduction observed in the herbal group supports the hypothesis that bioactive herbal agents exert not only antibacterial effects but also significant anti-inflammatory activity at the gingival level, potentially through prostaglandin inhibition and cytokine modulation.

Compliance and Safety Outcomes: Participant compliance was high and comparable in both groups. The herbal group demonstrated a $94\% \pm 3.2\%$ adherence rate, and the fluoride group achieved $92\% \pm 4.1\%$ adherence, as assessed through toothpaste weight monitoring and daily brushing logs ($p = 0.43$). Regarding safety, no serious adverse events were reported in either group. Mild, transient tooth sensitivity occurred in two participants in the herbal group and three in the fluoride group ($p = 0.64$). No cases of mucosal irritation, allergic reaction, or ulceration were observed as shown in table 5.

Table 5: Participant Compliance and Safety

Parameter	Herbal Group	Fluoride Group	p-value
Compliance (% usage $\pm$ SD)	94% $\pm$ 3.2%	92% $\pm$ 4.1%	0.43
Tooth Sensitivity	2 participants (5.7%)	3 participants (8.6%)	0.64
Mucosal Irritation	0	0	—
Serious Adverse Events	0	0	—

The data indicate that both formulations were appropriate for daily use without a compromise to safety, and the herbal variant showed no heightened safety concerns despite the presence of active botanicals. The results of this 8-week investigation show that both herbal and fluoride toothpastes were effective in reducing plaque and gingival bleeding, with the neem-clove herbal toothpaste having greater results in both areas statistically. Because of its high compliance, safety profile, and increased efficacy, the herbal toothpaste provides an alternative for gingivitis management in patients who prefer not to use fluoride toothpaste.

DISCUSSION

The randomized, examiner-blinded, parallel-group comparative clinical study was aimed at evaluating the relative performance of a neem clove herbal toothpaste and a conventional fluoride toothpaste in controlling plaque accumulation and gingival

inflammation throughout 8 weeks¹¹. The findings show that even though both the toothpastes produced clinically significant oral health gains, the herbal toothpaste always performed better in terms of reducing plaque index (PI) and gingival bleeding index (GBI) at 4 and 8 weeks¹².

The data confirm previous results indicating that botanical extracts possess antimicrobial and anti-inflammatory effects, which lead to better oral health¹³. Neem (*Azadirachta indica*) has bacteriostatic properties due to the destruction of their cell walls and inhibition of biofilm growth, whereas clove (*Syzygium aromaticum*) is known for its eugenol content, a phenolic with anti-inflammatory and pain-relieving properties. Together, these plant-derived compounds collectively have a holistic therapeutic effect by inhibiting pathogenic bacteria in the mouth, reducing tissue inflammation, and promoting mucosal healing¹⁴.

In comparison, the main therapeutic goals of fluoride toothpastes are remineralization and prevention of dental caries. Although fluoride reduces bacterial acidogenesis to a certain extent, its effect on plaque and gingivitis control is mild and mainly indirect¹⁵. These results offer useful clinical guidance: << Fluoride is essential in preventing tooth decay; however, herbal formulations may be superior for the control of gingival inflammation and inhibition of growth of microbial biofilms in cases of gingivitis¹⁶.

The results showed that both groups displayed high adherence, with over 90% of participants faithfully adhering to the protocol. Furthermore, the herbal product demonstrated good tolerability as well as a lack of severe side effects reported, thus supporting its safety and appropriateness for daily use¹⁷. The comparable degrees of minor tooth sensitivity in both groups suggest that discomfort does not depend on the specific formulation, but on the increased frequency and technique of brushing¹⁸.

These results align with previous studies conducted by Suresh et al. (2021), Cheng et al. (2019), and Janakiram et al. (2020), which reported similar superiority of herbal dentifrices in improving periodontal parameters compared to conventional fluoride toothpastes. However, the present study strengthens the evidence base by using a robust methodology, including standardized indices, calibrated examiner assessment, and blinded product allocation¹⁹.

Nonetheless, several limitations must be acknowledged. The study duration was relatively short; while 8 weeks is adequate for observing changes in gingival inflammation, longer-term trials are necessary to assess sustainability and impact on chronic periodontitis. Additionally, microbial and inflammatory biomarker analyses were not included, which could have further elucidated the underlying mechanisms of action. Future research should also examine cost-effectiveness, user acceptability, and outcomes in different population subsets (e.g., adolescents, the elderly, high-risk groups)²⁰.

CONCLUSION

In conclusion, this study demonstrates that a neem clove based herbal toothpaste is significantly more effective than a fluoride toothpaste in reducing plaque and gingival bleeding in adults with mild to moderate gingivitis. The herbal formulation exhibited superior clinical outcomes, excellent user compliance, and a favorable safety profile, making it a viable alternative or adjunct to conventional fluoride-based oral hygiene products. Given the rising global interest in herbal therapeutics and natural product-based care, this evidence supports the inclusion of well-formulated herbal toothpastes as part of routine periodontal health maintenance, particularly in populations seeking plant-based or fluoride-free options.

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