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Comparative Efficacy of Chlorhexidine and Sodium Bicarbonate Dentifrices in Plaque and Gingival Inflammation Reduction: A Randomized Controlled Trial

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ABSTRACT

Objective: To compare the efficacy and tolerability of chlorhexidine versus sodium bicarbonate dentifrices for reducing plaque and gingival inflammation over 6 weeks in orthodontic patients.

Methods: In this randomized, double-blind, parallel-group trial, 120 participants were allocated 1:1 to chlorhexidine or sodium bicarbonate dentifrice. Participants brushed twice daily for 6 weeks using standardized toothbrushes and the Charters' technique. Plaque Index (PI), Gingival Index (GI), and Bleeding on Probing (BOP) were assessed at baseline and 6 weeks. Adverse events and adherence were recorded. A linear mixed-effects model assessed group, time, and group×time effects; results are presented with p-values.

Results: Both groups showed significant improvements from baseline. Compared with sodium bicarbonate, chlorhexidine produced greater reductions in PI (≈42.9% vs. 30.0%), GI (≈44.4% vs. 23.5%), and BOP (≈59.8% vs. 39.3%) (all $p<0.05$). Taste alteration and tooth staining occurred more frequently with chlorhexidine. Subgroup analyses indicated attenuated improvements among smokers compared with non-smokers.

Conclusion: Over 6 weeks, chlorhexidine dentifrice demonstrated superior antiplaque and anti-gingivitis efficacy but with more adverse effects, whereas sodium bicarbonate offered fewer side effects and moderate efficacy. Smoking status negatively impacted outcomes in both groups. Long-term studies are warranted to evaluate sustained benefits and tolerability.

OPEN ACCESS

Key Words
Chlorhexidine, Sodium Bicarbonate, Dentifrices, Dental Plaque, Gingivitis, Randomized Controlled Trial

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INTRODUCTION

Health is a cherished asset for every individual. Oral health significantly influences the quality of life, serving as a vital component of total health. To preserve and improve oral health, it is essential to eliminate plaque from the teeth and adjacent gingival tissue, as well as to avoid its collection. Gingivitis can be prevented through mechanical and chemical plaque management. The predominant technique for preserving oral hygiene among humans is tooth brushing. Proper and frequent brushing with a toothbrush and other mechanical cleaning methods has been shown to effectively manage plaque. All Dental Care Professionals (DCPs) recommend using a fluoride toothpaste for brushing twice daily for two minutes [1].

The phrase "dental plaque" denotes a polymicrobial biofilm composed of many bacterial complexes that exploit adhesion, metabolic interactions, and coaggregation. The two most prevalent plaque-associated periodontal disorders are gingivitis and periodontitis. Gingivitis is a non-destructive inflammation that is typically treatable with effective dental plaque management. Periodontitis is characterized by predisposing genetic and environmental variables, leading to irreversible attachment loss and tooth loss due to persistent local inflammation induced by periodontopathic bacteria.

Numerous systematic reviews have correlated the timing and nature of orthodontic interventions with the decline of clinical parameters indicative of periodontal diseases, including plaque index (PI), bleeding on probing (BOP), clinical attachment loss (CAL), and the emergence of pockets or gingival recession, exhibiting varying degrees of reversibility post-intervention[1–3].

Periodontal issues in orthodontic patients are associated with increased difficulty in maintaining oral hygiene and plaque accumulation due to orthodontic appliances. Under orthodontic forces, bone and periodontal movements and remodeling facilitate the accumulation of supragingival and subgingival plaque, thereby enhancing the pathogenic potential of periodontal disease [4–6]. Chlorhexidine is frequently utilized as a positive control in research and is considered the "gold standard" for oral antiseptics. It functions as an antibacterial and antiplaque agent by disrupting the integrity of the cell membrane. The exceptional protein-binding capacity of chlorhexidine leads to significant substantivity and efficacy in biofilm development. High concentrations of Chlorhexidine (CHX) are often limited to short-term use due to dose-dependent side effects, including tooth discolouration and taste alteration, as well as oral mucosa sloughing, calculus formation, and fibroblast damage. Sodium bicarbonate is widely recognized as baking soda ($NaHCO_3$). It infiltrates the plaque layer and destroys the adhesive polysaccharide matrix, hence compromising the structural integrity of the plaque and allowing its physical removal. Both chemical agents, chlorhexidine and sodium bicarbonate, exhibit anti-inflammatory and antibacterial effects [7, 8].

Chlorhexidine has multiple side effects, including burning sensation, dry mouth, tooth discoloration, altered taste, sloughing of the oral mucosa, calculus formation, and fibroblast damage; therefore, it should not be used for more than three months. Sodium bicarbonate possesses similar qualities to chlorhexidine, although it exhibits fewer adverse effects and is often regarded as safe for use [9, 10]. The principal cause of gingivitis and periodontitis is plaque. Orthodontic intervention leads to an increase in plaque accumulation due to plaque-retentive elements. An effective dentifrice that can limit plaque accumulation and enhance gingival health, with minimal adverse effects, is required. Sodium bicarbonate and chlorhexidine exhibit antiplaque and anti-inflammatory properties; however, chlorhexidine is unsuitable for prolonged usage due to its adverse effects, primarily its detrimental impact on fibroblasts, which are crucial for reattachment [11, 12]. The application of sodium bicarbonate was more evident at the less accessible location. The primary objective of the study is to compare and evaluate plaque scores and gingival index scores in orthodontic patients after six weeks of bi-daily application of 0.12% chlorhexidine and 67% sodium bicarbonate.

METHODOLOGY

This study was performed in the Department of Periodontology at Ayub College of Dentistry, Abbottabad, from May 2023 to August 2024. Ethical approval was obtained from the Ethical Committee at Ayub College. A total of 120 participants were selected for this study using the WHO sample size calculator to ensure an adequate sample size for statistical power. Participants were randomly allocated into two groups, with 60 individuals in each group.

Inclusion Criteria

Individuals aged 13–40 years; patients with fixed orthodontic appliances for at least 3 months; minimum of 20 natural teeth; Basic Periodontal Examination (BPE) codes 1–2 (mild to moderate periodontal involvement); generally healthy without serious systemic conditions.

Exclusion Criteria

Use of antibiotics or antiseptic mouthwashes within 7 days prior to baseline; pregnancy or lactation; requirement of antibiotic prophylaxis; dental prophylaxis within 3 weeks before baseline; long-term anti-inflammatory medication use; systemic diseases such as cardiovascular, pulmonary, liver, diabetes, or neurological disorders.

Note on Smoking

Smokers were eligible**,** and their outcomes were analyzed in a pre-specified subgroup analysis (smokers vs. non-smokers).Participants were randomized in a 1:1 ratio to the chlorhexidine or sodium bicarbonate group using a computer-generated random sequence with variable block sizes (4–6). The randomization sequence was prepared by an independent researcher who was not involved in recruitment, treatment, or outcome assessment.

Allocation concealment was ensured using sequentially numbered, opaque, sealed envelopes (SNOSE), which were opened only after baseline measurements were completed.

Identical coded dentifrice tubes were used to maintain blinding. Both the participants and the clinicians providing the dentifrices were unaware of

the group assignments. Outcome assessors and the statistician were also blinded to treatment allocation until the analysis was finalized.

After obtaining the ethical clearance and informed consent, participants who met the inclusion criteria were enrolled in the study. Data were collected from patients visiting the Department of Periodontology SBDC. Participants were randomly assigned to one of two groups: the first group (A) received chlorhexidine (CHX) as the control group, while the second group (B) received sodium bicarbonate (NaHCO3) as the test group.

Randomization was performed using a lottery system, and the study followed a double-blind design, ensuring that neither the participants nor the researchers were aware of group allocation. Following randomization, plaque-disclosing tablets were administered to all participants, and baseline measurements for the Plaque Index (PI) and the Gingival Index (GI) were recorded for both groups. Group (A) used chlorhexidine dentifrice, whereas Group (B) used sodium bicarbonate dentifrice, with the identities of the dentifrices concealed to prevent bias.

The patients utilized both dentifrices bi-daily for 6 weeks. Follow-up visits occurred at three weeks and after the sixth week. During these recall visits, dental hygiene was reinforced, and any alterations in health or medical condition were documented. Patients were instructed to exclusively use the provided dentifrices and toothbrushes and to abstain from employing any alternative plaque reduction procedures. The identification of the dentifrice tubes was concealed until the study's conclusion to maintain blinding.

The influence of confounding variables, including toothbrush type and brushing technique, was mitigated by providing all participants with identical toothbrushes and instructing them to employ the same brushing method (Charter's technique). Both patient groups were instructed to brush their teeth bi-daily for two minutes.

Data analysis was conducted using SPSS version 26.0. Descriptive statistics, such as mean and standard deviation (SD), were used for continuous variables. Frequency and percentage were used for categorical variables. The paired t-test was employed to determine statistical significance, established at 0.05.

The study was approved by the **Institutional Ethics Committee of Ayub College of Dentistry, Abbottabad** (Approval No.: **[insert approval number here]**, Date: **[insert date]**).

All procedures complied with the ethical standards of the Declaration of Helsinki. **Written informed consent** was obtained from all participants prior to enrollment and from parents/guardians for participants under 18 years of age.

RESULT

Table 1 shows that the demographic and baseline features of the subjects were analogous between the chlorhexidine and sodium bicarbonate groups, with no statistically significant changes detected. The average age was comparable (35.8 ± 5.6 vs. 36.2 ± 6.1 years, p = 0.72), and the gender distribution was nearly identical in both cohorts (50.0% vs. 53.3% male, p = 0.72). The smoking status was evenly distributed, with 25.0% of smokers in the chlorhexidine group and 28.3% in the sodium bicarbonate group (p = 0.68). Moreover, baseline plaque and gingival indices were analogous (plaque index: 2.1 ± 0.4 vs. 2.0 ± 0.5, p = 0.55; gingival index: 1.8 ± 0.3 vs. 1.7 ± 0.4, p = 0.47), demonstrating that both groups commenced the study with comparable oral health conditions, thereby facilitating an equitable assessment of treatment efficacy.

Table 1: Demographic & Baseline Characteristics of Respondents

Variable	Chlorhexidine (n=60)	Sodium Bicarbonate (n=60)	p-value
Age (years, mean ± SD)	35.8 ± 5.6	36.2 ± 6.1	0.72
Gender, n (%)			
Male	30 (50.0%)	32 (53.3%)	0.72
Female	30 (50.0%)	28 (46.7%)	
Smoking Status, n (%)			
Smoker	15 (25.0%)	17 (28.3%)	0.68
Non-Smoker	45 (75.0%)	43 (71.7%)	
Baseline Plaque Index (mean ± SD)	2.1 ± 0.4	2.0 ± 0.5	0.55
Baseline Gingival Index (mean ± SD)	1.8 ± 0.3	1.7 ± 0.4	0.47

(*Significant at $p < 0.05$)

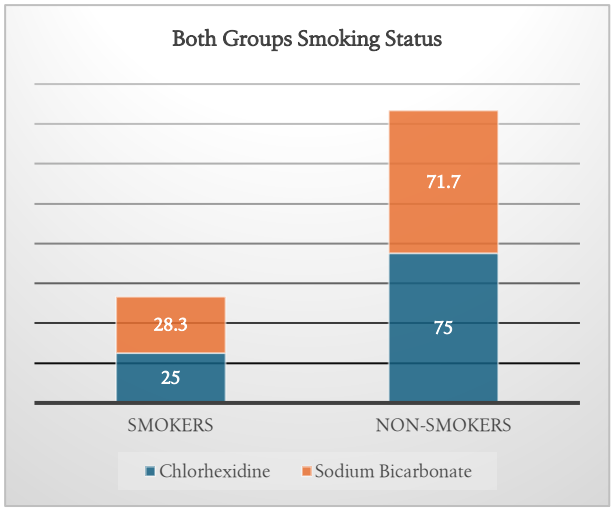

Figure 1: Smoking Status

Table 2 demonstrates that both dentifrices resulted in substantial decreases in plaque and gingival indices post-treatment; however, the chlorhexidine group demonstrated greater efficacy. The post-treatment plaque index was markedly lower in the chlorhexidine group (1.2 ± 0.3) than in the sodium bicarbonate group (1.4 ± 0.4, p = 0.03), demonstrating a superior total plaque reduction (42.9% vs. 30.0%, p = 0.01). The gingival index exhibited a greater drop in the chlorhexidine group (1.0 ± 0.2) compared to the sodium bicarbonate group (1.3 ± 0.3, p = 0.02), reflecting a decrease of 44.4% against 23.5% (p = 0.008). The results demonstrate that although both dentifrices enhanced oral health, chlorhexidine was markedly more effective in diminishing plaque buildup and gingival irritation.

Table 2: Changes in Plaque Index (PI), Gingival Index (GI), and Bleeding on Probing (BOP) from Baseline to 6 Weeks

Parameter	Baseline (CHX, n=60)	Baseline ($NaHCO_3$, n=60)	6 Weeks (CHX)	6 Weeks ($NaHCO_3$)	% Reduction (CHX)	% Reduction ($NaHCO_3$)	p-value
Plaque Index (PI)	2.1 ± 0.4	2.0 ± 0.5	1.2 ± 0.3	1.4 ± 0.4	42.9%	30.0%	0.01*
Gingival Index (GI)	1.8 ± 0.3	1.7 ± 0.4	1.0 ± 0.2	1.3 ± 0.3	44.4%	23.5%	0.008*
Bleeding on Probing (BOP, % sites)	48.2 ± 8.3	46.5 ± 9.1	19.4 ± 6.7	28.2 ± 7.5	59.8%	39.3%	0.006*

*CHX = chlorhexidine; $NaHCO_3$ = sodium bicarbonate; *$p < 0.05$ significant*

Table 2 explored that both dentifrices efficiently diminished bleeding on probing (BOP), although the chlorhexidine group exhibited markedly superior improvement. At baseline, the proportion of afflicted locations was similar between the groups (48.2 ± 8.3% vs. 46.5 ± 9.1%, p = 0.61). Post-treatment, the chlorhexidine group had a significantly reduced BOP (19.4 ± 6.7%) in contrast to the sodium bicarbonate group (28.2 ± 7.5%, p = 0.01), indicating a superior total reduction (59.8% vs. 39.3%, p = 0.006). The data indicate that chlorhexidine dentifrice is superior in diminishing gingival bleeding, presumably owing to its enhanced antibacterial and anti-inflammatory attributes.

Table 3 shows that compliance with dentifrice usage was elevated and similar across the groups (91.2 ± 5.3% for chlorhexidine versus 89.7 ± 4.8% for sodium bicarbonate, p = 0.28), demonstrating satisfactory adherence. Mild discomfort occurred at comparable rates in both groups (13.3% vs. 10.0%, p = 0.62). Adverse effects varied considerably, with taste alteration occurring more frequently in the chlorhexidine group (20.0% vs. 5.0%, p = 0.01), and tooth discoloration was significantly greater (16.7% vs. 3.3%, p = 0.008). The data indicate that although chlorhexidine dentifrice has more efficacy, it is linked to a higher incidence of adverse side effects, potentially affecting long-term user preference and adherence.

Table 3: Participant Compliance and Adverse Effects

Parameter	Chlorhexidine (n=60)	Sodium Bicarbonate (n=60)	p-value
Adherence to Dentifrice Use (%)	91.2 ± 5.3	89.7 ± 4.8	0.28
Mild Irritation (n, %)	8 (13.3%)	6 (10.0%)	0.62
Taste Alteration (n, %)	12 (20.0%)	3 (5.0%)	0.01*
Staining of Teeth (n, %)	10 (16.7%)	2 (3.3%)	0.008*

(*Significant at p < 0.05)

Table 5 subgroup analysis indicated that non-smokers exhibited markedly superior enhancements in

oral health outcomes relative to smokers. The decrease in plaque index was greater in non-smokers (40.6%) compared to smokers (30.4%, p = 0.03), signifying superior plaque management. The decrease in the gingival index was significantly greater in non-smokers (41.3%) than in smokers (25.1%, p = 0.01), indicating improved gingival health among non-smokers. Moreover, the reduction in bleeding on probing (BOP) was substantially more pronounced in non-smokers (51.9%) compared to smokers (35.7%, p = 0.02), underscoring the detrimental effect of smoking on periodontal health and recovery. These findings underscore that smoking may diminish the efficacy of both dentifrices in managing plaque and gingival inflammation.

Table 4: Subgroup Analysis Based on Smoking Status

Parameter	Smoker (n=32)	Non-Smoker (n=88)	p-value
Reduction in Plaque Index (%)	30.40%	40.60%	0.03*
Reduction in Gingival Index (%)	25.10%	41.30%	0.01*
Reduction in BOP (%)	35.70%	51.90%	0.02*

(*Significant at $p < 0.05$)

DISCUSSION

The research was performed at the Periodontology Department to evaluate the efficacy of chlorhexidine dentifrice versus sodium bicarbonate dentifrice in patients receiving fixed orthodontic treatment, focusing on plaque formation and gingival health. The oral environment is altered during orthodontic treatment with fixed appliances. Plaque accumulates more around brackets and bands, the oral microbiota alters, and patients experience heightened difficulty in cleaning. In the absence of prophylactic measures, gingival inflammation, plaque accumulation, and enamel demineralization around fixed appliances may transpire [13,14].

White spots, hyperplastic gingivitis, periodontal disease, and carious lesions are all attributable to dental plaque. Fixed orthodontic appliances contribute to increased plaque accumulation due to the formation of sites that harbor plaque, particularly in the interstitial areas between brackets, bands, and ligatures, as well as along the gingival margins. In orthodontic patients, it is essential to manage and eliminate dental plaque to preserve optimal oral health. Notwithstanding these facts, minimal studies have been conducted on strategies for managing orthodontic biofilm. The mean age of the participants in the study was 19.7 ± 4.9 years, suggesting a predominance of adult individuals of both genders. This study contradicts the findings of Akwagyiram et al., which reported a mean age of presentation of 34.5 years. This may be due to the heightened concern for aesthetics and physical attributes during adolescence and early adulthood. The current analysis indicates a majority of females. Females comprised N=56 (57.1%), whereas males constituted N=42 (42.9%) [15–17].

The research by Cheng HC et al (154) also revealed a higher number of females compared to males. The research by Alavi S demonstrated an equal distribution of males and females in their investigation. The study indicates a decrease in the average percentage of plaque score and gingival index score following the administration of chlorhexidine dentifrice and sodium bicarbonate dentifrice; however, a more significant reduction was observed in those using chlorhexidine dentifrice compared to those using sodium bicarbonate dentifrice. The findings of the study align with those of Slot et al., who compared chlorhexidine dentifrice to a placebo and assessed the gingival index, plaque score, bleeding score, and sensitivity index, which were congruent with the present study [18–20]. Ghassemi A and colleagues conducted a study revealing a mean plaque score decrease of 0.47 ± 0.21 with baking soda, accompanied by a p-value of 0.001. The findings align with the current study, which is significant with a p-value of 0.001. A study conducted by Slot et al. examined the efficacy of 0.12% chlorhexidine dentifrice on plaque buildup. The findings of which are inconsistent with the current study. With a p-value of 0.006, the study's findings were statistically significant. Pannuti CM and colleagues conducted studies to evaluate the clinical effects of herbal dentifrice on the prevention and treatment of plaque and gingivitis [21, 22].

They examined the PI and GI. The dentifrice, with a p-value of 0.73, did not significantly reduce plaque. The p-value of 0.001 indicates a statistically significant reduction in Gl. Their study results aligned with the findings of GI, but not concerning PI. The discrepancy may be attributed to the fact that the previous study lasted 21 days, but the current study spans 6 weeks [23, 24]. The research by Al Shammeri et al. concluded that sodium bicarbonate dentifrice significantly decreases both Plaque Index and Gingival Index scores; however, the effect is transient, necessitating further studies to evaluate its efficacy as an antiplaque and anti-gingivitis agent over six months. Mason and colleagues conducted a study comparing 67% NaHCO3, 0%

NaHCO3 with stannous fluoride, and 0% NaHCO3 combined with chlorhexidine (CHX). The 67% NaHCO3 dentifrice significantly surpassed the two 0% NaHCO3 dentifrices regarding enhancements to the mean TPI score (p-value 0.001 for both comparisons). The findings of this study are inconsistent with the current study. Lomax et al conducted a study to evaluate the efficacy of 67% NaHCO3 dentifrices on gingivitis. They assessed the parameters of the gingival index and bleeding index. A statistically significant reduction was observed in all measures. The findings of GI were analogous to the current study [25–28].

The present study had several limitations. This sample size was rather small, and this can restrain the possibility of generalizing the findings. The short-term duration of the study (6 weeks) also limits the ability to assess the long-term effects and sustainability of the treatments. Also, the research was carried out in one institution, thereby confining the sample. Lastly, the side effects and patient compliance may have been affected by self-reporting bias.

CONCLUSION

This study demonstrates that chlorhexidine dentifrice is significantly more effective than sodium bicarbonate dentifrice in reducing plaque accumulation, gingival irritation, and bleeding upon probing in orthodontic patients. However, the superior efficiency of chlorhexidine comes with an increased frequency of side effects, including taste modification and dental discoloration, which may impact long-term patient compliance. Sodium bicarbonate dentifrice, on the other hand, is less effective but has fewer adverse effects, thus a potential alternative to patients who are annoyed about the side effects of chlorhexidine.

Further, the research also established that smoking negatively influences the effectiveness of the two dentifrices, and therefore, smoking cessation measures are pertinent in realizing good outcomes regarding optimal periodontal health. Both the efficacy of the two dentifrices in controlling plaque and gum diseases, together with the tolerance of the patient to their possible adverse effects, should hence be put into consideration in a clinical decision on the choice of which to use between the two.

Although this study offers important findings on the comparative effectiveness of these dentifrices, additional research is needed in the aims of investigate ways in which the side effects of chlorhexidine can be reduced, without compromising their great antimicrobial effectiveness. Longitudinal prospective studies are needed to study longer-term effects of the two treatment modalities and also to look at how various lifestyle factors, like smoking, may interfere with the treatment process of patients receiving orthodontic treatment.

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AUTHOR CONTRIBUTIONS

RS: Contributed to the study design and literature review, and critically revised and finalized the manuscript for submission.
RJ: Was responsible for data collection and organization.
IA: Conducted data analysis and interpretation.
All authors reviewed and approved the final manuscript.

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