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Fluoride, pH Value, and Titratable Acidity of Commercially Available Mouthwashes

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ABSTRACT

Aim: The primary objective of this work was to assess total soluble fluoride (TSF), pH values, and titratable acidity (TA) of various mouthwashes “in vitro,” and the second was to compare fluoride content on labels with measured TSF.

Methods: Commercial mouthwashes were collected and analysed. Company, type, manufacturer data, and active ingredients (essential oils [EO], cetylpyridinium chloride [CPC], chlorhexidine [CHX], and fluoride) were described. TSF, pH, and TA capacity were measured. Descriptive quantitative analysis were performed per mouthwash.

Results: In total, 54 mouthwashes from 20 brands were included. These included mouthwashes with the active ingredients EO (n = 11), CPC (n = 17), CHX (n = 18), and fluoride (n = 32); 27 mouthwashes with more than 1 of these active ingredients; and 4 with none of the abovementioned ingredients. Fluoride was present in different formulations; most contained sodium fluoride (NaF), and a few had sodium monofluorophosphate and amine fluoride + NaF. The pH values of all evaluated mouthwashes ranged from 4.1 to 7.9. Twenty mouthwashes presented pHs below 5.5, of which 10 contained fluoride. TA ranged from 0 to 48. According to the manufacturer data, mouthwashes with fluoride had concentrations from 217 to 450 ppm, with 90% in the range from 217 to 254 ppm. Laboratory data revealed that TSF ranged from 229 to 500 ppm, with 90% in the range from 229 to 337 ppm. A statistically significant difference was observed between measured TSF and the labelled fluoride content on the packaging of the fluoride mouthwashes (mean difference, 43.92 ± 34.34; $P < .001$). Most of these mouthwashes contained at least the amount of fluoride as mentioned on the packaging (93%).

Conclusion: The pH values and TA of commercially available mouthwashes showed a large variation. TSF levels of the fluoride mouthwashes were found to be at least the amount of fluoride as labelled. Dental care professionals should be aware of the pH, TA, fluoride content, and other active ingredients of different mouthwashes to better understand their potential impact on oral health.

Introduction

To enhance oral health and reduce the risk of oral diseases, toothbrushing is widely recognised as the primary method for mechanical plaque control.[1] This approach relies on the cooperation and motivation of individuals. Mouthwashes, on

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the other hand, serve as supplementary tools in chemical plaque control and can aid in improving oral health.[2] Mouthwashes contain several active ingredients,[3] including cetylpyridinium chloride (CPC),[4] chlorhexidine (CHX),[5,6] essential oils (EO),[7,8] and fluoride.[9] Existing evidence shows that mouthwashes containing CPC, CHX, or EO are effective in reducing plaque accumulation and gingival inflammation.[4,10] For the prevention of caries, fluoride has been scientifically proven to strengthen tooth enamel, lower acid levels, and rebuild minerals.[11] Fluoride use is seen as inexpensive and highly effective[9,12-14] and is mentioned on the World Health Organization list of essential medicines.[15] The fluoride ion must be available (chemically soluble) to be effective in caries prevention.[16] There is a difference between the fluoride concentration and the availability in the form of total soluble fluoride (TSF).

Alongside the beneficial effects of mouthwashes,[10] side effects, like staining, taste modification, and abnormal oral sensation, have been reported.[17] It is suggested that a low pH of a mouthwash is relevant as it facilitates the binding of fluoride to enamel and ensures the chemical stability of fluoride compounds. Mouthwashes with 226 ppm sodium fluoride and a low pH presented a better bioavailability than those with a higher pH.[18] There is, however, concern that mouthwashes with a low pH could contribute to erosion.[19-22] As well as pH value, titratable acidity (TA; "the buffer capacity") plays an important role in erosion.[23] As the saliva needs more time to neutralise the acid, a higher buffering power of a solution enhances the dissolution process of enamel mineral, necessary for formation of the calcium fluoride layer.[23]

Based on a potential key role for mouthwashes in oral hygiene, it is important for dental care professionals (DCPs) to be cognizant of the active ingredients and clinically relevant effects of mouthwashes.[3] Although various lists of mouthwashes with fluoride content, pH values, and TA are available, via DCP magazines and online,[22,24] the published results to date have often been incomplete and or inconclusive. Furthermore, there is uncertainty of the source and the year of publication. It is also unexplained which instruments, techniques, and procedures were used for the assessments. This study aims to generate a comprehensive overview of commercially available mouthwashes, considering primarily the TSF, pH values, and TA "in vitro" and furthermore TSF as it relates to the fluoride concentration as specified on the product packaging label.

Methods

Design and guidelines

The experiments of this laboratory study were performed under controlled standardised conditions in the Dental Research Laboratory of Radboudumc in Nijmegen, the Netherlands. This study was performed in accordance with the CRIS guidelines, as described in the 2014 concept note.[25] It promotes the transparency and quality by being a Checklist for Reporting In Vitro Studies. In addition, methodological quality was reported by using the STROBE statement, a checklist of items that should be included in cross-sectional studies reports,[26] and by the Modified CONSORT checklist of items for reporting in vitro studies of dental materials.[27] The protocol was approved by the Ethical Committee of the HAN University of Applied Sciences (reference: ECO387.06/22.). The data that support the findings of this study are available from the first author upon reasonable request.

Samples

Search and selection

An extensive search online and in major local pharmacy companies was performed to retrieve all mouthwashes commercially available in the Netherlands. The online search was performed using the search engine Google,[28] as it has been proven effective in helping laypersons to obtain medical and health information.[29] The following search terms were used: mouthwashes, mouth rinses, commercial mouthwashes, and well-known mouthwashes. In order to challenge the prevailing patterns of online search behavior and mitigate the inherent biases that arise from personalised algorithms relying heavily on social data, an examination was conducted on the initial 25 search results for each query. This approach aimed to counteract the influence of personalisation algorithms and minimise the potential biases ingrained within social networks.[30]

Inclusion and exclusion

To obtain an accurate and complete overview, as many mouthwashes from international manufacturers as available on the Dutch market were evaluated.

Inclusion criteria:

- Mouthwashes, available over-the-counter (OTC) on the Dutch market, from internationally orientated manufacturing companies (BlueM, Curaden, Curasept S.p.A., Colgate-Palmolive, Dentaid, GSK, Johnson & Johnson, Mylan Healthcare (a Viatris Company), Sunstar, Procter & Gamble company, Unilever).

Exclusion criteria:

- Private-label and off-brand mouthwashes
- Mouthwashes without an expiration date or an expiration period after opening
- Expired mouthwashes
- Mouthwashes without a batch number
- Saliva substitutes

Collection

The available brands were grouped by the manufacturing companies. The companies were contacted by telephone and/or e-mail to obtain samples of the mouthwashes for research purposes. If the mouthwashes were not made available, they were purchased by the researcher (BVS) at her own expense from the drug store or online retailer. An inventory list of the obtained mouthwashes was made (Appendix A) which includes brand, type, company, millilitres, and active ingredients of interest: EO, CPC, CHX, and fluoride.

Photographs of labels were taken to record essential information as batch number, expiration date, and/or period after opening (Appendix C).

Measurements

All measurements were performed in duplicate in the laboratory at a temperature of 19 °C by the same researcher (BVS) under supervision by a lab technician (JR).

Fluoride

All mouthwashes were checked for information regarding fluoride on the package box (if available) or the bottle itself. Type of fluoride ingredient and fluoride concentration in parts per million (ppm F) were registered. If only a percentage of fluoride was given, the actual ppm F was requested from the manufacturer or calculated if not provided.

TSF was measured by a commercially available calibrated combined ion-selective electrode (ISE; F 800 DIN, WTW), connected to a laboratory metre (InoLab pH 720, WTW). The ISE detects the free fluoride ions in a mouthwash solution. The electrode was calibrated with fluoride standards (final F concentration of 1 ppm F and 1000 ppm F) and total ionic strength adjustment buffer (TISAB IV) in a volume ratio 1:1, resulting in a calibration curve. TISAB is used in the determination of fluoride using ISEs.[16,31] Mouthwash samples were placed on a shaker (KS130 Basic, IKA) to mix the liquids properly with TISAB IV solution in the same volume ratio for 2 minutes. After mixing, the ISE was immersed in the solutions, and after 10 minutes the F-value in mV was noted and converted to ppm (mg/L). The ISE was rinsed with deionised water (pH 5.5) and patted dry between each recording.

pH

A calibrated pH metre, with combined glass electrodes[19,21] (InoLab pH 720, WTW) was used to perform the pH measurements. Before each test day, the pH meter was calibrated using 2 standard solutions with pH4 and pH7 (buffer reference standard, Merck KGaA). The glass electrode was placed in 50 mL mouthwash, and the pH value was measured when the pH metre provided a stable reading. According to standard procedure, the measuring probe was rinsed with deionised water (pH 5.5) and patted dry between each measurement.

TA

The TA quantifies the amount of strong base required to raise the pH of a liquid from its native pH to a predefined value, typically 5.5 or 7.0.[32] For the present measurement, 50 mL of mouthwash was titrated stepwise by use of a mechanical pipette with 1 M NaOH (pH = 12.8).[33] A magnetic stirrer (KMO 2 basic, IKA) was used to mix the mouthwash gradually with the base until pH 7 was measured by the electrode. The amount of added base (V/mL) was recorded.[23,34] After finishing the measurements in duplicate, TA at pH 7 was calculated by averaging the 2 measurements (see Appendix D).

Analysis

The data were processed and analysed with IBM SPSS Statistics 25. Quantitative data were expressed as mean and standard deviation per product evaluated. After the normality of the data was assessed using the Kolmogorov–Smirnov test, Wilcoxon signed-rank tests were used for comparison between fluoride content on labels with measured TSF, at a significance level of $P < .05$.

Results

Study products

In total, 54 mouthwashes from 20 brands were included in the study. Eleven companies were approached, and 8 companies were willing to provide a total of 36 mouthwashes. Consequently, 18 mouthwashes were purchased by the researchers. The manufacturers involved were Unilever (n = 1), Procter & Gamble (n = 2), BlueM (n = 2), Mylan Healthcare (n = 3), GSK (n = 4), Colgate Palmolive (n = 4), Curaden (n = 4), Curasept SpA (n = 7), Sunstar Benelux (n = 7), Dentaid (n = 10), and Johnson & Johnson (n = 10). Active ingredients were EO (n = 11), CPC (n = 17), CHX (n = 18), fluoride (n = 32), more than 1 of these active ingredients (n = 27), or none of the above-mentioned ingredients (n = 4). The volume of the bottles ranged from 200 mL to 500 mL. See for details Appendix A+B.

Fluoride

The Table shows the results of fluoride analysis. A total of 32 mouthwashes (59%) contained fluoride. Of these 32 mouthwashes, 78% were formulated with sodium fluoride (NaF), 9% with sodium monofluorophosphate (MFP), and 13% with amine fluoride (AmF) + NaF (Appendix A and B).

Laboratory data revealed that TSF in mouthwashes with fluoride ranged from 229 to 500 ppm, with 90% in the range from 229 to 337 ppm (Appendix E). According to the manufacturer data, mouthwashes with fluoride had concentrations from 217 to 450 ppm, with 90% in the range from 217 to 254 ppm. Wilcoxon signed-rank test was used to compare labelled fluoride content with measured TSF, and a statistically significant difference was observed (mean difference, 43.92 ± 34.34; $P < .001$) implicating that on average there was more TSF available than labelled. The vast majority of the fluoride-containing mouthwashes (93%, n = 27) contained at least the amount of fluoride mentioned on the packaging.

pH and titratable acidity

The results of the mean pH and mean TA for each mouthwash are shown in the Table. The pH values of all evaluated mouthwashes ranged from 4.1 to 7.9. Twenty mouthwashes presented pHs below 5.5 (43%), of which 10 contained fluoride. TA ranged from 0 to 48. For details see Appendix F and G.

Table – Results of analysis of the presence, type, and amount of fluoride, pH, and TA of commercially available mouthwashes.

ID	Mouthwash, brand, and type	F label	F type (ingredient - list bottle)	Mean TSF analysis in ppm	F label in ppm	Diff TSF analysis vs label	Mean pH	Mean TA in Mmol/L**
1	Aquafresh Complete Care Fresh Mint	+	NaF	244.7	220	24.7	6.8	0.4
2	BlueM Mouthwash Fluoride Free	-	NA	1.0	0	1.0	6.1	7.4
3	BlueM Oxygen Fluid Oral Wound Support	-	NA	2.6	0	2.6	6.0	31.4
4	CB12	+	NaF	246.8	226[a]	20.8	5.8	6.0
5	CB12 Sensitive	+	NaF	258.3	226[a]	32.3	5.7	12.0
6	CB12 White	+	NaF	266.2	226[a]	40.2	5.5	5.0
7	Colgate Plax White + Charcoal*	+	NaF	280.3	225	55.3	7.9	0.0
8	Curaprox PerioPlus+ Balance CHX 0.05	+	NaF	228.6	230	-1.4	5.9	0.2
9	Curaprox PerioPlus+ Forte CHX 0.20	-	NA	0.2	0	0.2	5.6	0.2
10	Curaprox PerioPlus Protect CHX 0.12	-	NA	0.2	0	0.2	5.9	0.3
11	Curaprox PerioPlus+ Regenerate CHX 0.09	-	NA	0.2	0	0.2	7.1	0.0
12	Curasept ADS Implant	-	NA	0.4	0	0.4	5.4	34.3
13	Curasept ADS Perio	-	NA	0.4	0	0.4	5.4	37.0
14	Curasept Daycare	+	NaF	233.2	220	13.2	5.5	5.4
15	Curasept Eco Bio	-	NA	0.3	0	0.3	5.7	9.1
16	Curasept ADS 205	+	NaF	240.8	220	20.8	5.5	40.3
17	Curasept ADS 212	-	NA	0.2	0	0.2	5.4	40.1
18	Curasept ADS 220	-	NA	0.2	0	0.2	5.4	36.3
19	Dentaid Xeros	+	NaF	262.0	226	36.0	6.0	11.7
20	Elmex Sensitive*	+	AmF + NaF	239.4	250	-10.6	4.6	13.5
21	Elmex Sensitive Professional*	+	AmF + NaF	334.9	250[b]	84.9	6.1	48.0
22	Fluor-Aid 0.05	+	NaF	271.6	226	45.6	6.0	1.4
23	GUM Activital	+	NaF	284.4	248	36.4	6.1	0.8
24	Gum Gingidex	-	NA	0.2	0	0.2	5.9	1.8
25	GUM Halicontrol	-	NA	0.2	0	0.2	5.9	0.6
26	GUM ortho	+	AmF + NaF	468.1	400[c]	68.1	6.5	1.2
27	Gum Paroex	-	NA	0.2	0	0.2	5.7	1.6
28	GUM Sensivital +	+	MFP	11.0	250	-239.0	6.0	4.8
29	Halita	-	NA	0.2	0	0.2	5.1	1.2
30	Listerine Advanced White*	+	NaF	266.0	220	46.0	6.1	23.2
31	Listerine Anti-caries*	+	NaF	270.2	220	50.2	4.1	6.9
32	Listerine Anti-tartar*	+	NaF	323.7	220	103.7	4.4	9.0
33	Listerine Cool Mint*	-	NA	0.3	0	0.3	4.3	8.7
34	Listerine Cool Mint Mild*	+	NaF	250.3	220	30.3	4.1	6.8
35	Listerine Fresh Burst*	-	NA	0.3	0	0.3	4.2	9.3
36	Listerine Nightly reset*	+	NaF	500.4	450	50.4	4.3	7.5
37	Listerine Protection Dents & Gingives*	+	NaF	439.0	300	139.0	4.3	10.0
38	Listerine Total Care*	+	NaF	336.9	220	116.9	4.3	10.1
39	Listerine Total Care Sensitive*	+	NaF	255.9	220	35.9	4.3	7.2
40	Meridol*	+	AmF + NaF	254.4	254	0.4	4.6	6.5
41	O7 Active	+	NaF	243.3	226	17.3	7.3	0.0
42	Oral-B 3D White Luxe Perfection*	-	NA	0.2	0	0.2	4.9	14.4
43	Oral-B Pro-Expert*	-	NA	0.2	0	0.2	4.3	0.5
44	Parodontax	+	NaF	237.0	225	12.0	7.1	0.0
45	Parodontax Corsodyl*	-	NA	0.2	0	0.2	5.8	0.1
46	Perio Aid Active Control	-	NA	0.2	0	0.2	5.5	0.9
47	Perio Aid Intensive Care	-	NA	0.2	0	0.2	5.9	0.1
48	Sensodyne Fresh & Cool	+	NaF	252.8	217	35.8	6.7	2.3
49	Vitis CPC protect	-	NA	0.2	0	0.2	4.2	1.3
50	Vitis Gingival	+	NaF	269.0	226	43.0	5.5	3.2
51	Vitis Orthodontic	+	NaF	300.3	226	74.3	4.5	11.3
52	Vitis Sensitive	+	MFP	16.1	226	-209.9	5.8	7.4
53	Vitis Whitening	+	MFP	7.3	226	-218.7	5.9	17.7
54	Zendium Classic*	+	NaF	277.4	225	52.4	5.6	14.3

+ Mouthwash with fluoride. −Mouthwash without fluoride.

MFP, monofluorophosphate; TSF, total soluble fluoride; NA, not applicable; NaF, sodium fluoride; AmF, amine fluoride (Olaflur); TA, titratable acidity.

* Purchased at own expense.

** Titratable acidity calculated at pH 7.

[a] Requested from company.

[b] According to website Elmex.

[c] Calculated by authors.

Discussion

In today's global market, there is a need for precise product information. The International Organization for Standardization (ISO) defined a standard regarding oral care products, specifically for oral rinses ISO 16408 (2015). ISO presents labelling requirements, as common labelling aspects enhances international understanding and trade. There is a wide range of mouthwashes available, which vary in active ingredients, flavour compounds, colour, fluoride concentration, and manufacturer. Given the broad spectrum of mouthwash products available and their extensive usage,[35] it is necessary for DCPs to be aware of these active ingredients and their clinically relevant effects.[3,36] The present overview evaluated 54 commercially available OTC mouthwashes in relation to pH values, TA, and fluoride content. For DCPs, the present overview can be used as a source for making evidence-based recommendations regarding mouthwashes.

Fluoride

Previous studies on fluoride content of dentifrices and mouthwashes showed discrepancies between measurements and labels.[37,38] In general, the TSF concentrations of dentifrices are lower than indicated on the label. Possible explanations for this phenomenon are humidity, high storage temperature, incorrect production process, inadequate quality control, inferior ingredients, and expiry dates that have nearly lapsed.[39] In the present study, the majority (93%) of all fluoride mouthwashes contained at least the amount of fluoride indicated on the packaging. For 3 mouthwashes (samples 28, 52, and 53), a large difference was found between the measured fluoride content and the labelled values. This can be explained by different fluoride formulations and corresponding solubilities. NaF is the most soluble (40 g/100 mL), as it dissolves rapidly in water, and MFP is less soluble (25 g/100 mL), as it hydrolyses slowly "in vitro" to liberate fluoride ions. In order to quantify MFP, it is necessary to dissociate the bond between fluoride and the phosphate group,[16] which can be done through hydrolysis[40] or acid treatment.[41] Without this pretreatment, the fluoride ion will be poorly detected by the fluoride electrode.[16] This observation could account for the comparatively low recorded fluoride levels found in these particular 3 samples, which all contained MFP. Therefore, the results of samples 28, 52, and 53 should be interpreted with caution.

A study from Saudi Arabia in 2014 showed that 60% of the mouthwashes tested contained fluoride levels below those stated on the manufacturers' label.[42] It is unclear how the above-mentioned mechanisms or other mechanism affected the results of the Saudi Arabian study. Conflicting results between the Saudi Arabian study and the present study call for an effort for manufacturers to provide accurate information on the labels and also for a standardised method of analyses to allow for proper comparisons.

Caries

Supervised use of fluoride mouthwashes is associated with a large reduction in caries increasement in permanent teeth.[13] The use of a minimum concentration of 226 ppm F, corresponding to 0.05% NaF, is required for an anticaries effect.[43] The present study showed that all mouthwashes formulated with NaF or AmF + NaF contained fluoride levels above 226 ppm F. Based on their study outcome, Mystikos et al[43] advised that the general population would benefit more from higher concentrations of fluoride in mouthwash solutions. They found a dose-response relationship between fluoride concentration and caries-preventive effect. The higher the fluoride concentrations in mouth rinse solutions, the higher the fluoride concentration in saliva. Rinsing with an elevated concentration of the NaF solution (0.32%) suggests a possible contribution in caries prevention.[44]

Erosion

As well as having an anticaries effect, fluoride agents are very likely to be of use in the preventive treatment of erosive wear.[45,46] Fluoride-containing mouthwashes cause less dental material loss than fluoride-free mouthwashes.[46] The potential of conventional fluorides to prevent erosive demineralisation is mainly related to the formation of a calcium fluoride layer (CaF2), which can be increased by increasing the fluoride concentration, prolonging the exposure time, or using a fluoride solution with low pH.[47] Mouthwashes with AmF/NaF/SnF_2 and a low pH are effective in reducing erosive loss in enamel and dentin, even under severely erosive conditions.[45] The most promising are acidic mouthwashes with a high fluoride concentration, with the best evidence in support of SnF_2 formulations.[48,49] In the present study, 20 mouthwashes showed a low pH (below 5.5),[50,51] 10 of which contained fluoride. The exact balance amongst fluoride levels, fluoride formulation, and pH values for anti-erosive purposes is still unknown.

pH and TA

Chemical oral care products, such as toothpastes and mouthwashes, often have a low pH, which increases the chemical stability of ingredients. The pH values of all evaluated mouthwashes in this study ranged from 4.1 to 7.9. These results fall within the accepted values of the European Standard for Oral care products (NEN-EN-ISO16408:2015), which requires mouthwashes to have a pH value between 3.0 and 10.5. Previous laboratory studies concluded that some mouthwashes have a pH lower than the critical pH of enamel and dentine, which would potentially lead to erosion.[19-21] Acidified phosphate fluoride etches the enamel surface and increases surface roughness soon after application.[52] Therefore, a low pH favours the incorporation of fluoride ions into the lattice of hydroxyapatite and the precipitation and incorporation of calcium fluoride on the tooth surface.[53] In this study, 20 mouthwashes (43%) have a low pH (<5.5). It is confirmed that products with high amount of fluoride and an acidic pH are more effective in rehardening the surface of noncavitated caries lesions and in promoting fluoride uptake than those with a neutral pH.[54]

Acidity of a mouthwash is not exclusively dependent on its pH value, but it is also strongly influenced by mineral content; by the TA, also known as "the buffering capacity"; and by its calcium-chelation properties.[23] The classical buffer capacity measures the resistance of the solution to change from its native pH. TA is the amount of base required to raise the pH of a mouthwash from its native pH to a predefined value.[32] The TA of the mouthwashes in this "in vitro" study varied widely, ranging from 0 to 48. Well-buffered products require more saliva to neutralise, and the neutralisation process takes longer.[32] Therefore, mouthwashes with a relatively higher TA can better maintain a balanced pH environment in the oral cavity compared with oral rinses with a lower TA.

In the present study, most included mouthwashes contain fluoride, which is intended to enhance the product's effectiveness by remineralising tooth structures and preventing caries. Fluoride concentration and TA can have significant effects on erosive potential against enamel, but the effects are pH-dependent.[32] DCPs should be aware of the potential effects of chemical oral hygiene products without fluoride, a low pH, and a higher amount of TA, as this can lead to progressive demineralisation of dental hard tissues.[53] This applies in particular to patients undergoing radiotherapy or living with Sjogren's syndrome, as the protective and buffering effect of saliva is limited in these patients.[53]

Biological factors such as the dental pellicle[55] will also modify the erosive potential by protecting tooth surfaces against erosive effects. It is therefore a possibility that some mouthwashes, despite having a low pH and relatively higher TA, only have limited erosive potential in vivo. In addition, the exposure time can affect the amount of mineral that dissolves from enamel. Finally, the presence of calcium concentrations, phosphate, and fluoride in the mouthwash may counteract the dissolution.[34] Due to this multifactorial character, observed values in the present study are difficult to translate one-on-one to clinical practice.

Nonetheless, fluoride-containing mouthwashes may be a helpful addition to the oral hygiene routine and can be used on a daily basis.[56] Consequently, several governmental institutes indicate that a fluoride mouthwash can be used in addition to twice-daily brushing with a fluoride toothpaste. This advice is especially targeted at individuals or groups at high risk for decay.[57,58]

Limitations

The present study has some limitations, and therefore its results should be interpreted with caution.

- Sampling: The products were purchased in the Netherlands. However, most products are also available in other countries and the formulation may vary in some details. Nevertheless, these results do not only reflect data of local interest.
- Setting: The "in vitro" setup did not use saliva and its influence on fluoride ion release. However, the measurements were performed in a controlled environment, thus reducing the risk of bias and promoting repeatability and allowing for comparisons with other studies.[25]
- Analytical methodology: There is no fixed standard methodology for analysis of fluoride concentrations. As different researchers use a variety of techniques, this consequently may alter results.[16] The potentiometry with ISE is the most widely used method for determination of fluoride, is recommended by the ISO (ISO19448:2018), and shows good precision and sensitivity.[16,31,38,59]

Conclusion

The pH values and TA of commercially available mouthwashes showed a large variation. TSF levels of the fluoride mouthwashes were found to be at least the amount of fluoride as labelled. DCPs should be aware of the pH, TA, fluoride content, and other active ingredients of different mouthwashes to better understand their potential impact on oral health.

Conflict of Interest

Van Swaaij, Timmerman, and Ruben declare no conflicts of interest. Van der Weijden, Slot, and their research team at ACTA have previously received either external advisor fees, lecturer fees, or research grants from dental care product manufacturers. Those manufacturers included GABA/Colgate, Dentaid, Lactona, Oral-B/Procter & Gamble, Sara Lee, Sunstar Philips Unilever, GSK, Listerine, and Waterpik.

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Author contributions

BVS contributed to conception and design, execution of the experiment, and analysis and interpretation and drafted and critically revised the manuscript. DES contributed to conception and design, and analysis and interpretation and critically revised the manuscript. GAW contributed to analysis and interpretation and critically revised the manuscript. MFT contributed to analysis and interpretation and critically revised the manuscript. JR contributed to conception and design, execution of the experiment, and analysis and interpretation and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

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Supplementary materials

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