# Enhancement of Plaque Removal Efficacy by Tooth Brushing with Baking Soda Dentifrices: Results of Five Clinical Studies

**Mark S. Putt, MSD, PhD** **Kimberly R. Milleman, RDH, MS**

**University Park Research Center**
**Fort Wayne, IN, USA**

**Annahita Ghassemi, PhD** **Linda M. Vorwerk, BS** **William J. Hooper, PhD**

**Church & Dwight Company**
**Princeton, NJ, USA**

**Pramod M. Soparkar, DMD**

**Boston, MA, USA**

**Anthony E. Winston, BSc**

**R&D for Hire**
**New Brunswick, NJ, USA**

**Howard M. Proskin, PhD**

**H.M. Proskin and Associates,** Inc.
**Rochester, NY, USA**

**Abstract**

- **Objective:** An earlier clinical study demonstrated that brushing with a commercial Arm & Hammer® dentifrice containing baking soda physically removed significantly more plaque than brushing with either of two commercial dentifrices, which did not contain baking soda. However, little has been done to confirm these results and to compare baking soda-containing dentifrices with more recently commercialized non-baking soda dentifrice formulations. The objective of this study was to compare commercial dentifrices containing 20% to 65% baking soda and commercial dentifrices without baking soda in enhancing plaque removal efficacy of tooth brushing.
- **Methods:** Five randomized, controlled, blinded, crossover clinical studies were performed among healthy adult volunteers who provided informed consent. After approximately 24 hours without oral hygiene, subjects with sufficient plaque were enrolled in the study phase. Plaque was scored before and after supervised brushing for one minute using the Turesky, *et al*. modification of the Quigley-Hein Plaque Index at six sites per tooth according to Soparkar's modification as described by Lobene, *et al*. In each study, wash-out periods with a regular dentifrice not evaluated in the study separated each product treatment.
- **Results:** In all studies, every dentifrice exhibited a significant ($p < 0.0001$) reduction in 24-hour plaque scores. Between-group comparisons of whole mouth plaque scores in all five studies demonstrated that brushing with baking soda dentifrices resulted in statistically greater ($p < 0.01$) reductions in whole mouth mean plaque scores than brushing with dentifrices that did not contain baking soda. Results on other tooth surfaces, such as facial, lingual, proximal, and gingival surfaces also demonstrated statistically greater ($p < 0.05$) reductions in mean plaque scores for the baking soda-containing dentifrices as compared to the baking soda-free dentifrices. In three of the studies comparing different levels of baking soda, brushing with dentifrices with higher concentrations of baking soda consistently removed numerically more plaque than those containing lower levels. In one of these three studies, the difference in plaque removal between the baking soda dentifrices reached statistical significance. The results suggest a positive relationship between plaque removal efficiency and baking soda concentration.
- **Conclusion:** The collective results from the five controlled clinical studies on over 270 subjects reported in this paper, consistently demonstrate that Arm & Hammer baking soda dentifrices enhanced plaque removal effectiveness of tooth brushing to a significantly greater extent than the non-baking soda dentifrice products.

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## Introduction

The ability of a toothbrush and dentifrice to remove plaque biofilm depends on several variables. For example, brushing technique, bristle geometry, bristle stiffness, brush head configuration and brushing time may all potentially influence the ease of plaque removal.[1] While toothbrush design is important, it seems that the ability to remove plaque biofilm is not in general greatly affected by the dentifrice formulation used.[1-6] However, it should be noted that some studies have seen significantly enhanced plaque removal due to the use of a dentifrice.[7,8]

In recent years, dentifrice formulations have been developed containing antimicrobial agents. Some of these have been shown to inhibit plaque growth.[9-11] However, antimicrobial agents do not affect the ability of a toothbrush and dentifrice to physically

remove plaque. Reductions in plaque levels, resulting from the ongoing use of dentifrices containing antimicrobials, are due to inhibition of plaque growth between brushings, which results in the toothbrush having less plaque to remove each time.[12,13]

Prior to the development of current dentifrices, baking soda was widely used as a dentifrice. Since the crystals of baking soda are soft, a major benefit of baking soda was considered to be its low abrasivity and hence reduced potential for damage to enamel and dentin.[14,15] Indeed for many years, the American Dental Association recommended the use of baking soda as a dentifrice, stating that "…if only a slight degree of abrasion is necessary to keep teeth from staining, baking soda will usually be found satisfactory."[16] While baking soda itself seems to clean well, a disadvantage of using baking soda alone is its lack of fluoride, which is needed to provide cavity protection. Furthermore, baking soda has a salty flavor that consumers may find objectionable. Therefore, more recently, baking soda has been formulated as one of several ingredients in some dentifrices at different concentrations. These dentifrices contain fluoride at appropriate levels to provide cavity protection, and are flavored and sweetened to overcome the salty taste of the baking soda. Furthermore, other ingredients are often incorporated into these dentifrices to provide additional specific targeted oral care benefits. For example, some dentifrices containing baking soda are formulated with pyrophosphates to inhibit tartar formation and stain, while others contain additional abrasives or peroxides for enhanced tooth whitening.[17]

A major benefit of dentifrices containing baking soda is the especially "clean feeling" which is imparted to the mouth after brushing. To date, the specific cause of this clean feeling has not been identified, although it is tempting to propose that it might be related to better plaque removal. Mankodi, *et al*. reported that a dentifrice containing 65% baking soda removed significantly more plaque than two conventional baking soda-free dentifrices when compared in a single-use crossover clinical study.[18] However, until now very little has been done to confirm these results with other dentifrices or to investigate baking soda's role in removing plaque. While some *in vitro* studies have shown that long periods of exposure to baking soda can inhibit bacterial growth or even kill some oral bacteria, baking soda is not considered to impart significant antibactericidal activity to dentifrices.[19-21] Baking soda is highly soluble, and probably does not remain in the mouth long enough to greatly affect the survival of plaque bacteria or to inhibit plaque growth. It would seem that any effects of baking soda on enhancing plaque removal might be attributed to: 1) physical properties of baking soda crystals in displacing plaque from the tooth surface; 2) interactions with plaque matrix by dissolved baking soda, which may, for example, reduce plaque viscosity and make it more readily removable by the toothbrush; or 3) its ability to favor the disruption of plaque biofilm by improving the penetration of biofilm by toothbrush bristles.

The purpose of this series of five clinical studies was to confirm the ability of baking soda, as an ingredient in fluoride dentifrices, to further enhance plaque removal by brushing. To achieve this, commercial dentifrices containing various levels of baking soda were compared with several commercial baking soda-free dentifrices for their ability to remove dental plaque in controlled clinical studies.

## Materials and Methods

A series of five independent, randomized, controlled, blinded, crossover clinical studies in over 270 subjects was performed to evaluate and compare commercially available dentifrices containing baking soda, with several commercially available baking soda-free dentifrices, for their ability to remove plaque during a single brushing. Studies 1 through 4 were conducted at the same study site using the same examiner with different subject populations, while Study 5 was conducted at a different study site with a different examiner. Study 5 was performed to provide independent confirmation of baking soda dentifrice activity for enhanced plaque removal that was observed in the four studies done at the same site. Prior to subject recruitment, studies were approved by an independent institutional review board.

### *Subject Population*

At screening, after reading and signing an informed consent statement and completing a medical questionnaire, potential subjects were examined to determine whether the subjects met the study requirements. To be included in any of the studies, subjects had to be aged 18 years or older, in good health, and demonstrate adequate oral hygiene. They had to exhibit at least 20 natural teeth with both facial and lingual scoreable surfaces, which were in a good state of repair. Grossly carious, fully crowned, orthodontically banded abutment teeth and third molars were excluded from this count. Subjects had to present with a 24-hour full-mouth plaque score > 1.5 based on Soparkar's modification of the Turesky version of the Quigley-Hein Plaque Index, as described below.[22-24]

The exclusion criteria included physical limitations affecting the ability of subjects to brush, high levels of extrinsic stain, or calculus deposits which might interfere with plaque assessments. Dental neglect, soft tissue pathology or damage, moderate or severe recession, periodontitis affecting more than two teeth, or the presence of orthodontic bands, bridges, extensive crowns or removable partial dentures were also grounds for exclusion. In addition, subjects using antibiotics or with various medical conditions or diseases which might affect the outcome were excluded from the study.

### *Clinical Procedures*

For each study, selected subjects meeting the inclusion/exclusion criteria were initially provided with a regular baking soda-free fluoride dentifrice for use during wash-out periods between each product treatment. Each study visit involved a baseline (pre-brushing) plaque assessment, a one-minute supervised brushing with the assigned test dentifrice, and a post-brushing plaque assessment.

Subjects refrained from oral hygiene for 24 hours, and did not eat, drink, or smoke the morning of their examination visit. All subjects were randomly assigned to one of the test products in sequence of treatments according to a randomization plan generated in advance of the study. Before the baseline plaque assessment, subjects rinsed with an erythrosine-containing plaque

disclosing solution (G.U.M.® Dental Disclosing Solution [Red Cote], Sunstar Americas, Chicago, IL, USA), followed by a brief rinse with water to remove excess solution. They then moved to a separate examination room.

After an oral soft tissue examination, the examiner scored pre-brushing plaque using the grading scale of the Turesky modification of the Quigley-Hein Plaque Index[23,24] (Figure 1), at 6 sites per tooth, according to Soparkar's modification as described by Lobene, *et al*.[22] Each tooth was divided into six areas for scoring: mesio-facial; mid-facial; disto-facial; mesio-lingual; mid-lingual; and disto-lingual. The scores from the areas of each tooth were summed and divided by six to yield the mean score for the tooth. By adding the indices for the teeth and dividing by the number of teeth examined, the mean whole mouth plaque score for the individual subject was obtained.

| Score | Description |
|---|---|
| 0 | No visible plaque. |
| 1 | Separate flecks of plaque at the cervical margin of the tooth. |
| 2 | A thin, continuous band of plaque (up to 1 mm wide) at the cervical margin. |
| 3 | A band of plaque wider than 1 mm but covering less than one-third of crown. |
| 4 | Plaque covering at least one-third but less than two-thirds of crown. |
| 5 | Plaque covering two-thirds or more of crown. |

**Figure 1.** *Grading scale of the Turesky,* et al. *modification of the Quigley-Hein Plaque Index.*

After the baseline examination, subjects returned to the brushing room where they were instructed to brush their teeth with 1.5 g of the assigned test dentifrice weighed onto a new manual toothbrush (Oral-B® 35 Compact Toothbrush, Procter & Gamble, Cincinnati, OH, USA). In all five studies, the same type of toothbrush and weighed 1.5 g of assigned dentifrice were used to control for dentifrice dosing and toothbrush variability. The subjects brushed their teeth for exactly one minute under supervision. The subjects were then re-disclosed with the red disclosing solution, and the same examiner re-scored the plaque level. The post-brushing examination completed each test period and started the wash-out period. The subjects were instructed to follow their normal oral hygiene procedures at home during each wash-out period, using the regular baking soda-free fluoride dentifrice and toothbrush provided, until the next test period. The wash-out periods ranged from three to five days, and after each wash-out period the subjects refrained from oral hygiene for 24 hours, and did not eat, drink, or smoke the morning of their examination visit.

### *Test Products*

All baking soda dentifrice products were manufactured by Church & Dwight Co., Inc., Princeton, NJ, USA. The level of baking soda ranged from 20% to 65%. The non-baking soda dentifrices were: Colgate® Total® Clean Mint, containing 0.3% triclosan and a copolymer (Colgate-Palmolive Company, New York, NY, USA); Crest® Pro-Health™, containing stannous fluoride and sodium hexametaphosphate (Procter & Gamble, Cincinnati, OH, USA); Crest® Regular Cavity Protection, containing sodium fluoride and silica (Procter & Gamble, Cincinnati, OH, USA); and Aim® Cavity Protection Gel, containing sodium fluoride and silica (Church & Dwight Co., Inc., Princeton, NJ, USA).

In the first study, the performance of a dentifrice containing 65% baking soda (Arm & Hammer® Dental Care®) and a dentifrice containing 20% baking soda (Arm & Hammer® Advance White™ Brilliant Sparkle) were compared with a baking soda-free dentifrice (Colgate Total Clean Mint). In the second study, a dentifrice containing 48% baking soda (Arm & Hammer® Advance White™ Baking Soda and Peroxide), and a dentifrice containing 20% baking soda (Arm & Hammer Advance White Brilliant Sparkle) were compared with two baking soda-free dentifrices (Colgate Total Clean Mint and Crest Pro-Health). In the third study, a dentifrice containing 48% baking soda (Arm & Hammer Advance White Baking Soda and Peroxide), and a dentifrice containing 27% baking soda (Arm & Hammer® Advance White™ Liquid Gel) were compared with two baking soda-free dentifrices (Crest Regular Cavity Protection and Colgate Total Clean Mint). In the fourth study, a dentifrice containing 65% baking soda (Arm & Hammer Dental Care) and Aim Cavity Protection Gel with no baking soda were compared. In the fifth study, a dentifrice containing 20% baking soda (Arm & Hammer Advance White Brilliant Sparkle) was compared with Colgate Total Clean Mint.

### *Data Analysis*

All data are presented as Mean ± Standard Deviation (SD). In addition to whole mouth data, the plaque scores were analyzed according to facial, lingual, proximal, and gingival surfaces. As described previously, whole mouth plaque scores represented all six scoring index sites. Facial surfaces comprised the mesio-facial, mid-facial, and disto-facial scoring sites, and lingual surfaces constituted the mesio-lingual, mid-lingual, and disto-lingual sites. Proximal surfaces were defined as the mesio-facial, disto-facial, mesio-lingual, and disto-lingual sites, while gingival surfaces were the mid-facial and mid-lingual sites.

**Pre-Brushing Assessments.** Comparisons among treatment groups with respect to pre-brushing plaque scores were performed using the same model described above without the inclusion of the covariate. Within-treatment comparisons of pre-brushing plaque scores versus post-brushing plaque scores were performed using paired t-tests.

**Pre- to Post-Brushing Assessments.** Pre- to post-brushing plaque difference was calculated by subtracting the post-brushing plaque score from the pre-brushing plaque score. Comparisons among the study treatments were performed using an analysis of covariance (ANCOVA) model suitable for a crossover design, with the associated pre-brushing plaque score included as a covariate. Specifically, the ANCOVA model included the fixed effects treatment and period, the random effect subject, the pre-brushing score as a covariate, and pre- to post-brushing reduction as the response variable. Post-ANCOVA, pair-wise treatment comparisons were made using t-tests. Only subjects with data for all test periods of the study were included in the analyses. All pair-wise treatment comparisons were based on two-sided tests at a significance level of $\alpha = 0.05$. Tukey's method at a significance level of

$\alpha = 0.05$ was employed for those studies involving multiple comparisons.

## Results

Table I summarizes demographics for all five studies. Tables II to VI present plaque results of the five studies for whole mouth, facial, lingual, proximal, and gingival surfaces, respectively.

**Table I**
Demographics

| | N | Female Subjects | Male Subjects | Age (Mean ± SD) | Age Range |
|---|---|---|---|---|---|
| Study 1 | 65 | 50 | 15 | 42 ± 13 | 18–68 |
| Study 2 | 66 | 49 | 17 | 40 ± 13 | 22–81 |
| Study 3 | 64 | 46 | 18 | 41 ± 11 | 22–68 |
| Study 4 | 36 | 27 | 9 | 38 ± 11 | 19–64 |
| Study 5 | 41 | 33 | 8 | 42 ± 12 | 20–64 |

***Study 1***

A total of 71 subjects were qualified for this study, and six subjects discontinued for non-product-related reasons. Of 65 subjects completing the study, there were 15 males and 50 females, ranging in age from 18 to 68 years (overall mean age was 42 ± 13 years).

There were no significant statistical differences ($p > 0.05$) in the mean baseline whole mouth plaque scores for the three groups (Table II). Within-group analysis showed that brushing with each of the three dentifrices reduced the amount of plaque remaining on the teeth ($p < 0.0001$). Between-group comparisons showed that brushing with 65% and 20% baking soda dentifrices resulted in significantly ($p \leq 0.0001$) greater pre- to post-brushing plaque removal scores (0.73 ± 0.26 and 0.64 ± 0.26, respectively) than brushing with the triclosan dentifrice (0.52 ± 0.20). Brushing with the 65% baking soda dentifrice reduced the mean plaque score by 40% ($p < 0.0001$) more than the triclosan dentifrice, and brushing with the 20% baking soda dentifrice reduced the mean plaque score by 23% ($p = 0.0001$) more than the triclosan dentifrice. Comparison between the two baking soda dentifrices showed a 13% greater mean plaque removal for the 65% baking soda dentifrice than the 20% baking soda dentifrice ($p = 0.0033$), as measured by comparison of plaque reduction scores.

Analyses of mean plaque scores for facial, lingual, proximal, and gingival surfaces exhibited similar results as those of whole mouth plaque scores (Tables III–VI). For each of the four surfaces, mean baseline plaque scores were not statistically significantly different ($p > 0.05$). For all surface areas, brushing with the 65% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores) than the triclosan dentifrice by 25% for facial ($p < 0.0001$), 157% for lingual ($p < 0.0001$), 51% for proximal ($p < 0.0001$), and 30% for gingival ($p < 0.0001$) surfaces. The 20% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores) than the triclosan dentifrice by 15% for facial ($p = 0.0008$), 94% for lingual ($p = 0.0004$), 32% for proximal ($p < 0.0001$), and 15% for gingival ($p = 0.0166$) surfaces.

***Study 2***

A total of 68 subjects qualified for this study, and two subjects discontinued for non-product-related reasons. Of 66 subjects completing the study (Table I), there were 17 males and 49 females, ranging in age from 22 to 81 years (overall mean age was 40 ± 13 years).

There were no significant statistical differences ($p > 0.05$) in the mean baseline whole mouth plaque scores for the four groups (Table II). Within-group analysis showed that brushing with each of the four dentifrices reduced the amount of plaque remaining on the teeth ($p < 0.0001$). Between-group comparisons showed that brushing with the 48% and 20% baking soda dentifrices resulted in significantly greater ($p < 0.0001$) pre- to post-brushing plaque removal scores (0.72 ± 0.28 and 0.68 ± 0.27) than brushing with the triclosan dentifrice (0.58 ± 0.25). Brushing with the 48% baking soda dentifrice resulted in 23% ($p < 0.0001$) and 21% ($p < 0.0001$) greater reductions in mean plaque scores as compared to the triclosan dentifrice and the stannous fluoride/silica dentifrice, respectively. Brushing with the 20% baking soda dentifrice resulted in 17% ($p < 0.0001$) and 14% ($p = 0.0002$) greater plaque removal scores as compared to the triclosan dentifrice and the stannous fluoride/silica dentifrice, respectively. While the mean plaque reduction score by the 48% baking soda dentifrice was numerically higher than the 20% baking soda dentifrice, the difference in performance between the two baking soda product groups was not statistically significant ($p = 0.5661$).

For each of the facial, lingual, proximal, and gingival surfaces, mean baseline plaque scores were not statistically significantly different ($p > 0.05$). Analyses of mean plaque scores for facial, lingual, proximal, and gingival surfaces produced similar results to those of whole mouth plaque scores (Tables III–VI), in that brushing with the 48% or 20% baking soda dentifrices removed more plaque (*i.e.*, greater reduction in mean plaque scores) than the triclosan dentifrice and the stannous fluoride/silica dentifrice. For example, brushing with the 48% baking soda dentifrice reduced mean plaque scores by 15% for facial ($p < 0.0001$), 72% for lingual ($p < 0.0001$), 30% for proximal ($p < 0.0001$), and 17% for gingival ($p < 0.0001$) surfaces when compared to the triclosan dentifrice. Furthermore, brushing with the 48% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores) than brushing with the stannous fluoride/silica dentifrice by 17% for facial ($p < 0.0001$), 42% for lingual ($p = 0.0012$), 24% for proximal ($p < 0.0001$), and 18% for gingival ($p < 0.0001$) surfaces.

***Study 3***

A total of 69 subjects qualified for this study, and five subjects failed to complete the study for non-product-related reasons. Of 64 subjects completing the study, there were 18 males and 46 females, ranging in age from 22 to 68 years (overall mean age was 41 ± 11 years).

There were no significant statistical differences ($p > 0.05$) in the mean baseline whole mouth plaque scores for the four dentifrice groups (Table II). Within-group analysis showed that brushing with each of the four dentifrices reduced the average amount of plaque remaining on the teeth ($p < 0.0001$). Between-group comparisons showed that the reduction in whole mouth mean plaque scores was greater for the 48% and 27% baking soda dentifrices than for the triclosan dentifrice and the sodium fluoride/silica

**Table II**
Studies 1–5: Whole Mouth Plaque Results

| Dentifrice Group | N | Within-Group Analysis: Pre-Brushing Plaque Score* | Within-Group Analysis: Pre- to Post-Brushing Reduction* | Between-Group Comparison Analysis: Group Comparison | Between-Group Comparison Analysis: Greater Plaque Reduction Score# | Between-Group Comparison Analysis: Significance |
|---|---|---|---|---|---|---|
| Study #1 | | | | | | |
| A—65% Baking Soda | 65 | 3.16 ± 0.35 | 0.73 ± 0.26 | A vs. C | 1.40×; 40% | p < 0.0001 |
| B—20% Baking Soda | 65 | 3.18 ± 0.37 | 0.64 ± 0.26 | B vs. C | 1.23×; 23% | p = 0.0001 |
| C—Triclosan/Copolymer | 65 | 3.16 ± 0.37 | 0.52 ± 0.20 | — | — | — |
| Study #2 | | | | | | |
| A—48% Baking Soda | 66 | 3.05 ± 0.35 | 0.72 ± 0.28 | A vs. C | 1.23×; 23% | p < 0.0001 |
| | | | | A vs. D | 1.21×; 21% | p < 0.0001 |
| B—20% Baking Soda | 66 | 3.02 ± 0.36 | 0.68 ± 0.27 | B vs. C | 1.17×; 17% | p < 0.0001 |
| | | | | B vs. D | 1.14×; 14% | p = 0.0002 |
| C—Triclosan/Copolymer | 66 | 3.03 ± 0.33 | 0.58 ± 0.25 | — | — | — |
| D—Stannous Fluoride/Silica | 66 | 3.04 ± 0.40 | 0.59 ± 0.26 | — | — | — |
| Study #3 | | | | | | |
| A—48% Baking Soda | 64 | 3.14 ± 0.31 | 0.78 ± 0.31 | A vs. C | 1.27×; 27% | p < 0.0001 |
| | | | | A vs. D | 1.34×; 34% | p < 0.0001 |
| B—27% Baking Soda | 64 | 3.15 ± 0.34 | 0.73 ± 0.32 | B vs. C | 1.18×; 18% | p = 0.0009 |
| | | | | B vs. D | 1.25×; 25% | p = 0.0001 |
| C—Triclosan/Copolymer | 64 | 3.12 ± 0.40 | 0.62 ± 0.27 | — | — | — |
| D—Sodium Fluoride/Silica | 64 | 3.13 ± 0.34 | 0.58 ± 0.24 | — | — | — |
| Study #4 | | | | | | |
| A—65% Baking Soda | 36 | 2.94 ± 0.35 | 0.80 ± 0.31 | A vs. B | 1.71×; 71% | p < 0.0001 |
| B—Sodium Fluoride/Silica Gel | 36 | 2.97 ± 0.34 | 0.47 ± 0.23 | — | — | — |
| Study #5 | | | | | | |
| A—20% Baking Soda | 41 | 2.28 ± 0.36 | 1.07 ± 0.38 | A vs. B | 1.23×; 23% | p = 0.0014 |
| B—Triclosan/Copolymer | 41 | 2.25 ± 0.33 | 0.87 ± 0.37 | — | — | — |

* Mean ± SD

# Greater plaque reduction score for the baking soda dentifrice is expressed as a ratio and percentage of plaque reduction score for the other dentifrice. A positive value indicates greater plaque reduction in favor of brushing with baking soda dentifrice as compared to the other dentifrice. Ratio = (baking soda dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction); % difference in plaque reduction = 100% × (baking soda dentifrice mean plaque reduction – other dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction).

**Table III**
Studies 1–5: Facial Surfaces Plaque Results

| Dentifrice Group | N | Within-Group Analysis: Pre-Brushing Plaque Score* | Within-Group Analysis: Pre- to Post-Brushing Reduction* | Between-Group Comparison Analysis: Group Comparison | Between-Group Comparison Analysis: Greater Plaque Reduction Score# | Between-Group Comparison Analysis: Significance |
|---|---|---|---|---|---|---|
| Study #1 | | | | | | |
| A—65% Baking Soda | 65 | 3.28 ± 0.48 | 1.17 ± 0.44 | A vs. C | 1.25×; 25% | p < 0.0001 |
| B—20% Baking Soda | 65 | 3.29± 0.46 | 1.07 ± 0.41 | B vs. C | 1.15×; 15% | p = 0.0008 |
| C—Triclosan/Copolymer | 65 | 3.30 ± 0.50 | 0.93 ± 0.36 | — | — | — |
| Study #2 | | | | | | |
| A—48% Baking Soda | 66 | 3.14 ± 0.51 | 1.14 ± 0.43 | A vs. C | 1.15×; 15% | p < 0.0001 |
| | | | | A vs. D | 1.17×; 17% | p < 0.0001 |
| B—20% Baking Soda | 66 | 3.12 ± 0.52 | 1.09 ± 0.44 | B vs. C | 1.09×; 9% | p = 0.0107 |
| | | | | B vs. D | 1.11×; 11% | p = 0.0030 |
| C—Triclosan/copolymer | 66 | 3.13 ± 0.51 | 1.00 ± 0.39 | — | — | — |
| D—Stannous Fluoride/Silica | 66 | 3.13 ± 0.59 | 0.98 ± 0.43 | — | — | — |
| Study #3 | | | | | | |
| A—48% Baking Soda | 64 | 3.24 ± 0.49 | 1.29 ± 0.51 | A vs. C | 1.23×; 23% | p < 0.0001 |
| | | | | A vs. D | 1.25×; 25% | p < 0.0001 |
| B—27% Baking Soda | 64 | 3.25 ± 0.55 | 1.21 ± 0.54 | B vs. C | 1.15×; 15% | p = 0.0064 |
| | | | | B vs. D | 1.18×; 18% | p = 0.0007 |
| C—Triclosan/Copolymer | 64 | 3.20 ± 0.62 | 1.05 ± 0.44 | — | — | — |
| D—Sodium Fluoride/Silica | 64 | 3.21 ± 0.54 | 1.03 ± 0.44 | — | — | — |
| Study #4 | | | | | | |
| A—65% Baking Soda | 36 | 3.08 ± 0.51 | 1.22 ± 0.50 | A vs. B | 1.51×; 51% | p < 0.0001 |
| B—Sodium Fluoride/Silica Gel | 36 | 3.12 ± 0.48 | 0.81 ± 0.39 | — | — | — |
| Study #5 | | | | | | |
| A—20% Baking Soda | 41 | 2.40 ± 0.52 | 1.56 ± 0.48 | A vs. B | 1.16×; 16% | p = 0.0102 |
| B—Triclosan/Copolymer | 41 | 2.37 ± 0.47 | 1.35 ± 0.53 | — | — | — |

* Mean ± SD

# Greater plaque reduction score for the baking soda dentifrice is expressed as a ratio and percentage of plaque reduction score for the other dentifrice. A positive value indicates greater plaque reduction in favor of brushing with baking soda dentifrice as compared to the other dentifrice. Ratio = (baking soda dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction); % difference in plaque reduction = 100% × (baking soda dentifrice mean plaque reduction – other dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction).

**Table IV**
Studies 1–5: Lingual Surfaces Plaque Results

| Dentifrice Group | N | Within-Group Analysis: Pre-Brushing Plaque Score* | Within-Group Analysis: Pre- to Post-Brushing Reduction* | Between-Group Comparison Analysis: Group Comparison | Between-Group Comparison Analysis: Greater Plaque Reduction Score# | Between-Group Comparison Analysis: Significance |
|---|---|---|---|---|---|---|
| Study #1 | | | | | | |
| A—65% Baking Soda | 65 | 3.04 ± 0.39 | 0.29 ± 0.18 | A vs. C | 2.57×; 157% | p < 0.0001 |
| B—20% Baking Soda | 65 | 3.06 ± 0.41 | 0.22 ± 0.21 | B vs. C | 1.94×; 94% | p = 0.0004 |
| C—Triclosan/Copolymer | 65 | 3.02 ± 0.40 | 0.11 ± 0.17 | — | — | — |
| Study #2 | | | | | | |
| A—48% Baking Soda | 66 | 2.96 ± 0.34 | 0.29 ± 0.23 | A vs. C | 1.72×; 72% | p < 0.0001 |
| | | | | A vs. D | 1.42×; 42% | p = 0.0012 |
| B—20% Baking Soda | 66 | 2.93 ± 0.35 | 0.27 ± 0.24 | B vs. C | 1.59×; 59% | p = 0.0001 |
| | | | | B vs. D | 1.31×; 31% | p = 0.0221 |
| C—Triclosan/Copolymer | 66 | 2.94 ± 0.33 | 0.17 ± 0.18 | — | — | — |
| D—Stannous Fluoride/Silica | 66 | 2.96 ± 0.37 | 0.20 ± 0.20 | — | — | — |
| Study #3 | | | | | | |
| A—48% Baking Soda | 64 | 3.05 ± 0.32 | 0.27 ± 0.24 | A vs. C | 1.49×; 49% | p = 0.0011 |
| | | | | A vs. D | 1.96×; 96% | p < 0.0001 |
| B—27% Baking Soda | 64 | 3.04 ± 0.33 | 0.25 ± 0.23 | B vs. C | 1.36×; 36% | p = 0.0331 |
| | | | | B vs. D | 1.78×; 78% | p < 0.0001 |
| C—Triclosan/Copolymer | 64 | 3.05 ± 0.34 | 0.18 ± 0.19 | — | — | — |
| D—Sodium Fluoride/Silica | 64 | 3.04 ± 0.33 | 0.14 ± 0.16 | — | — | — |
| Study #4 | | | | | | |
| A—65% Baking Soda | 36 | 2.80 ± 0.31 | 0.38 ± 0.22 | A vs. B | 2.95×; 195% | p < 0.0001 |
| B—Sodium Fluoride/Silica Gel | 36 | 2.81 ± 0.29 | 0.13 ± 0.15 | — | — | — |
| Study #5 | | | | | | |
| A—20% Baking Soda | 41 | 2.16 ± 0.33 | 0.58 ± 0.46 | A vs. B | 1.50×; 50% | p = 0.0114 |
| B—Triclosan/Copolymer | 41 | 2.13 ± 0.34 | 0.39 ± 0.39 | — | — | — |

* Mean ± SD

# Greater plaque reduction score for the baking soda dentifrice is expressed as a ratio and percentage of plaque reduction score for the other dentifrice. A positive value indicates greater plaque reduction in favor of brushing with baking soda dentifrice as compared to the other dentifrice. Ratio = (baking soda dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction); % difference in plaque reduction = 100% × (baking soda dentifrice mean plaque reduction – other dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction).

**Table V**
Studies 1–5: Proximal Surfaces Plaque Results

| Dentifrice Group | N | Within-Group Analysis: Pre-Brushing Plaque Score* | Within-Group Analysis: Pre- to Post-Brushing Reduction* | Between-Group Comparison Analysis: Group Comparison | Between-Group Comparison Analysis: Greater Plaque Reduction Score# | Between-Group Comparison Analysis: Significance |
|---|---|---|---|---|---|---|
| Study #1 | | | | | | |
| A—65% Baking Soda | 65 | 3.31 ± 0.32 | 0.56 ± 0.25 | A vs. C | 1.51×; 51% | p < 0.0001 |
| B—20% Baking Soda | 65 | 3.32 ± 0.34 | 0.49 ± 0.25 | B vs. C | 1.32×; 32% | p < 0.0001 |
| C—Triclosan/Copolymer | 65 | 3.31 ± 0.35 | 0.37 ± 0.18 | — | — | — |
| Study #2 | | | | | | |
| A—48% Baking Soda | 66 | 3.19 ± 0.33 | 0.55 ± 0.25 | A vs. C | 1.30×; 30% | p < 0.0001 |
| | | | | A vs. D | 1.24×; 24% | p < 0.0001 |
| B—20% Baking Soda | 66 | 3.18 ± 0.32 | 0.51 ± 0.23 | B vs. C | 1.21×; 21% | p = 0.0004 |
| | | | | B vs. D | 1.16×; 16% | p = 0.0049 |
| C—Triclosan/Copolymer | 66 | 3.18 ± 0.30 | 0.43 ± 0.22 | — | — | — |
| D—Stannous Fluoride/Silica | 66 | 3.19 ± 0.37 | 0.44 ± 0.22 | — | — | — |
| Study #3 | | | | | | |
| A—48% Baking Soda | 64 | 3.29 ± 0.29 | 0.62 ± 0.31 | A vs. C | 1.32×; 32% | p < 0.0001 |
| | | | | A vs. D | 1.45×; 45% | p < 0.0001 |
| B—27% Baking Soda | 64 | 3.29 ± 0.31 | 0.58 ± 0.29 | B vs. C | 1.22×; 22% | p = 0.0010 |
| | | | | B vs. D | 1.35×; 35% | p < 0.0001 |
| C—Triclosan/Copolymer | 64 | 3.27 ± 0.37 | 0.47 ± 0.25 | — | — | — |
| D—Sodium Fluoride/Silica | 64 | 3.27 ± 0.32 | 0.43 ± 0.21 | — | — | — |
| Study #4 | | | | | | |
| A—65% Baking Soda | 36 | 3.12 ± 0.32 | 0.63 ± 0.29 | A vs. B | 2.04×; 104% | p < 0.0001 |
| B—Sodium Fluoride/Silica Gel | 36 | 3.13 ± 0.32 | 0.31 ± 0.20 | — | — | — |
| Study #5 | | | | | | |
| A—20% Baking Soda | 41 | 2.31 ± 0.35 | 1.01 ± 0.36 | A vs. B | 1.25×; 25% | p = 0.0007 |
| B—Triclosan/Copolymer | 41 | 2.30 ± 0.30 | 0.80 ± 0.36 | — | — | — |

* Mean ± SD

# Greater plaque reduction score for the baking soda dentifrice is expressed as a ratio and percentage of plaque reduction score for the other dentifrice. A positive value indicates greater plaque reduction in favor of brushing with baking soda dentifrice as compared to the other dentifrice. Ratio = (baking soda dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction); % difference in plaque reduction = 100% × (baking soda dentifrice mean plaque reduction – other dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction).

**Table VI**
Studies 1–5: Gingival Surfaces Plaque Results

| Dentifrice Group | N | Within-Group Analysis: Pre-Brushing Plaque Score* | Within-Group Analysis: Pre- to Post-Brushing Reduction* | Between-Group Comparison Analysis: Group Comparison | Between-Group Comparison Analysis: Greater Plaque Reduction Score# | Between-Group Comparison Analysis: Significance |
|---|---|---|---|---|---|---|
| Study #1 | | | | | | |
| A—65% Baking Soda | 65 | 2.86 ± 0.43 | 1.07 ± 0.38 | A vs. C | 1.30×; 30% | p < 0.0001 |
| B—20% Baking Soda | 65 | 2.89 ± 0.43 | 0.95 ± 0.38 | B vs. C | 1.15×; 15% | p = 0.0166 |
| C—Triclosan/Copolymer | 65 | 2.86 ± 0.43 | 0.83 ± 0.33 | — | — | — |
| Study #2 | | | | | | |
| A—48% Baking Soda | 66 | 2.76 ± 0.41 | 1.05 ± 0.41 | A vs. C | 1.17×; 17% | p < 0.0001 |
| | | | | A vs. D | 1.18×; 18% | p < 0.0001 |
| B—20% Baking Soda | 66 | 2.72 ± 0.49 | 1.00 ± 0.41 | B vs. C | 1.12×; 12% | p = 0.0002 |
| | | | | B vs. D | 1.13×; 13% | p < 0.0001 |
| C—Triclosan/Copolymer | 66 | 2.74 ± 0.43 | 0.89 ± 0.38 | — | — | — |
| D—Stannous Fluoride/Silica | 66 | 2.74 ± 0.48 | 0.89 ± 0.40 | — | — | — |
| Study #3 | | | | | | |
| A—48% Baking Soda | 64 | 2.86 ± 0.38 | 1.10 ± 0.37 | A vs. C | 1.21×; 21% | p < 0.0001 |
| | | | | A vs. D | 1.22×; 22% | p < 0.0001 |
| B—27% Baking Soda | 64 | 2.86 ± 0.43 | 1.04 ± 0.46 | B vs. C | 1.14×; 14% | p = 0.0056 |
| | | | | B vs. D | 1.15×; 15% | p = 0.0008 |
| C—Triclosan/Copolymer | 64 | 2.83 ± 0.47 | 0.91 ± 0.37 | — | — | — |
| D—Sodium Fluoride/Silica | 64 | 2.84 ± 0.41 | 0.90 ± 0.36 | — | — | — |
| Study #4 | | | | | | |
| A—65% Baking Soda | 36 | 2.58 ± 0.45 | 1.13 ± 0.43 | A vs. B | 1.45×; 45% | p < 0.0001 |
| B—Sodium Fluoride/Silica Gel | 36 | 2.64 ± 0.40 | 0.78 ± 0.36 | — | — | — |
| Study #5 | | | | | | |
| A—20% Baking Soda | 41 | 2.20 ± 0.39 | 1.20 ± 0.44 | A vs. B | 1.20×; 20% | p = 0.0069 |
| B—Triclosan/Copolymer | 41 | 2.16 ± 0.40 | 1.00 ± 0.42 | — | — | — |

* Mean ± SD

# Greater plaque reduction score for the baking soda dentifrice is expressed as a ratio and percentage of plaque reduction score for the other dentifrice. A positive value indicates greater plaque reduction in favor of brushing with baking soda dentifrice as compared to the other dentifrice. Ratio = (baking soda dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction); % difference in plaque reduction = 100% × (baking soda dentifrice mean plaque reduction – other dentifrice mean plaque reduction) / (other dentifrice mean plaque reduction).

dentifrice (Table II). Brushing with dentifrices containing 48% and 27% baking soda exhibited 27% ($p < 0.0001$) and 18% ($p = 0.0009$) greater reduction in mean plaque scores, respectively, than the triclosan dentifrice. In addition, brushing with dentifrices containing 48% and 27% baking soda exhibited 34% ($p < 0.0001$) and 25% ($p < 0.0001$) greater reduction in mean plaque scores, respectively, as compared to the sodium fluoride/silica dentifrice. While the average plaque reduction by the dentifrice containing 48% baking soda was numerically higher than the 27% baking soda dentifrice, the difference in performance between the two baking soda product groups was not statistically significant ($p = 0.1813$).

For each of the facial, lingual, proximal, and gingival surfaces, mean baseline plaque scores were not statistically significantly different ($p > 0.05$). Analyses of mean plaque scores for facial, lingual, proximal, and gingival surfaces produced similar results as those of whole mouth plaque scores (Tables III–VI), in that brushing with the 48% or 27% baking soda dentifrices removed more plaque (*i.e.*, greater reduction in mean plaque scores) than the triclosan dentifrice and the sodium fluoride/silica dentifrice. For example, brushing with the 48% baking soda dentifrice reduced mean plaque scores by 23% for facial ($p < 0.0001$), 49% for lingual ($p = 0.0011$), 32% for proximal ($p < 0.0001$), and 21% for gingival ($p < 0.0001$) surfaces when compared to the triclosan dentifrice. Furthermore, brushing with the 48% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores) than brushing with the sodium fluoride/silica dentifrice by 25% for facial ($p < 0.0001$), 96% for lingual ($p < 0.0001$), 45% for proximal ($p < 0.0001$), and 22% for gingival ($p < 0.0001$) surfaces. Similar results were obtained in favor of the 27% baking soda dentifrice when compared to the triclosan or the sodium fluoride/silica dentifrice.

***Study 4***

A total of 36 subjects qualified for this study, and all of these subjects completed the study. Of 36 subjects, there were 9 males and 27 females, ranging in age from 19 to 64 years (overall mean age 38 ± 11 years).

There was no significant statistical difference ($p > 0.05$) in the mean baseline whole mouth plaque scores for the two groups (Table II). Within-group analysis showed that brushing with each of the two dentifrices reduced the average amount of plaque left on the teeth ($p < 0.0001$). The pre- to post-brushing plaque reduction for the 65% baking soda dentifrice (0.80 ± 0.31) was significantly ($p < 0.0001$) greater than that for the sodium fluoride/silica gel dentifrice (0.47 ± 0.23). Between-group comparisons showed that brushing with the 65% baking soda dentifrice resulted in a 71% greater plaque removal score than brushing with the sodium fluoride/silica gel dentifrice.

For each of the facial, lingual, proximal, and gingival surfaces, mean baseline plaque scores were not statistically significantly different ($p > 0.05$). Analysis of mean plaque scores for facial, lingual, proximal, and gingival surfaces produced similar results as those of whole mouth plaque scores (Tables III–VI), in that brushing with the 65% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores)

than the sodium fluoride/silica gel dentifrice by 51% for facial ($p < 0.0001$), 195% for lingual ($p < 0.0001$), 104% for proximal ($p < 0.0001$), and 45% for gingival ($p < 0.0001$) sites.

***Study 5***

The fifth study was conducted at a different study site with a different examiner from the above four studies. A total of 45 subjects qualified for this study, and 4 subjects discontinued for non-product-related reasons. Of the 41 subjects in the study, there were 8 males and 33 females, ranging in age from 20 years to 64 years (overall mean age 42 ± 12 years).

There were no significant statistical differences ($p > 0.05$) in the baseline mean whole mouth plaque scores for the 20% baking soda dentifrice group and the triclosan dentifrice group (Table II). Within-group analysis showed that brushing with each of the two dentifrices reduced the average amount of plaque remaining on the teeth ($p < 0.0001$). Brushing with the 20% baking soda dentifrice resulted in pre- to post-brushing plaque reduction of 1.07 ± 0.38, compared with a reduction of 0.87 ± 0.37 for the triclosan dentifrice. The 20% baking soda dentifrice was associated with 23% greater whole mouth plaque removal score as compared to the triclosan dentifrice ($p = 0.0014$).

For each of the facial, lingual, proximal, and gingival surfaces, mean baseline plaque scores were not statistically significantly different ($p > 0.05$). Analysis of mean plaque scores for facial, lingual, proximal, and gingival surfaces exhibited similar results as those of whole mouth plaque scores (Tables III–VI), in that brushing with the 20% baking soda dentifrice removed more plaque (*i.e.*, greater reduction in mean plaque scores) than the triclosan dentifrice, by 16% for facial ($p = 0.0102$ ), 50% for lingual ($p = 0.0114$), 25% for proximal ($p = 0.0007$), and 20% for gingival ($p = 0.0069$) surfaces.

## Discussion

Five separate, controlled, crossover clinical studies consistently demonstrated a significant benefit for baking soda dentifrices in enhancing the physical removal of plaque biofilm by tooth brushing as compared to commercial dentifrices without baking soda. In all five studies, every dentifrice significantly reduced 24-hour whole mouth mean plaque scores following a single one-minute supervised tooth brushing. Between-group comparisons of whole mouth plaque scores in all five studies demonstrated that brushing with dentifrices containing from 20% to 65% baking soda resulted in greater plaque removal (*i.e.*, greater reductions in mean plaque scores) than brushing with other commercial dentifrices that did not contain baking soda. Analysis of plaque scores according to tooth surfaces and sites for each study resulted in the same relationships between dentifrices as observed for whole mouth scores, in which brushing with baking soda dentifrices produced statistically significantly greater plaque removal (*i.e.*, greater reduction in mean plaque scores) than brushing with non-baking soda dentifrices. In the three studies (Studies 1–3) which also compared different levels of baking soda, the results may suggest a positive relationship between baking soda concentration and greater plaque reduction scores. Also, it is noteworthy that Study 5 (which was conducted at a different site with a different examiner) confirmed the results of Studies 1 and 2, wherein the same 20% baking soda dentifrice demonstrated statistically significantly greater reductions in plaque scores than the triclosan dentifrice. In fact, all three studies provided similar plaque reduction scores, ranging from 17% to 23% for the whole mouth data.

The five studies confirm the findings of Mankodi, *et al*., who demonstrated higher plaque removal from a dentifrice containing 65% baking soda over two baking soda-free dentifrices.[18] In a separate comparison of three dentifrices containing baking soda, Mankodi, *et al*. also seemed to detect a positive relationship between baking soda concentration and enhanced plaque removal by brushing.[18] In our studies, a significant dose-dependent effect for baking soda in the removal of plaque was also found in one of these comparisons (Study 1). In others, while the dentifrices containing the highest levels of baking soda consistently removed greater quantities of plaque than those with lower baking soda concentration, those differences were not statistically significant.

It is unlikely that baking soda's mechanism of action is based on an antimicrobial activity. First, baking soda has relatively weak antibacterial properties, and it is slow-acting.[19] Since baking soda is highly soluble, it is not present in the mouth for long enough at sufficient concentrations to reduce bacterial counts. Furthermore, the single brushing technique used in these studies does not allow for the detection of plaque growth inhibitory effects which would result from the use of a bactericide.

We propose three possible reasons for baking soda's effect on plaque. A first possible explanation is that baking soda's crystals are much larger than the conventional abrasive particles used in other dentifrices. While the baking soda crystals are considerably softer and potentially less damaging to tooth mineral, these larger crystals may physically help the toothbrush displace the soft sticky plaque from the tooth surface. Secondly, plaque consists primarily of bacteria in a polysaccharide matrix.[25] The viscosity of many polymer-thickened gels is often affected by ionic strength and pH. It is conceivable that baking soda dissolves in plaque fluid and has a physical affect on the structure of this adherent material, reducing its viscosity and adhesiveness/cohesiveness, and making it easier to remove by the toothbrush. Rose, *et al*. proposed a role for fluoride in removing plaque from teeth, suggesting that fluoride breaks calcium bonds between adhering strains of bacteria and between bacteria and pellicle surfaces.[26] Busscher, *et al*. confirmed that sodium fluoride and sodium lauryl sulfate from dentifrices stimulate bacterial detachment from pellicle surfaces.[27] Therefore, a third possible explanation for baking soda's effectiveness in promoting plaque removal is that bicarbonate ions from baking soda play a similar bond-breaking role by their detersive action, disrupting bacterial attachment and possibly sequestering the calcium as calcium carbonate. Carbon dioxide gas would be produced in the process, which might further help loosen plaque. If this mechanism is correct, superior plaque removal could result from the relatively high concentrations of baking soda present in the dentifrices used in these studies, compared to the small amounts of sodium fluoride and sodium lauryl sulfate present in baking soda-free dentifrices.

Collective data from five controlled clinical studies in over 270 subjects consistently demonstrate that baking soda dentifrices enhanced plaque removal efficacy of tooth brushing by exhibiting

a significantly greater reduction in plaque scores compared to tooth brushing with the baking soda-free dentifrices. Future studies should focus on plaque reduction and control efficacy of baking soda dentifrices under uncontrolled daily brushing home-use conditions, and evaluate their potential for helping to enhance the reduction and control of gingival inflammation.

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***For further correspondence with the author(s) of this paper, contact Dr. Annahita Ghassemi—annahita.ghassemi@churchdwight.com.***

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