Measuring Total and Ionized Fluoride Content in Toothpastes Used by Egyptian Children

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Abstract:

Background: As the prevalence of dental caries in Egypt is high, it is imperative that fluoride content in toothpastes be sufficient to prevent it.

Aim: To measure total and ionized fluoride content in toothpastes most commonly used by Egyptian children.

Methods: A cross-sectional descriptive study was carried out by conducting a pilot survey to determine the two most commonly used toothpastes by Egyptian children aged 2-6 years. Triplicates of each were purchased from different stores and emptied into sterile, labeled containers. An ion chromatography system with fluoride ion-specific electrode was utilized to measure total and ionized fluoride content in each of the triplicates.

Results: According to the pilot study, FKB and SKS toothpastes were the two most commonly used in the Egyptian market. Total fluoride content in FKB was not declared on its box, and when measured was 878.23±26.76 ppm. Its ionized fluoride content was 648.87±47.93 ppm. Total fluoride concentration in SKS was declared to be 1000 ppm, and when measured was 896.73±25.12 ppm, while the ionized fluoride content was 686.07±68.53 ppm. Total and ionized mean released fluoride from both brands of toothpastes were all significantly lower than 1000 ppm ($p<0.05$), which is the fluoride concentration needed for caries prevention.

Conclusion: Fluoride content in the examined toothpastes is not coincident with that declared by the manufacturer, and significantly lower than the concentration needed for caries prevention. More care and better monitoring of toothpastes in the Egyptian market are recommended.

Keywords: pediatric dentistry, preventive dentistry, dental caries, ionized fluoride, total fluoride.

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Introduction

Caries has been and remains the most common oral disease worldwide.[1] Prevalence of dental caries in Egypt was estimated to be nearly 70%, according to the World Health Organization (WHO) in 2014.[2] According to the American Dental Association (ADA), dental caries is a "biofilm-mediated, sugar-driven, multifactorial, dynamic disease that results in the phasic demineralization and remineralization of dental hard tissues." When demineralization has the upper hand for ample time, caries occurs.[3,4]

Fluoride has been proven to be very effective in preventing dental caries and arresting early lesions by multiple mechanisms.[5–10] It can be delivered in several ways; community water fluoridation, applied professionally, or self-administered using toothpastes and mouthrinses.[11]Fluoride's effect is greater when applied topically.[12]

Toothpastes are of utmost importance in maintaining oral health.[13,14] The composition of toothpaste is complex, as it is formed of a mixture of active and inactive ingredients suspended in an aqueous medium.[15–17] Inactive ingredients give toothpaste its consistency, taste, color and bind components together. They are mostly abrasives and humectants. On the other hand, active ingredients are those that have a positive effect on oral hygiene. Those are listed in Table (1).[18]

Table (1): Active Ingredients of Toothpastes

Active Ingredient	Function	Examples
Anti-gingivitis agents	Anti-inflammatory effects	Triclosan, stannous fluoride, zinc salts
Anti-malodor agents	Prevent bad breath	Zinc salts
Anti-tartar agents	Prevent supragingival plaque formation	Phosphate salts, zinc salts
Whitening agents	Remove extrinsic stains	Phosphate salts

Desensitizing agents	Relief dentin hypersensitivity	Strontium salts, stannous fluoride, calcium sodium phosphosilicate
Remineralizing-agents	Mineral deposition in tooth structure	CPP, CPP-ACP, Calcium sodium phosphosilicate, hydroxyapatite, xylitol
Anti-caries agents	Prevent caries	Fluoride

There are three factors that affect the anticaries effect of fluoridated toothpastes: fluoride concentration, frequency of brushing, and post-brushing rinsing behavior.[19] Low-fluoride toothpastes, containing less than 600 parts per million (ppm) fluoride, are available for young children in many countries. However, these toothpastes have limited evidence on their anticaries effect.[20] Standard toothpastes contain 1000 ppm up to 1500 ppm fluoride, while high fluoride toothpastes containing up to 5000 ppm are available on prescription.[19,21]

There is a strong relation between the type of abrasive used in the toothpaste and the fluoride compound. In toothpastes, sodium fluoride ionizes to give fluoride ions, while sodium monofluorophosphate requires the action of salivary phosphatase enzyme to ionize.[22]Abrasives should be compatible with the fluoride compound used, as they have the ability to inactivate fluoride by binding to the ionized fluoride available and rendering it inactive.[17,18]

Accordingly, it can be concluded that toothpastes contain ionized (bioavailable) fluoride and non-ionized (compound) fluoride. Their sum is the total fluoride content of toothpaste. The cariostatic effect of fluoride in toothpastes is related to the free or ionized (F^-) fluoride rather than its total fluoride content.[23]

Studies in different countries such as India[24], Brazil[25], Saudi Arabia[26], South Africa[27] and Peru[28] have shown that there's inconsistency of total fluoride content measured with that declared by the

manufacturer. They also reveal in homogeneity of total fluoride (TF) and free or total soluble fluoride (TSF) concentrations in toothpastes. Moreover, they reveal that TSF is inappropriate for dental caries control. Therefore, it is of utmost importance to measure total and ionized fluoride content in toothpastes most commonly used by Egyptian children to ensure that it is of optimal level for caries prevention.

Methods:

The present study is a cross-sectional descriptive study that was concerned with the measurement of total and ionized fluoride content in the most commonly used toothpastes by Egyptian children.

Sampling

A pilot study was conducted at the Pediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Ain Shams University. Thirty-five caregivers escorting their children for dental care on different days were asked whether their children use toothpaste or not. If yes, they were asked about the type of toothpaste used. The most commonly used types were FKB and SKS. Hence, these were employed in this study.

Each type of toothpaste was bought in triplicate, similar to other studies.[24,26,28] Toothpastes were bought from different stores to ensure that their storage hasn't affected the toothpastes' fluoride concentration.

Flavors with similar colors of the selected toothpastes (SKS and FKB) were used. Toothpaste tubes were randomly emptied into sterile containers, each labeled with a letter from A through F. This ensured blinding of both the assessor and the statistician.

Fluoride content analysis

Measurement of toothpastes' fluoride content was conducted at the Faculty of Science Central Laboratory, Ain Shams University. A Thermo Scientific Ion Chromatography System[29] was used. Analysis was achieved according to Pearce protocol.[30] In the current study, both total fluoride (TF) and fluoride ions (FI) were measured.

The Pearce protocol has been used since 1980 at the Laboratory of Oral Biochemistry at Piracicaba Dental School. The protocol is as follows: 90 to 110 mg of toothpaste were weighed (± 0.01 mg). They were homogenized in 10 mL of deionized water. Duplicates of 0.25 mL of the suspension were transferred to test tubes for TF analysis. The remaining of the suspension was centrifuged (3,000 g, 10 min, r.t.) to

remove fluoride bound to the abrasive. Duplicates of 0.25 mL of the supernatant were transferred to test tubes to determine FI concentrations. For the TF tubes, 0.25 mL of 2.0 M HCl was added. After 1 hour at 45°C, the samples were neutralized with 0.5 mL 1.0 M NaOH 1.0 M and buffered with 1.0 mL of Total Ionic Strength Adjustment Buffer (TISAB II). TISAB II is 1.0 M acetate buffer, pH 5.0, containing 1.0 M NaCl and 0.4% CDTA. It is a property of Sigma Aldrich Company. To the FI tubes, 0.50 mL of 1.0 M NaOH was added and buffered with 1.0 mL of TISAB II and 0.25 mL of 2.0 M HCl.

Data analysis

Numerical data were presented as mean and standard deviation values. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. Data were normally distributed and were analyzed using one-sample t-test. The significance level was set at $p \leq 0.05$. Statistical analysis was performed with R statistical analysis software version 4.1.3 for Windows[1] .

[1] R Core Team (2023). R: A language and environment for statistical computing. RFoundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/.

Results:

Total fluoride content in FKB was not declared on its box, and when measured was 878.23±26.76 ppm. Ionized fluoride content was 648.87±47.93 ppm. Total fluoride content in SKS was declared to be 1000 ppm, and when measured was 896.73±25.12 ppm, while ionized fluoride content was 686.07±68.53 ppm. Total and ionized mean released fluoride from both brands of toothpastes were all significantly lower than 1000 ppm ($p<0.05$). This is shown in Table 2.

Table 2: Mean and standard deviation values for toothpaste fluoride release and its difference from 1000 ppm

Parameter	Toothpaste	Mean±SD	p-value for the difference from 1000 (ppm)
Ionized Fluoride (ppm)	**FKB**	648.87±47.93	0.006*
	SKS	686.07±68.53	0.016*
Ionized Fluoride (ppm)	**FKD**	878.23±26.76	0.016*
	SKS	896.73±25.12	0.019*

*; significant ($p \leq 0.05$)

Discussion:

The ionized fluoride content of a toothpaste should be at least 1000 ppm to have an anti-caries effect.[20] Both toothpastes in the current study showed total and ionized fluoride contents significantly lower than 1000 ppm.

These results are similar to other studies conducted internationally. *Cury et al*[25] (Brazil, 2010), *Sebastian and Siddanna*[24] (India, 2015), *Farooq et al*[26] (Saudi Arabia, 2018), *Vorster et al*[27] (South Africa, 2018) and *Jairoun et al*[31] (U.A.E., 2021) found that some companies did not declare the fluoride concentration on the packaging. Toothpastes mainly showed in homogeneity between the fluoride content declared by the manufacturer and that measured. Most toothpaste had lower ionized fluoride content than the total content. This may be due to the lack of monitoring on producing companies; it may also be due to lack of guidelines on manufacturing toothpastes. Some toothpaste had insufficient fluoride concentration for caries prevention. This could be due to the use of cheap ingredients, especially abrasives, in the manufacturing process.

These results showed us that companies must be obliged to declare the fluoride content of its toothpastes. It also shows that closer monitoring of the fluoride content of toothpastes is needed, as there is an inconsistency between that declared by the manufacturer and that actually measured.

Moreover, care must be taken to allow compatibility between the used fluoride compound and the abrasive. This is to make sure that the ionized (active) fluoride level is sufficient enough for caries prevention.

Although this study has only been performed on the two most commonly used kids' toothpastes in Egypt, it has shown that there is a significant problem. This problem could be one of the reasons behind the high caries prevalence amongst Egyptian children.

Limitations

Measurement of fluoride content was carried out on only two types of toothpastes used by children, whereas the market has many more different kinds. Choosing the most commonly used children's toothpastes was carried out by a pilot study in the Department of Pediatric Dentistry, Ain Shams University. This is not representative of the entire Egyptian population.

Conclusions:

Within the limitations of the current study, it can be concluded that some manufacturers do not label their toothpaste with its fluoride concentration. Also, some manufacturers label their toothpastes with a fluoride concentration less than that actually available.

Recommendations

- There is a need to monitor toothpastes production in Egypt and their fluoride content (both total and ionized).
- Toothpaste manufacturers should clearly label their products with the amount of total and ionized fluoride present.
- Manufacturers should follow up on the available guidelines regarding fluoride concentration in toothpaste for different ages.
- Authorities should send updates of the guidelines to manufacturers.

Declarations

Ethics approval

Ethical approval was granted from the research ethical committee at Faculty of Dentistry, Ain Shams University (Approval number FDASU-ReclM122004).

Consent for publication

All authors have approved the final version and its publication.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to the conceptualization of the study: Alaa Eissa contributed to the clinical work of the study and writing the manuscript. Reham Elghazawy contributed to the revision of the manuscript. Amira Badran contributed to the final review and approval of publication.

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References:

1. Selwitz RH, Ismail AI, Pitts NB. Dental caries. Lancet. 2007 Jan 6;369(9555):51–9.

2. Ministry of Public Health, WHO. Results-of-epidemiological-study-on-oral-health-status-released.pdf [Internet]. [cited 2022 Oct 11]. Available from: https://www.emro.who.int/pdf/egy/egypt-events/results-of-epidemiological-study-on-oral-health-status-released.pdf?ua=1

3. Pitts N, Zero D, Marsh P, Ekstrand K, Weintraub J, Gomez F, et al. Dental caries. Nature Reviews Disease Primers. 2017 May 25;3:1–16.

4. Souza J, Souza S, Noronha M, Ferreira E, Martins A. Impact of untreated dental caries on the daily activities of children: Impact of untreated dental caries. Journal of Public Health Dentistry. 2017 Nov 29;78:1–6.

5. Ten Cate JM, Buzalaf MAR. Fluoride Mode of Action: Once There Was an Observant Dentist . . . J Dent Res. 2019 Jul 1;98(7):725–30.

6. CDC. Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States [Internet]. [cited 2021 Jun 5]. Available from: https://www.cdc.gov/mmwr/preview/mmwrhtml/rr5014a1.htm

7. Chu CH, Mei ML, Lo E. Use of fluorides in dental caries management. General dentistry. 2010 Jan 1;58:37–43.

8. Tenuta LMA, Cury JA. Fluoride: its role in dentistry. Braz oral res. 2010;24(suppl 1):9–17.

9. Kato MT, Bolanho A, Zarella BL, Salo T, Tjäderhane L, Buzalaf MAR. Sodium Fluoride Inhibits MMP-2 and MMP-9. J Dent Res. 2014 Jan;93(1):74–7.

10. Marquis RE. Antimicrobial actions of fluoride for oral bacteria. Can J Microbiol. 1995 Nov;41(11):955–64.

11. O'Mullane DM. Fluoride and Oral Health. Community Dental Health. 2016;(33):69–99.

12. Bibby BG, Wilkins E, Witol E. A preliminary study of the effects of fluoride lozenges and pills on dental caries. Oral

Surgery, Oral Medicine, Oral Pathology. 1955 Feb 1;8(2):213–6.

13. Cury JA, Tenuta LMA. Evidence-based recommendation on toothpaste use. Braz oral res. 2014 Jan 24;28(spe):1–7.

14. Bahammam S, Chen CY, Ishida Y, Hayashi A, Ikeda Y, Ishii H, et al. Electric and Manual Oral Hygiene Routines Affect Plaque Index Score Differently. IJERPH. 2021 Dec 12;18(24):1–10.

15. Lippert F. An Introduction to Toothpaste - Its Purpose, History and Ingredients. Monographs in oral science. 2013 Jul 2;23:1–14.

16. Watson CA. Synthetic hydrocolloids and dentifrices. Journal of the Society of Cosmetic Chemist. 1970;21:459–70.

17. Hattab FN. The state of fluorides in toothpastes. Journal of Dentistry. 1989 Apr;17(2):47–54.

18. Subramanian S, Appukuttan D, Tadepalli A, Gnana PPS, Victor DJ. The Role of Abrasives in Dentifrices. J Pharm Sci. 2017;9:221–4.

19. Davies RM, Ellwood RP, Davies GM. The rational use of fluoride toothpaste. International Journal of Dental Hygiene. 2003;1(1):3–8.

20. Santos APP, Oliveira BH, Nadanovsky P. Effects of low and standard fluoride toothpastes on caries and fluorosis: systematic review and meta-analysis. Caries Res. 2013;47(5):382–90.

21. Toumba KJ, Twetman S, Splieth C, Parnell C, Van Loveren C, Lygidakis NA. Guidelines on the use of fluoride for caries prevention in children: an updated EAPD policy document. Eur Arch Paediatr Dent. 2019 Dec;20(6):507–16.

22. Harris NO, García-Godoy F, editors. Primary preventive dentistry. 6th ed. Upper Saddle River, N.J: Pearson Education; 2004. 706 p.

23. Hattab F. The State of Fluorides in Toothpastes. Journal of dentistry. 1989 May 1;17:47–54.

24. Sebastian ST, Siddanna S. Total and Free Fluoride Concentration in Various Brands of Toothpaste Marketed in India. J Clin Diagn Res. 2015 Oct;9(10):9–12.

25. Cury JA, Oliveira MJL de, Martins CC, Tenuta LMA, Paiva SM. Available fluoride in toothpastes used by Brazilian children. Brazilian Dental Journal. 2010;21(5):396–400.

26. Farooq I, Ali S, Al-Khalifa KS, Alhooshani K. Total and soluble fluoride concentration present in various commercial brands of children toothpastes available in Saudi Arabia - A pilot study. Saudi Dent J. 2018 Apr;30(2):161–5.

27. Vorster L, Naidoo S, Stauf N, Holmgren C, Benzian H. Fluoride content of toothpastes available in South Africa. Community Dent Health. 2018 Aug 30;35(3):186–92.

28. Chávez BA, Vergel GB, Cáceres CP, Perazzo MF, Vieira-Andrade RG, Cury JA, et al. Fluoride content in children's dentifrices marketed in Lima, Peru. Brazilian Oral Research. 2019;33:1–9.

29. Haddad P. Ion chromatography. Analytical and bioanalytical chemistry. 2004 Jul 1;379:341–3.

30. Pearce EI. A laboratory evaluation of New Zealand fluoride toothpastes. N Z Dent J. 1974 Apr;70(320):98–108.

31. Jairoun AA, Al-Hemyari SS, Shahwan M, Jairoun O, Zyoud SH. Analysis of Fluoride Concentration in Toothpastes in the United Arab Emirates: Closing the Gap between Local Regulation and Practice. Cosmetics. 2021 Nov 30;8(4):113–25.