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Fluoride content of toothpastes marketed for children in Thailand: an analytical study

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To evaluate the total fluoride and total soluble fluoride concentrations in children's toothpaste products available in Thailand, and to compare measured values with labeled fluoride concentrations. Twenty-one brands of children's toothpaste were purchased from supermarkets in Bangkok in 2024. Three samples from different manufacturing lots were collected for each brand. Total fluoride and total soluble fluoride concentrations were determined using a fluoride ion-selective electrode after appropriate acid hydrolysis, neutralization, and buffering. Measured fluoride concentrations were compared with labeled values using one-sample t-tests, with statistical significance set at $p < 0.05$. Twenty-one toothpaste brands were analyzed, 14 (66.67%) exhibited total fluoride concentrations consistent with their labeled fluoride values, while seven (33.33%) demonstrated significant discrepancies. Three brands (14.28%) contained total fluoride levels significantly lower than declared, whereas four brands (19.05%) demonstrated higher total fluoride concentrations than stated on their labels. For total soluble fluoride, 14 brands (66.67%) showed concentrations consistent with labeled claims. In contrast, six brands (28.57%) exhibited significantly lower total soluble fluoride levels than declared, and one brand (4.76%) showed a significantly higher total soluble fluoride concentration. Notably, several toothpaste products demonstrated adequate total fluoride levels but reduced total soluble fluoride concentrations, indicating limited fluoride bioavailability. The findings indicate that labeled fluoride concentrations in children's toothpaste do not always reflect the amount of bioavailable fluoride. Although most products complied with declared total fluoride values, reduced total soluble fluoride levels were observed in several brands, potentially compromising their anticariogenic efficacy. Ongoing market surveillance focusing on both total and bioavailable fluoride is recommended to ensure the efficacy and safety of children's toothpaste products in Thailand.

Keywords: children's toothpaste, fluoride concentration, total fluoride, total soluble fluoride

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Introduction

Dental caries remains one of the most prevalent oral diseases worldwide and continues to pose a significant public health burden, particularly among children [1]. Fluoride has long been recognized as a cornerstone in caries prevention owing to its ability to enhance enamel remineralization, inhibit demineralization, and promote the formation of fluorapatite, which is more resistant to acid dissolution than hydroxyapatite [2,3]. The widespread use of fluoride-containing products has contributed substantially to the global decline in caries prevalence.

Among various fluoride delivery methods, toothpaste is the most practical and commonly used vehicle. Fluoridated dentifrices are available in different chemical forms, including sodium fluoride (NaF), sodium monofluorophosphate (Na_2FPO_3), amine fluoride (AmF), stannous fluoride

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(SnF_2), or combinations thereof [3]. Evidence from systematic reviews has consistently demonstrated that toothpastes containing 1,000–1,500 ppm fluoride provide superior caries-preventive efficacy compared with lower-fluoride formulations, whereas very low fluoride concentrations (e.g., 250 ppm) offer minimal protection [4].

In Thailand, regulatory and professional guidelines recommend the use of fluoride toothpaste with concentrations generally ranging from 1,000 to 1,500 ppm for daily brushing. Age-appropriate amounts and supervised brushing are emphasized to optimize caries prevention while minimizing the risk of dental fluorosis in young children. However, fluoride in toothpaste exists in different forms. Total fluoride (TF) represents the overall fluoride content declared on product labels, whereas total soluble fluoride (TSF) reflects the bioavailable fraction that is clinically effective in caries prevention. Interactions between fluoride compounds and abrasive agents, as well as manufacturing factors, may reduce TSF availability, potentially compromising anticariogenic efficacy despite adequate TF levels [5].

Although regulations specify recommended fluoride concentrations, up-to-date data on the actual fluoride content of children's toothpaste products in Thailand are limited. The most recent comprehensive evaluation was conducted in 2015, and no updated analysis has been published since then, despite the rapid expansion and diversification of children's oral care products in the Thai market [6].

This study aimed to analyze the TF and TSF concentrations of children's toothpaste products commercially available in Thailand and to compare the measured fluoride levels with manufacturers' labeled claims. The findings are intended to assess labeling accuracy, product efficacy, and safety, and to provide evidence supporting regulatory oversight of children's oral health products in Thailand.

Materials and Methods

This study was conducted entirely under laboratory conditions and did not involve human participants, human-derived biological materials, or identifiable personal data. Therefore, ethical approval was not required in accordance with institutional research guidelines.

Sample selection

This laboratory-based analytical study evaluated the fluoride content of children's toothpaste products commercially available in Thailand. Twenty-one brands of children's fluoride toothpaste were purchased from major supermarkets in Bangkok between August and November 2024. For each brand, three toothpaste samples representing different manufacturing lots were obtained from separate supermarkets to minimize batch-related variability. Although the products were purchased from major supermarkets in Bangkok, these retail outlets distribute nationally available brands. Nevertheless, the sampling frame may not fully represent all toothpaste products available throughout Thailand. All products were purchased in commercially available retail packaging. Information regarding labeled fluoride concentration, type of fluoride compound, presence of abrasive agents, manufacturing lot number, and expiration date was recorded. Samples were stored at room temperature in a dry environment until analysis [6].

Determination of TF and TSF

All toothpaste samples were coded with alphabetical identifiers to ensure blinded analysis. Two forms of fluoride were evaluated: TF, representing the sum of soluble and insoluble fluoride, and TSF, representing the bioavailable fluoride fraction.

Each toothpaste sample (approximately 90–110 mg) was weighed using an analytical balance with a precision of ±0.01 mg and homogenized in 10 mL of deionized water. The suspension was thoroughly mixed to ensure uniform dispersion [5, 7].

TF analysis

For TF determination, a 0.25 mL aliquot of the homogenized suspension was transferred into a test tube and treated with 0.25 mL of 2.0 M hydrochloric acid. The mixture was incubated at 45°C for 1 hour to facilitate acid hydrolysis. Subsequently, the sample was neutralized with 0.5 mL of 1.0 M sodium hydroxide and buffered with 1.0 mL of total ionic strength adjustment buffer (TISAB II; 1.0 M acetate buffer, pH 5.0, containing 1.0 M sodium chloride and 0.4% CDTA) [5, 7].

TSF analysis

For TSF determination, the remaining homogenized suspension was centrifuged at 3,000 × g for 10 minutes at room temperature to separate insoluble fluoride bound to abrasive components. A 0.25 mL aliquot of the supernatant was collected and subjected to the same acid hydrolysis, neutralization, and buffering procedures used for TF analysis to ensure conversion of sodium monofluorophosphate to free fluoride ions [5,7].

Fluoride measurement

Fluoride concentrations in both TF and TSF samples were measured using a fluoride ion-selective electrode (VSTAR40A, Thermo Fisher Scientific Inc., USA). The electrode was calibrated prior to analysis using standard fluoride solutions ranging from 0.06 to 8.0 ppm. All measurements were performed in triplicate, and the mean values were used for data analysis [7].

Statistical analysis

Statistical analyses were conducted using SPSS for Windows, version 19.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics, including means and standard deviations, were calculated for TF and TSF concentrations. Data normality was assessed using the Kolmogorov–Smirnov test. Comparisons between labeled fluoride concentrations and measured TF and TSF values were performed using a one-sample t-test. Differences between TF and TSF concentrations within the same toothpaste products were analyzed using an independent-samples t-test. Statistical significance was set at $p < 0.05$.

Results

The mean TF and TSF concentrations of the 21 children's toothpaste brands are presented in Supplementary Tables S1 and S2, respectively. Fluoride-free toothpastes demonstrated undetectable TF and TSF levels, whereas fluoridated products showed a wide range of fluoride concentrations across brands.

When comparing measured TF concentrations with labeled fluoride values (Table 1), 14 brands (66.67%) exhibited TF levels consistent with the declared fluoride content. In contrast, seven brands (33.33%) demonstrated significant discrepancies. Among these, three brands (14.28%)—Dentiste Max Kids, Grants of Australia Kids, and Dodolove—contained TF concentrations significantly lower than stated on their product labels, while four brands (19.05%)—Dr.Ray, Jordan Step2 (6-12y), Kodomo Ultra Shield formula Sugar free, and Vidhyasom showed significantly higher TF concentrations than declared.

Table 1 Comparison of labeled fluoride concentrations with measured mean total fluoride (TF) and total soluble fluoride (TSF) concentrations in children's toothpaste brands. Fluoride concentrations are expressed as ppm F.

Toothpaste brand	Labeled fluoride concentration (ppm F)	Total Fluoride		Total Soluble Fluoride	
		Mean ± SD	*p*-value	Mean ± SD	*p*-value
1. Omeg Kids	0	0	NA	0	NA
2. Colgate Kids	1000	1051.48 ± 34.11	0.120	1033.58 ± 42.71	0.306
3. Dentiste Max Kids	1500	1110.77 ± 66.37	0.010*	1062.04 ± 123.74	0.026*
4. Dr.Ray	500	595.68 ± 11.30	0.005*	499.69 ± 30.21	0.987
5. Fluocaril	1000	968.04 ± 32.48	0.230	849.63 ± 23.06	0.008*
6. Gum Kids	498	482.56 ± 16.47	0.246	472.47 ± 9.56	0.044*
7. Jordan Step1 (1-5y)	500	550.90 ± 37.85	0.145	514.98 ± 52.26	0.669
8. Jordan Step2 (6-12y)	1000	1043.98 ± 3.27	0.002*	1027.14 ± 68.26	0.562
9. Kindee 6m+	0	0	NA	0	NA
10. Kindee 1y+	500	548.48 ± 25.10	0.079	501.34 ± 21.62	0.924
11. Kindee 6y+	1500	1545.79 ± 41.97	0.199	1388.01 ± 41.67	0.043*
12. Kodomo Ultra Shield formula Xylitol plus	1000	1015.03 ± 81.46	0.780	973.38 ± 61.39	0.531
13. Kodomo Ultra Shield formula Sugar free	1000	1053.79 ± 20.59	0.046*	994.60 ± 17.36	0.644
14. Kolbadent Kids	0	0	NA	0	NA
15. Vidhyasom	1000	1052.72 ± 17.95	0.037*	1023.93 ± 4.57	0.012*
16. Babi Mild Kids	1000	1124.36 ± 59.12	0.068	1094.98 ± 109.36	0.271
17. St. Andrews	500	563.53 ± 43.62	0.128	535.54 ± 44.4	0.300
18. Jollikidz	1000	1071.33 ± 54.36	0.151	1032.99 ± 52.01	0.386
19. Grants of Australia Kids	500	60.68 ± 10.62	<0.001*	31.72 ± 2.75	<0.001*
20. Palmmade	1000	1068.39 ± 30.04	0.059	977.75 ± 15.62	0.133
21. Dodolove	1000	426.56 ± 25.30	<0.001*	402.49 ± 16.06	<0.001*

* Statistically significant at $p < 0.05$, as determined using a one-sample t-test

NA = not applicable (fluoride-free products).

For TSF, 14 brands (66.67%) showed concentrations consistent with labeled claims, whereas seven brands (33.33%) demonstrated significant differences (Table 1). Six brands (28.57%) exhibited TSF levels significantly lower than declared, including Dentiste Max Kids, Fluocaril, Gum Kids, Kindee 6y+, Grants of Australia Kids, and Dodolove. Only one brand (4.76%)—Vidhyasom showed a significantly higher TSF concentration than the labeled value.

A comparison between TF and TSF concentrations within each toothpaste brand is shown in Table 2. Statistically significant differences between TF and TSF were observed in several products, including Dr. Ray, Fluocaril, Kindee 6y+, Kodomo Ultra Shield Formula Sugar free, Grants of Australia Kids, and Palmmade ($p < 0.05$), indicating a reduction in soluble, bioavailable fluoride relative to TF content. Other brands demonstrated no significant differences between TF and TSF concentrations. Fluoride-free toothpaste products were analyzed separately and were not included in statistical comparisons between TF and TSF concentrations to avoid distortion of statistical results.

A brand-by-brand comparison of labeled and measured fluoride concentrations is shown in Supplementary Table S1, while an overall summary of agreement between measured and labeled values for TF and TSF is presented in Supplementary Table S2.

Table 2 Comparison of measured total fluoride (TF) and total soluble fluoride (TSF) concentrations in children's toothpaste brands. Fluoride concentrations are expressed as ppm F.

Toothpaste brand	Mean ± SD		*p*-value
	Total Fluoride	Total Soluble Fluoride	
1. Omeg Kids	0	0	NA
2. Colgate Kids	1051.48 ± 34.11	1033.58 ± 42.71	0.601
3. Dentiste Max Kids	1110.77 ± 66.37	1062.04 ± 123.74	0.580
4. Dr.Ray	595.68 ± 11.30	499.69 ± 30.21	0.007*
5. Fluocaril	968.04 ± 32.48	849.63 ± 23.06	0.007*
6. Gum Kids	482.56 ± 16.47	472.47 ± 9.56	0.411
7. Jordan Step1 (1-5y)	550.90 ± 37.85	514.98 ± 52.26	0.390
8. Jordan Step2 (6-12y)	1043.98 ± 3.27	1027.14 ± 68.26	0.711
9. Kindee 6m+	0	0	NA
10. Kindee 1y+	548.48 ± 25.10	501.34 ± 21.62	0.069
11. Kindee 6y+	1545.79 ± 41.97	1388.01 ± 41.67	0.010*
12. Kodomo Ultra Shield formula Xylitol plus	1015.03 ± 81.46	973.38 ± 61.39	0.518
13. Kodomo Ultra Shield formula Sugar free	1053.79 ± 20.59	994.60 ± 17.36	0.019*
14. Kolbadent Kids	0	0	NA
15. Vidhyasom	1052.72 ± 17.95	1023.93 ± 4.57	0.101

Table 2 Comparison of measured total fluoride (TF) and total soluble fluoride (TSF) concentrations in children's toothpaste brands. Fluoride concentrations are expressed as ppm F. (continued)

Toothpaste brand	Mean ± SD		*p*-value
	Total Fluoride	Total Soluble Fluoride	
16. Babi Mild Kids	1124.36 ± 59.12	1094.98 ± 109.36	0.703
17. St. Andrews	563.53 ± 43.62	535.54 ± 44.4	0.480
18. Jollikidz	1071.33 ± 54.36	1032.99 ± 52.01	0.427
19. Grants of Australia Kids	60.68 ± 10.62	31.72 ± 2.75	0.010*
20. Palmmade	1068.39 ± 30.04	977.75 ± 15.62	0.010*
21. Dodolove	426.56 ± 25.30	402.49 ± 16.06	0.237

* Statistically significant at $p < 0.05$, as determined by an independent-samples t-test.

NA = not applicable (fluoride-free products).

Supplementary Table S1 Mean total fluoride (TF) concentrations of children's toothpaste products available in Thailand. Fluoride concentrations are expressed as ppm F.

Toothpaste brand	Total Fluoride			Mean ± SD
	1	2	3	
1. Omeg Kids	0	0	0	0
2. Colgate Kids	1047.34	1087.47	1019.63	1051.48 ± 34.11
3. Dentiste Max Kids	1152.97	1145.07	1034.26	1110.77 ± 66.37
4. Dr.Ray	588.64	608.71	589.68	595.68 ± 11.30
5. Fluocaril	965.92	936.67	1001.53	968.04 ± 32.48
6. Gum Kids	499.63	481.29	466.76	482.56 ± 16.47
7. Jordan Step1 (1-5y)	507.54	567.82	577.33	550.9 ± 37.85
8. Jordan Step2 (6-12y)	1040.21	1046	1045.74	1043.98 ± 3.27
9. Kindee 6m+	0	0	0	0
10. Kindee 1y+	531.74	577.34	536.37	548.48 ± 25.10
11. Kindee 6y+	1585.93	1502.21	1549.22	1545.79 ± 41.97
12. Kodomo Ultra Shield formula Xylitol plus	928.32	1089.95	1026.83	1015.03 ± 81.46
13. Kodomo Ultra Shield formula Sugar free	1034.02	1052.24	1075.12	1053.79 ± 20.59
14. Kolbadent Kids	0	0	0	0
15. Vidhyasom	1043.35	1041.4	1073.42	1052.72 ± 17.95
16. Babi Mild Kids	1117.78	1186.5	1068.81	1124.36 ± 59.12
17. St. Andrews	516.38	571.75	602.45	563.53 ± 43.62

Supplementary Table S1 Mean total fluoride (TF) concentrations of children's toothpaste products available in Thailand. Fluoride concentrations are expressed as ppm F. (continued)

Toothpaste brand	Total Fluoride			Mean ± SD
	1	2	3	
18. Jollikidz	1102.98	1008.57	1102.45	1071.33 ± 54.36
19. Grants of Australia Kids	62.36	49.32	70.36	60.68 ± 10.62
20. Palmmade	1038.25	1068.59	1098.33	1068.39 ± 30.04
21. Dodolove	419.42	405.6	454.66	426.56 ± 25.30

Supplementary Table S2 Mean total soluble fluoride (TSF) concentrations of children's toothpaste products. Fluoride concentrations are expressed as ppm F.

Toothpaste brand	Total Soluble Fluoride			Mean ± SD
	1	2	3	
1. Omeg Kids	0	0	0	0
2. Colgate Kids	1047.34	1087.47	1019.63	1033.58 ± 42.71
3. Dentiste Max Kids	1152.97	1145.07	1034.26	1062.04 ± 123.74
4. Dr.Ray	588.64	608.71	589.68	499.69 ± 30.21
5. Fluocaril	965.92	936.67	1001.53	849.63 ± 23.06
6. Gum Kids	499.63	481.29	466.76	472.47 ± 9.56
7. Jordan Step1 (1-5y)	507.54	567.82	577.33	514.98 ± 52.26
8. Jordan Step2 (6-12y)	1040.21	1046	1045.74	1027.14 ± 68.26
9. Kindee 6m+	0	0	0	0
10. Kindee 1y+	531.74	577.34	536.37	501.34 ± 21.62
11. Kindee 6y+	1585.93	1502.21	1549.22	1388.01 ± 41.67
12. Kodomo Ultra Shield formula Xylitol plus	928.32	1089.95	1026.83	973.38 ± 61.39
13. Kodomo Ultra Shield formula Sugar free	1034.02	1052.24	1075.12	994.60 ± 17.36
14. Kolbadent Kids	0	0	0	0
15. Vidhyasom	1043.35	1041.40	1073.42	1023.93 ± 4.57
16. Babi Mild Kids	1117.78	1186.50	1068.81	1094.98 ± 109.36
17. St. Andrews	516.38	571.75	602.45	535.54 ± 44.40
18. Jollikidz	1102.98	1008.57	1102.45	1032.99 ± 52.01
19. Grants of Australia Kids	62.36	49.32	70.36	31.72 ± 2.75
20. Palmmade	1038.25	1068.59	1098.33	977.75 ± 15.62
21. Dodolove	419.42	405.6	454.66	402.49 ± 16.06

Discussion

This study evaluated and compared the total fluoride (TF) and total soluble fluoride (TSF) concentrations among 21 commercially available children's toothpaste brands in Thailand in 2024. Overall, while most products demonstrated agreement between labeled and measured total fluoride concentrations, discrepancies were identified in several brands, particularly with respect to total soluble fluoride, the bioavailable fraction responsible for anticaries activity. Fluoride concentration remains a key determinant of toothpaste anticariogenic efficacy, and it has been well established that toothpastes containing at least 1,000 ppm fluoride provide clinically meaningful caries prevention [4].

Fluoride-free toothpastes were analyzed and discussed as a separate category in the present study. These products represent a distinct segment of the pediatric oral care market and are often selected by parents who may have specific concerns regarding fluoride exposure and potential adverse effects. Because their fluoride content is zero, they were excluded from statistical comparisons between TF and TSF concentrations. Unlike fluoride-containing formulations, fluoride-free products lack bioavailable fluoride ions necessary for enhancing enamel remineralization and inhibiting demineralization and therefore do not provide evidence-based anticariogenic benefits [2,3]. From a public health perspective, the increasing availability and consumer uptake of fluoride-free toothpastes may warrant further educational efforts to ensure informed decision-making among caregivers [8].

A key finding of this study is that agreement between labeled total fluoride content and measured TF does not necessarily guarantee adequate TSF availability. TF represents the overall fluoride content in a formulation, including both soluble and insoluble forms, whereas TSF reflects the fraction of fluoride that remains soluble and bioavailable in the oral environment [5]. Because anticaries efficacy depends primarily on the availability of soluble fluoride ions to interact with enamel surfaces and promote remineralization, TSF is considered the clinically relevant parameter [2, 3, 5].

The observed discrepancies between TF and TSF in several products may be explained by formulation-related factors. Interactions between fluoride compounds—particularly sodium monofluorophosphate—and calcium-based abrasive systems can lead to the formation of insoluble fluoride complexes during manufacturing or storage, thereby reducing fluoride solubility over time [5, 7]. Similar findings have been reported in previous investigations from various countries, where measured soluble fluoride levels were substantially lower than labeled concentrations despite adequate total fluoride content [6,7,9-13]. Our findings are consistent with this body of evidence and extend it by providing updated, brand-specific data from the Thai market.

From a clinical perspective, it is important to distinguish between minor analytical deviations and clinically meaningful discrepancies. Minor differences between labeled and measured fluoride concentrations (e.g., approximately ±50 ppm) are unlikely to substantially affect caries-preventive efficacy, as fluoride levels remain within a therapeutic range. However, larger discrepancies—particularly where measured TF or TSF concentrations are markedly lower than labeled values—may compromise anticaries effectiveness. Systematic reviews have demonstrated a dose–response relationship between fluoride concentration and caries reduction, with reduced preventive effects observed at lower fluoride levels [4]. Therefore,

insufficient TSF availability may diminish the protective benefit of toothpaste, especially in children at elevated caries risk who rely heavily on daily topical fluoride exposure for caries control.

The discrepancies identified in this study also raise concerns regarding product quality control and labeling accuracy. Accurate labeling is essential not only for regulatory compliance but also for clinical decision-making and parental trust. When labeled fluoride concentrations overestimate the amount of bioavailable fluoride, clinicians and caregivers may assume adequate caries protection despite suboptimal TSF levels. Previous studies have similarly highlighted inconsistencies between declared and analytically measured fluoride concentrations, emphasizing the need for continued regulatory monitoring [6, 7, 9–13].

Within the Thai context, fluoride toothpaste is widely recommended as a primary caries-preventive measure. Regular surveillance of both TF and TSF concentrations in commercially available products may therefore be necessary to ensure that marketed formulations meet therapeutic expectations. Incorporating assessment of bioavailable fluoride into regulatory frameworks may strengthen consumer protection and support evidence-based pediatric oral health strategies [5]. From a consumer perspective, toothpaste selection is often influenced not only by labeled fluoride concentration but also by parental perceptions of safety, marketing claims, and product availability. Therefore, professional guidance from dental practitioners remains important to help caregivers make informed decisions regarding appropriate fluoride toothpaste use for children. Increasing public awareness about the importance of bioavailable fluoride may further support effective caries prevention strategies.

This study has several strengths. First, the simultaneous evaluation of TF and TSF provides a more clinically meaningful assessment of fluoride availability compared with studies that rely solely on labeled or total fluoride concentrations. Second, the inclusion of a broad range of widely marketed children's toothpaste brands enhances the practical relevance of the findings. However, certain limitations should be acknowledged. The sampling period was limited, and not all products could be obtained from three fully independent production batches. Additionally, this investigation was laboratory-based and did not directly assess in vivo fluoride bioavailability or clinical caries outcomes. Furthermore, toothpaste products were primarily purchased from major supermarkets in Bangkok. Although these retail outlets distribute nationally available brands, regional variations in product availability cannot be entirely excluded, and the findings may not fully represent all toothpaste products marketed throughout Thailand. Future research should explore longitudinal batch variability, stability during storage, and the relationship between TSF levels and clinical caries incidence in pediatric populations.

Conclusion

This study demonstrates that labeled fluoride concentrations do not always accurately reflect bioavailable fluoride content in children's toothpaste products. Ensuring adequate total soluble fluoride availability is critical for maintaining the expected anticariogenic efficacy of fluoride-containing formulations. Ongoing surveillance and strengthened regulatory oversight may help safeguard therapeutic effectiveness and support optimal caries prevention in children.

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