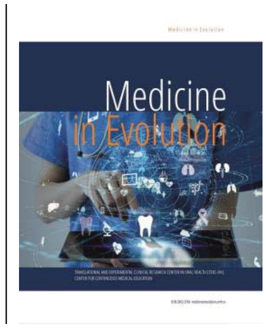
Association of Oral Hygiene Products and Their Impact on Oral Health



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Abstract

1.Background/Objectives: Oral hygiene plays a crucial role in maintaining ecological balance within the oral cavity. Salivary pH is a key functional marker, closely linked to enamel demineralization–remineralization dynamics and microbial homeostasis. The study aimed to compare the influence of two oral hygiene regimens-using Elmex Anti-Caries Professional toothpaste alone versus its combination with alcohol-free Listerine Coolmint mouthwash-on salivary pH values in young adults. 2.Methods: A controlled crossover design was applied to 30 participants aged 20–30 years. Saliva samples were collected under standardized conditions at 30 minutes and 2 hours after toothbrushing with Elmex toothpaste (Day 1) and after toothbrushing followed by mouthrinse with Listerine Coolmint (Day 2). Salivary pH was assessed using the Saliva Check Buffer kit, which provides semi-quantitative values in 0.5-unit intervals. Data were analyzed with descriptive statistics and the Wilcoxon signed-rank test.3.Results: Toothbrushing alone maintained salivary pH mostly in the physiological range of 6.5–7.0, while the combined regimen produced a significant alkalinizing effect, with values shifting towards 7.0–7.5 at both time points. Statistical analysis confirmed significant differences between the two protocols ($p < 0.001$).4.Conclusion: The combined use of fluoridated toothpaste and alcohol-free antiseptic mouthwash enhances salivary pH stability compared with toothbrushing alone, supporting remineralization and reducing acidogenic bacterial activity. These findings provide evidence-based support for integrating complementary oral hygiene products into daily preventive protocols, especially in young adults at increased risk for caries.

Keywords: Salivary pH, Oral hygiene, Fluoride toothpaste, Mouthwash

INTRODUCTION

Oral hygiene is an essential component of individual health, defined as the set of systematic, self-applied and/or professionally supported measures aimed at maintaining the health of the oral cavity, preventing the onset and progression of dento-periodontal diseases and preserving the functionality of the dento-maxillary apparatus [1]. The modern approach integrates daily practices – toothbrushing, use of floss and interdental brushes, oral irrigators and mouthwashes – with periodic prophylactic interventions in the office (professional scaling, topical fluoridation, sealing and advice on the correct techniques) [1]. The central purpose of these measures is to maintain an ecological balance at the level of the oral ecosystem, by controlling bacterial biofilm and preventing dysbiosis associated with gingival inflammation, caries and other pathologies [1,2].

In the absence of rigorous hygiene, the composition and metabolism of plaque become more adherent and pathogenic; the metabolism of fermentable carbohydrates by acidogenic microorganisms lowers the pH below the critical threshold of 5.5, favoring the demineralization of the enamel and the initiation of carious processes [1,2]. Well-structured hygiene routines – adapted to age, oral health status and individual particularities – directly influence the quality of the oral environment. Clinical evidence indicates that a constant sanitation regimen supports the maintenance of salivary pH in the physiological range 6.2-7.6, a favorable condition for the remineralization and inhibition of acidophilic bacteria [2]. The educational dimension is also crucial: early formation of correct habits and compliance with periodic check-ups correlate with lower prevalences of caries and periodontal diseases in adolescents and young adults [1].

Oral hygiene products have evolved to respond to the multifactorial etiology of oral diseases. Toothpastes, mouthwashes and auxiliary means (floss, interdental brushes, irrigators) are the core of home interventions, complemented by topical fluoride gels, concentrated antiseptic solutions and formulas for dentine sensitivity or incipient periodontal disease [3]. Paste formulas include abrasives (hydrated silica, calcium carbonate), surfactants (e.g. sodium lauryl sulfate), as well as fluorides (NaF, SnF_2, sodium monofluorophosphate) for remineralizing, antacid and antibacterial effects; incorporation of fluoride into the enamel crystal in the form of fluorhydroxyapatite increases resistance to acid attackand inhibits bacterial enzymes involved in carbohydrate metabolism [4,5]. Mouthwashes, selected according to clinical objective, may contain antimicrobials (chlorhexidine, essential oils, cetylpyridine), anti-inflammatory, hemostatic or remineralizing agents (fluorides) and, in some cases, desensitizers (potassium nitrate, arginine) [4-6].

Fluoride remains the cornerstone of caries prophylaxis, acting in the demineralization-remineralization dynamics and exerting antibacterial effects by reducing the acidogenicity of the biofilm (e.g. inhibition of enolase and glucose transport in cariogenic bacteria) [4,7]. Clinical efficacy depends on local bioavailability, modeled by pharmaceutical form, concentration, contact time and post-application behaviors; Immediate loosening after brushing increases salivary retention of fluorine ions and enamel exposure [8]. The different chemical forms—NaF, SnF_2, amine fluorides—exhibit distinct stability, release, and adhesion profiles, with SnF_2 additionally providing antimicrobial benefits when properly stabilized [9].

Salivary pH is a functional marker of oral homeostasis. Neutral or slightly alkaline values support remineralization and inhibit acidophilic bacteria, while dropping below pH 5.5 triggers demineralization [10]. Diet, hydration, salivary flow, medication, smoking and hygiene quality modulate this parameter; a correct regimen, especially with fluorinated products (NaF, SnF_2), contributes to acid neutralization and pH stabilization, synergistic with the buffering capacity of saliva (bicarbonate, phosphates, proteins) [7,9,10]. Clinical studies show that consistent hygiene practices reduce the acidogenic microbial load and increase buffer capacity, accelerating the return of pH to physiological values after acid challenges [9,10].

The association of toothpaste with mouthwash is supported by the literature for biofilm control, reducing gingival inflammation, and maintaining acid-base balance [4,5]. However, synergies depend on ingredient compatibility and timing of use. Certain compounds (e.g., chlorhexidine or surfactant anions such as sodium lauryl sulfate) may reduce local fluoride retention if mouthwash is used immediately after brushing; Therefore, it is recommended to postpone the administration by 15-60 minutes or to use it at times of the day without brushing, respecting the chemical compatibility of the products [6,11]. Recent meta-analyses and reviews support the implementation of combined strategies especially in patients with increased carious/periodontal risk, xerostomia, halitosis or orthodontic treatments, in accordance with the current direction of personalized prophylaxis [3,12-15].

In this context, there is a growing interest in how concrete combinations of products influence salivary pH, a clinical indicator that is easy to measure and relevant for the demineralization-remineralization balance. In view of the possible interactions between fluorides, surfactants and other active agents, it becomes necessary to assess the effects on pH when toothpaste and mouthwash are used in combination [4-6,9,11]. The present paper aims to investigate, in an experimental setting, the impact of the association of Elmex Anti-Caries Professional toothpaste (GABA International AG, Therwil, Switzerland) with alcohol-free Listerine Coolmint mouthwash (Johnson & Johnson Consumer Inc., Skillman, NJ, USA) on salivary pH. The results may have direct clinical implications for optimizing hygiene recommendations in the young population at high risk of carious lesions and for refining evidence-based prophylactic protocols [3-6,9-15].

Aim and objectives

The overall aim of the study is to comparatively evaluate the influence of two oral hygiene regimens on salivary pH in young adults: the exclusive use of Elmex Anti-Caries Professional toothpaste and the association of the same paste with alcohol-free Listerine Coolmint mouthwash, under controlled conditions and at defined time intervals of 30 minutes and 2 hours.

The specific objectives aim to determine the salivary pH values 30 minutes and 2 hours after the exclusive use of Elmex Anti-Caries Professional paste and after the use of Elmex paste followed by alcohol-free Listerine Coolmint mouthwash, respectively. The research also aims to compare the values obtained in the two regimes at each measurement moment and over the overall temporal evolution, as well as to estimate the clinical relevance of the observed differences, through indicators such as the average pH difference and the proportion of participants who maintain protective values above the thresholds of 6.2 and 7.0.

Another objective is to explore the mechanistic explanations of the observed pH variations, related to the composition of the tested products, namely fluorides, surfactants or antimicrobials. The paper also aims to formulate evidence-based practical recommendations on the sequence and timing of the use of toothpaste and mouthwash in oral prophylaxis in the young population.

As complementary directions, the study can analyze individual pH variations from baseline and time to return to neutrality, the influence of control factors such as resting salivary flow, interval from last food intake or initial caryoperiodontal status, as well as participants' perception of tolerability and compliance with the two oral hygiene regimens.

MATERIAL AND METHODS

The study included 30 volunteers, young adults aged between 20 and 30, Romanian citizens, with medium or higher level of education. All participants have signed the informed consent and agreement for the processing of personal data before the start of the procedures. The recruitment was carried out anonymously, voluntarily and non-discriminatory, with the subjects being fully informed about the purpose, methodology, benefits and potential risks of the research, as well as the data protection measures. After consent, subjects were clinically evaluated for eligibility.

Inclusion and exclusion criteria

Participants aged 20–30 years, who report daily use of oral hygiene products, with a history of mild oral conditions (caries, dental hypersensitivity, gingivitis), without active carious lesions at initial examination, and without incorrectly adapted dental/prosthetic restorations were included. Subjects with active oral conditions (ulcerative lesions, abscesses, untreated infections), recent drug treatments with an impact on saliva (antibiotics, antidepressants, anticholinergics), active smokers, people with dental interventions in the last 4 weeks or with systemic diagnoses that may alter salivary composition/flow (diabetes, Sjögren's syndrome, autoimmune diseases) were excluded. The establishment of these criteria aimed at clinical homogeneity and the reduction of confounding factors; All determinations were performed by a single examiner to limit inter-observer variability.

Material

Toothpaste: Elmex Anti-Caries Professional (GABA International AG, Therwil, Switzerland), aminofluoride-based formula (olaflur), with increased fluoride adhesion to enamel and prolonged release (Figure 1).

Figure 1. Characteristics of Elmex Anti-Caries Professional toothpaste (GABA International AG, Therwil, Switzerland)

Mouthwash: Alcohol-free Coolmint Listerine (Johnson & Johnson Consumer Inc., Skillman, New Jersey, USA), with antimicrobial essential oils (eucalyptol, thymol, menthol, methyl salicylate), chosen for antiseptic efficacy and oral tolerability (Figure 2).

Figure 2. Features of Alcohol-Free Listerine Coolmint Mouthwash (Johnson & Johnson Consumer Inc., Skillman, New Jersey, USA)

Saliva testing: Saliva Check Buffer kit (GC Corporation, Tokyo, Japan), including measuring cups, colorimetric pH/buffer capacity strips, pipettes and wax strips for flow stimulation, used according to the manufacturer's instructions (Figure 3).

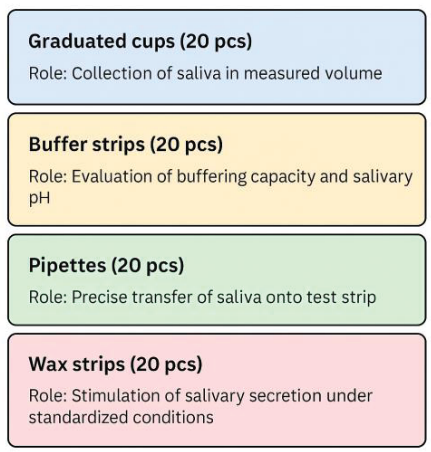

Figure 3. The components of the Saliva Check Buffer kit and their role in the experimental protocol

Study design

A crossover design was used, with each participant serving as their own control. The interventions were carried out on two consecutive mornings, at a comparable time interval (08:00–10:00), prior to the ingestion of food/beverages and any other oral hygiene procedure, to control circadian saliva variations.

Experimental protocol

Day 1: brush your teeth for 2 minutes with Elmex Anti-Caries Professional, using a brush with medium hardness and modified horizontal technique on all dials. After brushing, without ingestion of food/liquids, samples of non-induced saliva were collected every 30 minutes and every 2 hours.

Day 2: identical brushing protocol, followed immediately by rinsing for 30 seconds with 20 ml of alcohol-free Listerine Coolmint. Harvests every 30 minutes and 2 hours after rinsing. Each participant provided four samples in total (two for the paste alone regime and two for the paste + mouthwash regimen). All harvests were carried out in the sitting position, at rest, without mechanical or gustatory stimulation.

pH collection and measurement

The samples were collected by expectoration in graded sterile containers, at the defined times. The pH measurement was carried out with colorimetric strips of the Saliva Check Buffer kit, by immersion according to the instructions and visual reading after about 10 seconds, based on the standardized color scale. The method is semi-quantitative, reporting ranges (e.g., 6.0–6.5; 6.5–7.0), with potential variability minimized by using a single trained operator. The readings were taken in natural light, on a white background.

Control of disruptive factors

Participants were instructed to avoid acidic foods/drinks, alcohol, smoking and the use of oral hygiene products other than those indicated by the protocol in the 24 hours prior to each visit. The collections were carried out at similar times on the two days, before any food or liquid intake.

Data logging

For each participant, an individual form with an anonymous code was filled in, noting the basic demographics, the regime applied and the pH values at each time, as well as observations on the volume, color or viscosity of saliva. The data were centralized in a password-protected electronic database (Excel format), with predefined fields for the analyzed variables.

Statistical analysis plan

The descriptive analysis included the mean, median, standard deviation and coefficient of variation for pH at 30 minutes and 2 hours, in each regimen. The distributions were verified with the Shapiro–Wilk test. Given that most of the sets did not follow normal ($p < 0.05$), even comparisons between regimes and time moments were performed with the nonparametric Wilcoxon test for paired samples. Comparative charts and summary tables were generated in Microsoft Excel; The accuracy of the calculations was verified by independent recalculations.

Ethics and privacy

The study complied with the principles of biomedical research ethics and data protection regulations (GDPR). Participant identities were kept confidential through anonymous coding, and access to the database was restricted to the principal investigator. The crossover design, standardized procedures, and the use of a single examiner were chosen to enhance the internal validity and reproducibility of the results.

RESULTS

The results obtained in this study were structured on the stages of the experimental protocol, following the evolution of salivary pH after using the two oral hygiene regimens tested: simple brushing and combined brushing with mouthwash.

In the first stage, which focused exclusively on the effect of brushing with Elmex Anti-Caries Professional toothpaste (GABA International AG, Therwil, Switzerland), salivary pH values were predominantly in the physiological range of 6.5-7.0, both at 30 minutes and at 2 hours post-brushing. The slightly upward trend observed in a small number of participants, including reaching the 7.0 threshold at two hours, reflects the cumulative effect of slow-release fluoride and brushing-induced salivary stimulation. These data confirm that the exclusive use of fluoridated toothpaste maintains a stable salivary pH close to neutral, an optimal condition for the prevention of demineralization and inhibition of cariogenic microorganisms (Table 1).

At 30 minutes, all 30 participants (100%) had salivary pH values within the range of 6.5–7.0. At 2 hours, 29 participants (96.7%) remained within the range of 6.5–7.0, while 1 participant (3.3%) recorded a salivary pH value of 7.0.

Table 1. Salivary pH values after simple brushing, at 30 minutes and 2 hours

Participant	Ph in 30 min	Ph in 2 h
P01	6.5–7.0	6.5–7.0
P02	6.5–7.0	6.5–7.0
P03	6.5–7.0	6.5–7.0
P04	6.5–7.0	6.5–7.0
P05	6.5–7.0	7.00
P06	6.5–7.0	6.5–7.0
P07	6.5–7.0	6.5–7.0
P08	6.5–7.0	6.5–7.0
P09	6.5–7.0	6.5–7.0
P10	6.5–7.0	6.5–7.0
P11	6.5–7.0	6.5–7.0
P12	6.5–7.0	6.5–7.0
P13	6.5–7.0	6.5–7.0
P14	6.5–7.0	6.5–7.0
P15	6.5–7.0	6.5–7.0
P16	6.5–7.0	6.5–7.0
P17	6.5–7.0	6.5–7.0
P18	6.5–7.0	6.5–7.0
P19	6.5–7.0	6.5–7.0
P20	6.5–7.0	6.5–7.0
P21	6.5–7.0	6.5–7.0
P22	6.5–7.0	6.5–7.0
P23	6.5–7.0	6.5–7.0
P24	6.5–7.0	6.5–7.0
P25	6.5–7.0	6.5–7.0
P26	6.5–7.0	6.5–7.0
P27	6.5–7.0	6.5–7.0
P28	6.5–7.0	6.5–7.0
P29	6.5–7.0	6.5–7.0
P30	6.5–7.0	6.5–7.0

In the second step, by combining brushing with the use of alcohol-free Listerine Coolmint mouthwash (Johnson & Johnson Consumer Inc., Skillman, New Jersey, USA), an obvious increase in salivary pH values was observed. At 30 minutes after the application of the combined regimen, most participants had pHs in the range of 7.0–7.5, and this trend was maintained or accentuated at 2 hours, with several cases reaching the upper threshold of the reference range. These findings suggest an additional alkalizing effect, attributed to antimicrobial essential oils in mouthwash, which reduce bacterial acidogenic activity and reflexively stimulate salivary secretion (Table 2).

At 30 minutes: 27 participants (90%) had salivary pH values in the range of 7.0–7.5, while 3 participants (10%) remained in the range of 6.5–7.0.

At 2 hours: all 30 participants (100%) had salivary pH values in the range of 7.0–7.5.

Table 2. Salivary pH values after brushing and rinsing with mouthwash, at 30 minutes and 2 hours

Participant	Ph in 30 min	Ph in 2 h
P01	7	7.0–7.5
P02	7.0–7.5	7.0–7.5
P03	6.5-7	7.0–7.5
P04	7.0–7.5	7.0–7.5
P05	7.0–7.5	7.0–7.5
P06	7.0–7.5	7.0–7.5
P07	6.5-7	7
P08	7	7.0–7.5
P09	7.0–7.5	7.0–7.5
P10	7.0–7.5	7.0–7.5
P11	7.0–7.5	7.0–7.5
P12	7	7.0–7.5
P13	7.0–7.5	7.0–7.5
P14	7.0–7.5	7.0–7.5
P15	7.0–7.5	7.0–7.5
P16	7.0–7.5	7.0–7.5
P17	6.5-7	7.0–7.5
P18	7.0–7.5	7.0–7.5
P19	7	7.0–7.5
P20	7.0–7.5	7.0–7.5
P21	7.0–7.5	7.0–7.5
P22	7.0–7.5	7.0–7.5
P23	6.5-7	7.0–7.5
P24	7.0–7.5	7.0–7.5
P25	7.0–7.5	7.0–7.5
P26	7.0–7.5	7.0–7.5
P27	7.0–7.5	7.0–7.5
P28	7.0–7.5	7.0–7.5
P29	7	7.0–7.5
P30	6.5-7	7.0–7.5

The comparative analysis between the two protocols revealed clear differences. Simple brushing kept the pH in the range of 6.5–7.0, while brushing followed by mouthwash determined higher values, frequently in the range of 7.0–7.5, especially at 2 hours post-intervention. This synergistic effect between the amine fluoride in the paste and the antiseptic essential oils in the mouthwash indicates a superior impact on the oral acid-base balance, with potential benefits in remineralization and in reducing the activity of acidophilic microorganisms (Table 3).

Table 3. The results of the Wilcoxon test

Compare	W Statistic	p-value	Interpret
T30 – Day 1 vs Day 2	0.0	0.0000	statistically significant difference
T120 – Day 1 vs Day 2	0.0	0.0000	statistically significant difference

Statistical interpretation by the Wilcoxon test for paired samples confirmed significant differences between the two protocols. Both at 30 minutes and 2 hours post-intervention, salivary pH values were significantly higher in the case of the combined regimen ($p = 0.0000$ for both intervals). This statistical significance reinforces the clinical relevance of the results, supporting the superiority of the protocol that integrates brushing and rinsing with alcohol-free antiseptic mouthwash.

Overall, the data obtained confirm the initial hypothesis that the combination of Elmex Anti-Caries Professional toothpaste with alcohol-free Listerine Coolmint mouthwash results in a more pronounced and stable increase in salivary pH compared to simple brushing. These results validate the importance of hybrid oral hygiene strategies, with direct implications in the prevention of tooth decay and in the maintenance of oral homeostasis (Figure 4).

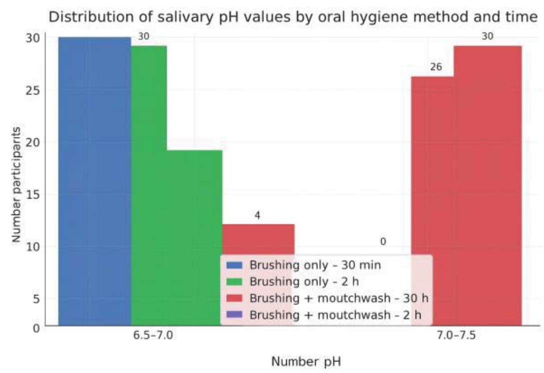

Figure 4. Distribution of salivary pH values at 30 minutes and 2 hours after simple brushing and mouthwash brushing

DISCUSSIONS

The results obtained in this study are congruent with recent data from the literature, confirming the significant impact of oral hygiene products on the acid-base balance of saliva and, implicitly, on general oral health. The increase in pH values observed after both protocols tested, with a more pronounced trend in the case of the combined use of toothpaste and mouthwash, demonstrates the effectiveness of this strategy in maintaining an alkaline oral environment, conducive to enamel remineralization and inhibition of acidophilic microorganisms.

Fluoride, a central element in caries prophylaxis, has once again demonstrated its role in stabilizing salivary pH. According to the study by Albahrani et al. (2022), increased fluoride retention in the salivary by avoiding rinsing with water immediately after brushing prolongs the protective effect and promotes enamel remineralization [7]. The results of the present research, where pH values remained in the physiological range of 6.5-7.0 after simple brushing, correlate with these conclusions, suggesting that fluoride potentiates the natural buffer response of saliva.

The addition of antiseptic mouthwash had an additional effect of increasing salivary pH, which corresponds to the observations of Jiemkim et al. (2023) and Memarpour et al. (2024), who showed that the association of fluoridated paste with mouthwash reduces tooth erosion and enhances enamel protection by enhancing buffering capacity and reducing microbial levels [4,6]. Also, Raj et al. (2021) highlighted that this combination lowers postprandial salivary acidity and protects more effectively against incipient carious lesions [5].

These findings are also supported by recent guidelines in the field, which recommend the integration of complementary products to optimize oral hygiene. Gallione et al. (2025) and

Ingleshwar et al. (2024) emphasize the importance of including the combination of fluorinated toothpaste and antiseptic mouthwash in standard protocols, especially among young people, a category at high risk for cavities and with often poor hygiene habits [14,3]. Thus, the results of the current study align with these recommendations, demonstrating the synergistic role of fluoride and antiseptic essential oils in maintaining a favorable salivary pH and reducing the risk of cariogenic.

However, the interpretation of the results must be carried out taking into account certain limitations. The small sample size (n=30), made up of young adults, limits the generalization of the conclusions to the general population. Also, pH monitoring was performed only at two points (30 minutes and 2 hours), without an assessment of the long-term effect persistence. Another important limitation is the semi-quantitative measurement method used, based on the Saliva Check Buffer kit, which estimates the pH in ranges of 0.5 units and does not provide exact values.

To deepen these results, future research should adopt a longitudinal design, which tracks changes in pH and other biochemical (fluorine, calcium) and microbiological parameters over longer periods. The diversification of the investigated population, by including children, the elderly, people with active oral diseases or with varied eating and hygiene habits, would provide a more complete picture of the effects of oral hygiene products. In addition, testing of other combinations of pastes and mouthwashes, with different types of fluoride and bioactive compounds, could highlight relevant variations in the ability to maintain oral homeostasis.

This study confirms the effectiveness of the combined fluoridated toothpaste-antiseptic mouthwash regimen in maintaining a more stable and alkaline salivary pH , with direct clinical implications in preventing cavities and protecting oral health. At the same time, the data obtained offer an additional argument for integrating this type of routine into personalized oral hygiene recommendations, thus contributing to reducing the incidence of oral pathologies at the population level.

CONCLUSIONS

The results of the study clearly demonstrate that the combined use of a fluoridated toothpaste and an antiseptic mouthwash leads to a significant and stable increase in salivary pH values compared to simple brushing. This evolution highlights the effectiveness of the combined diet in maintaining a more alkaline oral environment, favorable to enamel remineralization and reducing the activity of acidophilic bacteria involved in the etiology of dental caries.

Maintaining the salivary pH in a neutral or slightly alkaline range, both 30 minutes and 2 hours post-intervention, confirms the protective role of fluoride and essential oils in the composition of mouthwash on the oral acid-base balance. These results align with the data in the literature, which emphasize the importance of an optimal salivary pH for the prevention of microbiological imbalances and inflammatory gum-periodontal diseases.

Beyond its experimental value, the study also makes an educational contribution, supporting the need to promote a complete oral hygiene routine, which includes both daily brushing and the use of an effective mouthwash, with a prophylactic role. The consistent implementation of these measures can contribute to reducing the prevalence of caries and other untreated oral pathologies, having a positive impact on oral health at the population level.

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