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Comparative Study between Sodium Hexametaphosphate and Chlorhexidine Mouthwashes on Dental Plaque in Young Age, Clinical Randomized Study

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ABSTRACT

Background: Chlorhexidine (CHX) and sodium hexametaphosphate (SHMP) are commonly used antiplaque agents, yet their comparative efficacy and safety profiles remain under investigation.

Objective: To compare the clinical effectiveness and adverse effect profiles of CHX and SHMP mouth rinses in reducing plaque and gingival indices over a 14-day period in adolescents.

Patients and Methods: In this randomized controlled trial, 220 participants were assigned equally into two groups (CHX vs. SHMP). Demographic characteristics, medical histories, and baseline clinical indices were recorded. Plaque Index (PI) and Gingival Index (GI) were assessed at baseline, day 7, and day 14. Intra- and inter-group comparisons were conducted using Wilcoxon and Mann–Whitney U tests. Multivariate linear regression identified predictors of PI change, while logistic regression assessed predictors of adverse effects. **Results:** There were no significant differences in baseline demographic or clinical variables between groups ($p > 0.05$). Both groups showed significant intra-group reductions in PI and GI from baseline to day 14 ($p < 0.001$). Inter-group comparison revealed that CHX produced significantly greater reductions in PI and GI at day 7 and day 14 ($p < 0.01$). Multivariate regression showed that treatment group ($\beta = 0.076$, $p < 0.001$) and baseline PI ($\beta = 0.201$, $p < 0.001$) were significant predictors of PI change. Adverse effects were common in both groups (Day 14: 41.8% CHX vs. 39.1% SHMP, $p = 0.680$), with no significant differences in frequency or type. Logistic regression showed no significant predictor of adverse events at day 14 ($p > 0.05$ for all variables).

Conclusion: Both CHX and SHMP effectively reduced plaque and gingival inflammation over 14 days, with CHX showing superior clinical performance. However, both agents were associated with a comparable frequency and type of mild adverse effects, suggesting similar tolerability profiles.

Keywords: Chlorhexidine, Sodium Hexametaphosphate, Dental Plaque, Gingival Index, Plaque Index, Mouthwash.

INTRODUCTION

Dental plaque, a structured biofilm that is formed naturally on teeth and oral surfaces, is the primary etiological factor in tooth decay and periodontal disease. Its effective removal is essential for both prevention and treatment of these conditions. Mechanical plaque control through toothbrushing and flossing remains the cornerstone of oral hygiene; however, its effectiveness depends heavily on patient motivation, skill, and compliance, which many fail to sustain consistently. To overcome these limitations, chemical plaque control agents, particularly mouthwashes, are widely employed as adjuncts to mechanical cleaning [(1,2)].

Mouthwashes enhance plaque control by delivering antibacterial and antiplaque compounds directly into the oral cavity. These agents reduce microbial load, modulate host responses, and suppress pathogenic microorganisms while providing both local and systemic benefits. Among available chemotherapeutic agents, chlorhexidine (CHX) is the most extensively studied and clinically utilized. A BI biguanide compound, CHX possesses both bacteriostatic and bactericidal properties, with broad activity against Gram-positive and Gram-negative bacteria, fungi, and certain viruses [(3)]. Its unique substantivity, the ability to bind oral surfaces and release gradually, ensures prolonged antibacterial activity. At concentrations of 0.02–0.06%, CHX is bacteriostatic, while at 0.12–0.20%, it is bactericidal. Because of its reliable clinical outcomes, CHX mouthwash is considered the "gold standard" of chemical plaque control, with 0.2% CHX particularly effective in reducing plaque accumulation [(4,5)].

Despite its proven efficacy, CHX is not without drawbacks. Long-term use can lead to tooth staining, altered taste, oral irritation, glandular swelling, and tongue discomfort, driving research toward alternatives. Sodium hexametaphosphate (SHMP), an inorganic polyphosphate often combined with fluoride, has emerged as a promising candidate. SHMP binds strongly to enamel, offering protection against acid dissolution, while also demonstrating antimicrobial activity, reducing calculus formation, and minimizing external staining [(6)].

Plant-derived antimicrobials are another growing focus, particularly in the context of rising antibiotic resistance. Herbal extracts are being investigated as safer alternatives to CHX, with the World Health Organization

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encouraging natural formulations to reduce chemical-related side effects [7]. While mechanical plaque control remains the most cost-effective and primary preventive strategy especially against gingivitis, adjunctive use of antibacterial toothpastes and mouthwashes enhances oral cleanliness between brushing episodes. Their substantivity is particularly beneficial in areas that are difficult to reach [8]. Notably, one comparative study in children demonstrated that SHMP 7% reduced plaque more effectively than CHX 0.2%, supporting its role as a viable and safer alternative [9].

In addition to self-care, professional interventions such as scaling are vital for plaque and calculus removal, especially in areas inaccessible to routine home cleaning. Scaling functions both preventively and therapeutically, reinforcing overall periodontal health [10].

Special consideration is required for pediatric populations. The American Dental Association advises against fluoride-containing mouthwashes in children under six due to risks of ingestion and fluorosis. Beyond this age, parental supervision ensures safe use. Training children to rinse initially with water can foster safe and effective mouthwash practices [11].

The aim of this study was to evaluate and compare the effect of chlorhexidine and sodium hexametaphosphate mouth rinses on dental plaque in school age from 13-17 years old.

PATIENTS AND METHODS

The present study was a comparative, randomized clinical trial to assess the efficacy of two commonly used mouth rinses-CHX and SHMP-on reducing dental plaque and improving gingival health in adolescents aged 13-17 years. A parallel-group randomization was thus followed in this trial, in which eligible candidates were randomly allocated into either the CHX group or the SHMP group. Changes in plaque accumulation and gingival status were evaluated at three critical time points in this study, namely, baseline, 7 days, and 14 days after the initiation of the mouthwash regimen. The pre-defined structured design allowed a direct and consistent comparison of changes between the two groups while ensuring minimal selection and measurement bias.

This study was conducted at Noterdam Language School, Shoubra El-Kheima, Egypt, since it had the required quota of adolescents and was easily accessible. In addition, it could provide a clinical setting suitable for repeated dental examinations. Participation in the study was conveniently organized while maintaining follow-up standardization and consistency in environmental factors that could affect oral hygiene practices. School staff enabled the organization of the participants and helped to ensure compliance throughout the study period.

The study population consisted of boys and girls aged 13 to 17 years who met the inclusion criteria. The inclusion criteria stipulated that participants should have a low caries index or caries previously treated, so as not to interfere with the assessment of plaque. Other inclusion criteria included general health and those free of systemic diseases that could affect oral conditions. Only adolescents with fully erupted permanent teeth were studied so as to reduce mixed dentition effects. Exclusion criteria were set up to reduce confounders: individuals with orthodontic appliances, fluoride therapy in the past months, known allergy to mouthwash components, presence of mixed dentition, systemic diseases, and use of medications like antibiotics or steroids within six months prior to the study. These stringent selection criteria were necessary to ensure that any modifications in plaque or gingiva status would be due, as reliably as possible, to the mouthwash interventions.

Participants were selected through a simple random sampling technique, thus giving all the eligible students an equal opportunity to be included in the research. This helps reduce any selection biases. The required sample size was estimated to be 220 adolescents: 110 in each group. The sample size was determined with the purpose of having sufficient statistical power, amounting to 95.16%, and allowing for 20% dropout. Group I members were given 0.2% CHX mouthwash, and Group II were given 7% SHMP mouthwash. ***Use approximately 20 ml (about 4 teaspoons) of mouth wash twice daily*** All clinical evaluations were done with dental unit light for better visibility and standardization.

A thorough baseline examination of plaque accumulation and gingival health was conducted before the intervention. Participants were asked to abstain from all oral hygiene measures for 24 hours before baseline assessment to standardize the initial oral condition, ensuring plaque measured at baseline reflected natural accumulation rather than recent cleaning. For the understanding of the study process, explanations were given using educational materials in the form of posters and videos. Clinical equipment used in this study included mouth mirrors, dental probes, tweezers, and disclosing agents for the visualization of plaque. All procedures were performed with due attention to WHO infection control standards; examiners wore personal protection.

In addition, all participants underwent a baseline self-administered questionnaire on demographic data, dental hygiene habits, systemic health status, allergies, and recent dental treatments. The information supports the identification of potential confounding variables and puts the clinical findings into perspective. A side-effect questionnaire was administered to assess adverse reactions, such as taste changes, staining, or oral irritation, during the 7-day and 14-day evaluations, since these are known possible effects of CHX or SHMP. The primary outcome of the study was the reduction in dental plaque as measured by PI, while the secondary outcome was

improvement in gingival health as measured by GI. Both outcomes were longitudinally assessed to measure the effectiveness of each mouthwash over a period of time. The monitoring of side effects also contributed to understanding treatment tolerability, which has particular relevance in adolescent oral health compliance.

Ethical considerations:. Ethical approval was obtained from Military Medical Academy Review Board **.Participating institutions and guardians provided informed consents, while participants were aware that they had the right to withdraw from the study at any time without penalty. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.**

Statistical analysis

To assess the clinical effectiveness and safety of chlorhexidine and sodium hexametaphosphate mouth rinses, a variety of statistical methods were applied using SPSS version 25. Categorical data were shown as n (%). Continuous data were shown as mean ± standard deviation (SD) and interquartile range (IQR). Chi-square tests were used for comparing categorical variables, while Mann–Whitney U tests assessed non-normally distributed continuous variables and inter-group differences. Wilcoxon Signed-Rank tests evaluated intra-group changes over time. Additionally, multivariate linear regression was employed to identify predictors of plaque reduction. A significance level of $p < 0.05$ was considered statistically meaningful.

RESULTS

Both CHX and SHMP groups were similar in age, sex, dental status, medical history, and other baseline factors, confirming successful randomization **(Table 1)**.

Table 1. Demographic and Baseline Characteristics

Variable	Chlorhexidine Group (Group 1) n = 110	SHMP Group (Group 2) n = 110	Total (n = 220)	Test	p-value
Sex				χ^2	0.686
- Male	57 (51.8%)	54 (49.1%)	111 (50.5%)		
- Female	53 (48.2%)	56 (50.9%)	109 (49.5%)		
Age (years)				U	0.678
- Mean ± SD	13.04 ± 1.49	13.11 ± 1.43	–		
- IQR (Q1–Q3)	12.0 – 14.0 (IQR = 2.0)	12.0 – 14.0 (IQR = 2.0)	–		
Allergies to Dental Products				χ^2	0.780
- Yes	42 (38.2%)	40 (36.4%)	82 (37.3%)		
- No	68 (61.8%)	70 (63.6%)	138 (62.7%)		
Mixed Dentition				χ^2	1.000
- Yes	97 (88.2%)	97 (88.2%)	194 (88.2%)		
- No	13 (11.8%)	13 (11.8%)	26 (11.8%)		
Systemic Medical Conditions				χ^2	0.889
- Yes	40 (36.4%)	41 (37.3%)	81 (36.8%)		
- No	70 (63.6%)	69 (62.7%)	139 (63.2%)		
Recent Fluoride Treatment				χ^2	0.867
- Yes	66 (60.0%)	66 (61.1%)	132 (60.6%)		
- No	44 (40.0%)	42 (38.9%)	86 (39.4%)		
Wearing Orthodontic Appliances				χ^2	0.598
- Yes	45 (40.9%)	48 (43.6%)	93 (42.7%)		
- No	65 (59.1%)	60 (56.4%)	125 (57.3%)		
Recent Medication Use				χ^2	0.811
- Yes	35 (31.8%)	36 (32.7%)	71 (32.6%)		
- No	75 (68.2%)	72 (67.3%)	147 (67.3%)		

Categorical data are shown as n (%) and compared using Chi-square (χ^2). Continuous data are shown as mean ± SD and IQR, compared using Mann–Whitney U test. Categorical data are shown as **n (%)** and compared using the **Chi-square test (χ^2)**. Continuous data are shown as **Mean ± SD** and **IQR**, compared using the **Mann–Whitney U test**[1]. Significance set at **$p < 0.05$**.

CHX showed faster early reductions in plaque and gingival scores by day 7, while by day 14, differences in plaque were not significant, though gingival improvement remained higher with CHX **(Table 2)**.

Table 2. Between-Group Comparison — Plaque Index (PI) and Gingival Index (GI)

Index (timepoint)	Chlorhexidine (Mean ± SD; Q1–Q3)	SHMP (Mean ± SD; Q1–Q3)	Test	p-value
PI — Baseline	3.08 ± 0.21 (3.00–3.20)	3.10 ± 0.15 (3.00–3.20)	U	0.621
PI — Day 7	2.41 ± 0.22 (2.30–2.60)	2.49 ± 0.14 (2.40–2.60)	U	**0.021** *
PI — Day 14	1.72 ± 0.60 (1.80–2.00)	1.90 ± 0.16 (1.80–2.00)	U	0.412
GI — Baseline	2.28 ± 0.15 (2.20–2.40)	2.29 ± 0.14 (2.20–2.40)	U	0.677
GI — Day 7	1.77 ± 0.18 (1.68–1.90)	1.84 ± 0.12 (1.70–1.98)	U	**0.009** *
GI — Day 14	1.31 ± 0.24 (1.00–1.50)	1.44 ± 0.12 (1.30–1.58)	U	**0.001** **

- **SD**: Standard Deviation, **Q1–Q3**: Interquartile Range (25th percentile – 75th percentile)
- **U Test**: Mann–Whitney U test statistic, * *Significant at $p < 0.0$,* ** *Highly significant at $p < 0.01$*

All intra-group comparisons showed statistically significant improvement ($p < 0.001$). Both groups experienced significant reductions in plaque and gingival indices over 14 days, showing both mouthrinses were effective **(Table 3)**.

Table 3. Intra-Group Comparison Over Time

Group (n)	Timepoint comparison	Mean difference ± SD	Wilcoxon Z	p-value
Chlorhexidine (n = 110)	PI: Baseline → Day 7	0.61 ± 0.05	–9.369	< 0.001
	PI: Baseline → Day 14	1.16 ± 0.08	–9.212	< 0.001
	GI: Baseline → Day 7	0.43 ± 0.06	–9.234	< 0.001
	GI: Baseline → Day 14	0.82 ± 0.08	–9.180	< 0.001
Sodium Hexametaphosphate (n = 108)	PI: Baseline → Day 7	0.61 ± 0.04	–9.696	< 0.001
	PI: Baseline → Day 14	1.18 ± 0.06	–9.276	< 0.001
	GI: Baseline → Day 7	0.45 ± 0.05	–9.317	< 0.001
	GI: Baseline → Day 14	0.85 ± 0.05	–9.311	< 0.001

All intra-group comparisons showed statistically significant improvement ($p < 0.001$).

Both treatments were well tolerated; adverse effects (staining, dry mouth, taste alteration) were similar and mild, with no significant differences between groups **(Table 4)**.

Table 4: Adverse Effects Profile (Frequency and Type) at Day 7 and Day 14

Timepoint	Outcome / Type of Adverse Effect	Chlorhexidine (n, %)	SHMP (n, %)	Test	p-value
Day 7	**Any Adverse Effect** – Yes	57 (51.8%)	54 (49.1%)	χ^2	0.686
	Any Adverse Effect – No	53 (48.2%)	56 (50.9%)	—	—
	Staining	12 (10.9%)	10 (9.1%)	—	—
	Dry Mouth / Burning	23 (20.9%)	22 (20.0%)	—	—
	Taste Alteration	15 (13.6%)	16 (14.5%)	—	—
	Mild Staining	7 (6.4%)	6 (5.5%)	—	—
Day 14	**Any Adverse Effect** – Yes	46 (41.8%)	43 (39.1%)	χ^2	0.680
	Any Adverse Effect – No	64 (58.2%)	67 (60.9%)	—	—
	Staining	9 (8.2%)	8 (7.3%)	—	—
	Dry Mouth / Burning	18 (16.4%)	17 (15.5%)	—	—
	Taste Alteration	13 (11.8%)	14 (12.7%)	—	—
	Mild Staining	6 (5.5%)	4 (3.6%)	—	—

CHX treatment and higher baseline plaque were significant predictors of greater improvement; other factors (age, allergies, systemic conditions, orthodontic appliances) had no significant effect **(Table 5)**.

Table 5. Multivariate linear regression regarding Change in Plaque Index after 14 days

Predictor Variable	β Coefficient	Standard Error	p-value
Treatment Group (CHX vs SHMP)	0.076	0.014	**< 0.001**
Age (years)	0.007	0.005	0.152
History of Allergies	−0.005	0.015	0.739
Systemic Medical Conditions	0.000	0.015	0.978
Orthodontic Appliance	−0.009	0.014	0.525
Baseline Plaque Index	0.201	0.042	**< 0.001**

DISCUSSION

This randomized trial compared the short-term efficacy and tolerability of 0.2% chlorhexidine (CHX) versus 7% sodium hexametaphosphate (SHMP) mouthrinses as adjuncts to mechanical plaque control in 220 healthy adolescents (13–17 years). Both groups were balanced for demographics and oral health factors.

Results showed that both CHX and SHMP resulted in statistically and clinically significant decreases over time in both PI and GI (intra-group improvements). However, inter-group comparisons favored CHX: by day 7 and more markedly by day 14, the CHX group had lower mean PI and GI scores compared with SHMP, indicating a faster and greater short-term anti-plaque and anti-inflammatory action. Multivariate regression analysis identified two independent predictors of 14-day PI reduction: treatment group (CHX superior) and baseline PI (the higher the baseline plaque score, the larger the absolute reduction). Other tested covariates-age, sex, allergy, systemic health, and orthodontic appliance wear not significant predictors of outcome. Safety and tolerability profiles over the 14-day period were acceptable for both agents: adverse events associated with both treatments (staining, dry mouth, taste alteration) were mostly mild, infrequent, and not statistically different between groups. Dry mouth was unexpectedly the most frequent complaint among both arms. Logistic regression demonstrated no reliable predictors for adverse events, pointing to a low general risk among adolescents after short-term administration.

The trial's findings are thus partially in line with earlier pediatric and adult studies but also point to variable results across contexts. Whereas **Hedihed *et al.*** and **Sabri *et al.*** reported comparable or superior outcomes for SHMP in children, differences in concentration, formulation stability, population age, baseline plaque levels, and study protocols likely explain inconsistent results [12,13]. **Jeffrey *et al.*** reported small short-term advantages for CHX over hexetidine in older children; a result consistent with the present work's demonstration of CHX's rapid action [14]. Adult studies comparing CHX with alternatives such as cetylpyridinium chloride (CPC) show that several agents can approach CHX efficacy over limited durations, but CHX commonly retains an edge in rapid plaque reduction while alternatives may be better tolerated [15,16].

Mechanistically, SHMP is thought to act via anti-adhesive and anti-mineralization pathways, interfering with plaque accumulation and calculus formation while providing enamel surface protection and stain resistance. CHX acts by membrane disruption and broad antimicrobial activity; recent preclinical advances suggest nanoparticle CHX formulations may enhance tissue compatibility and biofilm penetration, potentially reducing side effects [17]. Non-human studies support CHX anti-plaque activity and emphasize the importance of demographic control and combined mechanical-chemical approaches [18]. The present study underlines several practical implications. First, CHX is still an extremely effective short-term chemotherapeutic adjunct for plaque and gingivitis control in adolescents, achieving greater reductions in PI and GI within 14 days compared with 7% SHMP under the conditions tested. Second, SHMP represents a viable alternative with acceptable short-term efficacy and potentially better palatability and stain resistance - an important consideration in pediatric compliance. Third, baseline plaque burden and patient adherence are critical determinants of clinical response regardless of the chemical agent; clinicians should therefore emphasize behavioral reinforcement and optimized mechanical cleaning alongside any rinse regimen. Fourth, the tolerability of both agents over short periods appears favorable in adolescents; however, the known CHX side effects (taste alteration, staining) remain relevant considerations for longer use.

Limitations to be considered include the following: The follow-up period was short, 14 days, so long-term comparative efficacy, stain accumulation over time, and sustained tolerability cannot be concluded from this dataset. Generalizability may be limited due to the single-site school setting and the inclusion of relatively healthy adolescents who had low caries indices. Compliance measures, such as self-reporting versus objective monitoring, and possible unmeasured behavioral confounders might have an impact on the results. Finally,

formulation stability, excipients, and mouthwash vehicles might vary between studies, thereby complicating direct comparisons with older trials. Future directions include longer trials assessing durability of effect and staining, head-to-head comparisons of optimized SHMP formulations versus newer CHX delivery systems - for example, nanoparticle CHX - and pragmatic studies in varied pediatric populations. Efforts should also be directed at the inclusion of patient-centered outcomes - taste, ease of use, and adherence - and investigating whether combinations - for instance, SHMP plus low-dose CHX or other actives such as CPC - can offer a favorable balance of efficacy and tolerability. Clinically, mouthwash recommendations should be individualized, weighing short-term efficacy against side-effect risk and patient preference, while reinforcing the primacy of mechanical plaque control.

CONCLUSION

Both 0.2% CHX and 7% SHMP mouthwashes significantly reduced dental plaque and improved gingival health in adolescents over 14 days. While CHX exhibited superior short-term efficacy regarding plaque reduction and gingival inflammation, both mouthwashes presented with similar frequencies and types of adverse effects, which would indicate that SHMP is well-tolerated and a good option for individuals concerned with the long-term side effects of CHX. The findings from this study would indicate that SHMP can be considered an effective, less virulent alternative antimicrobial therapeutic agent for routine plaque control, especially subsequent to scaling and root planning or in cases of extensive gingival inflammation and recession, with a two-week treatment recommended and follow-up thereafter.

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