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Compositional Analysis and Systemic Considerations of Fluoridated Toothpastes for Children Available in Ankara, Türkiye

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ABSTRACT

Purpose: This study aimed to analyze the composition, fluoride content, and potential health risks of fluoride-containing children's toothpaste available in Turkey. Given the rising concerns over fluoride toxicity and market trends favoring fluoride-free products, the study also evaluated the presence of potentially harmful excipients and assessed their compliance with international pediatric dental guidelines.

Methods: A total of 92 children's toothpaste products were identified through Turkey-based online marketplaces, of which 18 (19.56%) contained fluoride. Fluoride concentrations were classified into 500–990 ppm (9.78%) and 1000 ppm (9.78%), the latter aligning with European Academy of Paediatric Dentistry (EAPD) recommendations. A comprehensive ingredient analysis was performed, categorizing compounds based on their function, prevalence, and toxicity risk. The safety of these ingredients was further assessed using PubMed, ScienceDirect, and Google Scholar databases to determine their documented health effects.

Results: The majority (80.44%) of children's toothpaste products were fluoride-free, raising concerns regarding effective caries prevention. Additionally, fluoridated products contained potentially harmful preservatives (Sodium Benzoate - 44.44%), surfactants (Sodium Lauryl Sulfate - 5.55%), and whitening agents (Titanium Dioxide - 27.77%), all of which have been linked to cytotoxic, irritative, or systemic toxic effects.

Conclusions: These findings highlight a disparity between fluoride availability and professional recommendations, emphasizing the need for improved regulatory oversight, consumer education, and safer pediatric oral care formulations. Given growing concerns about fluoride toxicity, future research should explore fluoride-free remineralization alternatives such as hydroxyapatite and calcium phosphate-based compounds.

Key-words: *Children's toothpaste, fluoridated toothpaste, online market, Türkiye*

INTRODUCTION

Type Dental caries is the most common oral disease worldwide. The World Health Organization (WHO) estimates that 20% to 90% of 6-year-old children have dental caries.[1] Cavities in children can be a source of pain and can lead to tooth loss, impaired growth, and developmental failure. Additionally, they can affect speech, appearance, self-esteem, and school performance.[2] Dental caries are prevalent globally, particularly among adults and children from low

socioeconomic backgrounds. Furthermore, due to disparities in access to dental care, these populations are often overlooked or receive inadequate services in many countries.[1,2]

The regular use of toothpaste has been associated with a decrease in cavities in many countries. The use of fluoridated toothpaste is found to be beneficial for children and adolescents.[3] Since the 1950s, fluoride has been added to toothpaste formulations. It is widely accepted by dentists worldwide that individuals, both children and adults, should be exposed to fluoride through regular use of fluoridated toothpaste.[4] However, despite the benefits of fluoridated toothpaste, it is considered a risk factor for dental fluorosis. Therefore, the fluoride concentration in toothpaste is extensively debated, especially for children, in order to mitigate the risk of fluorosis.[5] Some alternatives, such as delaying the use of fluoride-containing toothpaste or using variable fluoride concentrations based on the child's age, have been proposed to reduce the risk of fluorosis.[3]

There is a lack of consensus among professional organizations regarding recommendations for the use of fluoridated toothpaste.[5,6] For instance, while Australia is one of the few countries recommending a reduction in fluoride concentration in toothpaste for children under 6 years of age to decrease the incidence of dental fluorosis, many countries advise using fluoridated toothpaste with at least 1000 ppm for children, which is the adult concentration.[7] This situation is thought to be a result of lower fluoride concentrations in water or higher rates of childhood caries in their respective countries, leading to a prioritization of the caries-preventive effect of higher fluoride doses over the risk of dental fluorosis.[8,9]

Fluoride is an effective agent in reducing the incidence of dental caries. Therefore, there are no dental organizations advocating for the use of fluoride-free toothpaste nowadays.[8] In contrast, despite the growing market for herbal and fluoride-free toothpaste, it is expected that the majority of children's toothpaste available in the market will be fluoridated.[6,10]

Children's specific toothpaste is a relatively new phenomenon, developed both as a way to increase marketability through added flavors, scents, and colorful packaging, and to keep fluoride levels low to reduce the incidence of fluorosis.[11] International studies compiling lists of children's toothpaste available in stores have been conducted, revealing the fluoride contents of existing toothpaste.[3,10, 12, 13] However, there is no similar study available nationwide in Türkiye. This study examines the fluoride levels and contents of toothpaste for children aged 0-6 years available in various markets and platforms across Türkiye.

MATERIAL AND METHODS

This study did not involve the use of human or animal tissues, saliva, organs, or any other materials requiring ethical approval. The research was conducted between September 2024 and December 2024, focusing on the compositional analysis of children's toothpaste products available exclusively in Türkiye-based online marketplaces operating in the Ankara region.

Initially, children's toothpaste products were identified from the oral care sections of major supermarkets in Ankara, Türkiye. The study was later expanded to include only Turkish-based online marketplaces serving the Ankara region. Products were identified using search terms such as "children's toothpaste," "baby toothpaste," and "kids' oral care." To ensure regional specificity, only e-commerce platforms registered in Ankara and shipping within the region were included in the analysis. International e-commerce websites or sellers operating outside Ankara were not considered.

A comprehensive database was created, recording the name, label information, and ingredient list of each toothpaste. A total of 92 different children's toothpaste products were documented and analyzed. Products were categorized into two groups: fluoride-containing and fluoride-free toothpastes. Only fluoride-containing products underwent detailed ingredient analysis.

Following this classification, only the fluoride-containing toothpastes underwent detailed content analysis, focusing on: Fluoride compounds (e.g., sodium fluoride (NaF), amine fluoride (AmF), calcium fluoride (CaF_2)), abrasive agents, preservatives and stabilizers, flavoring and sweetening agents, potential health effects of each ingredient on children.

To assess the safety and effectiveness of fluoride-based formulations, each ingredient was analyzed for its functional role and prevalence across different toothpaste products. Toothpaste ingredient data were recorded in an Excel database. Google Scholar, PubMed, and ScienceDirect databases were utilized to compile scientific data for each component present in the toothpaste formulations.

The quantitative aspect of this study involved calculating the occurrence rate (percentage frequency) of each ingredient across all analyzed fluoride-containing children's toothpaste products. For each ingredient, the presence or absence was recorded. The occurrence rate was calculated by dividing the number of products containing the ingredient by the total number of products analyzed (n = 92). No inferential statistical analyses were conducted; the study employed descriptive statistics only.

The occurrence rate of each ingredient across all toothpaste samples was calculated as a percentage. For

each ingredient, an assessment was conducted to determine:

1. Its role in toothpaste formulation
2. Its potential impact on dental health
3. Any documented health concerns or benefits

All findings were organized into a systematic ingredient-function table, where each component was classified based on its intended function and frequency in the analyzed toothpastes.

Additionally, the fluoride concentrations in these products were compared with the 2019 European Academy of Paediatric Dentistry (EAPD) guidelines to assess compliance with recommended fluoride levels for children.[14]

By analyzing the ingredient composition and accessibility of children's toothpaste products, this study aimed to provide a comprehensive quantitative evaluation of fluoride-based toothpaste formulations available in Türkiye, specifically in the Ankara region.

RESULTS

A total of 92 different children's toothpaste products from 42 brands were identified from Türkiye-based online marketplaces serving the Ankara region. Among these, 18 toothpastes (19.56%) contained fluoride, while 74 toothpastes (80.44%) were fluoride-free (Table 1).

The fluoride-containing toothpaste samples exhibited varying fluoride concentrations: 6 toothpastes (6.52%) contained 500 ppm fluoride, 2 toothpastes (2.17%) contained 990 ppm fluoride, 1 toothpaste (1.09%) contained 700 ppm fluoride, 9 toothpastes (9.78%) contained 1000 ppm fluoride, aligning with the recommended concentration by the EAPD (Table 1).

The predominance of fluoride-free toothpastes raises concerns regarding the accessibility of fluoride-based oral care products and their potential impact on Children's dental health.

The compositional analysis of the fluoridated toothpastes revealed 146 distinct ingredients (Table 1). These ingredients served diverse functions, including cavity protection (fluoride compounds), mechanical cleaning (abrasives), moisture retention (humectants), foaming (surfactants), product stabilization (preservatives), and flavor enhancement (sweeteners).

Table 1. Fluoride Content of Toothpastes

Fluoride Content	Fluoride Level (ppm)	Toothpaste (n)	Toothpaste (%)
Absent	0	74	80,44
Low	500-990	9	9,78
Optimal	1000	9	9,78

Table 2. Ingredients in children's Fluoridated Toothpastes

Ingredient Type	Occurrence in Flouridated Toothpastes (n)	Function in Toothpaste	Possible Side Effects
Amin Flouride	3 (%16,66)	Cariostatic activity[15]	Skeletal, dental and some systemic problems [15,16]
Amyloglucosidase	1 (%5,55)	Anti-plaque effect, Cariostatic potential [17]	Mild irritation in sensitive individuals [17]
Anise Alcohol	1 (%5,55)	Flavoring agent, antimicrobial and anti-fungal activity [18]	Possible allergic reactions [18]
Aroma	17 (%94,4)	Sweetener	No specific side effect listed [22]
Benzyl Alcohol	4 (%22,22)	Solvent, antimicrobial effect [19]	Mild oral irritation, systemic toxicity, allergic reaction [19]
Butyl P-Hydorxybenzoate	2 (%11,11)	Antimicrobial activity, stabilizer [18]	Potential endocrine-disrupting effects, may cause irritation or allergic reactions [18]
Calcium Carbonate	1 (%5,55)	Cleaning, plaque and stain removal[21]	Milk-alkali syndrome, allergy or irritation[21]

Table 2. Ingredients in children's Fluoridated Toothpastes (continue)

Ingredient Type	Occurrence in Flouridated Toothpastes (n)	Function in Toothpaste	Possible Side Effects
Carbomer	2 (%11,11)	Stabilizing ingredients, improving spreadability and thickening agent [22]	Mild irritation, allergic reactions, dryness or sensitivity [22]
Cellulose Gum	8 (%44,44)	Viscosity and rheology modifier [23]	Rare allergies (itching, redness), dry mouth feeling, stomach discomfort[23]
Cinnamal	1 (%5,55)	Essence, effective against *C. Albicans* [24]	Mouth irritation (burning, tingling), contact dermatitis[25]
CCP-ACP	2 (%11,11)	Remineralize enamel, cariostatic effect [26]	Milk allergy concern, mild irritation[26]
CMC-Na	2 (%11,11)	Thickener and stabilizer [27]	Skin and digestive irritations [23]
CI 16035	3 (%16,66)	Synthetic colorant [28]	Allergic reactions, hyperactivity risk[28]
CI 16185	1 (%5,55)	Synthetic colorant [26]	No specific side effects listed
CI 16255	1 (%5,55)	Synthetic colorant [22]	Mild allergic reactions [26]
CI 17200	1 (%5,55)	Synthetic colorant [28]	No specific side effects listed
CI 77019	1 (%5,55)	Pearlescent pigment [28]	Minor skin or lung irritation[26]
CI 42090	1 (%5,55)	Synthetic colorant [28]	Rare allergic reactions [23]
CI 77891	2 (%11,11)	Opacifying agent [27]	Mild irritation, inhalation concerns[28]
CI 77491	1 (%5,55)	Pigment colorant [27]	No specific side effects listed [22]
Citric acid	2 (%11,11)	Prevents dry mouth [29]	Halitosis, demineralization, dentin hypersensitivity, burning mouth syndrome [30]
Cocamidopropyl Betaine	7 (%38,88)	Surfactant [29]	Irritation [29]
Ethyl p-hydroxybenzoat	2 (%11,11)	Presevative [29]	Rare allergies [29]
Decyl Glucoside	1 (%5,55)	Cleanser [29]	No specific side effects listed
D-sorbitol	2 (%11,11)	Humectant [29]	No specific side effects listed
Disodium Cocoyl Glutamate	1 (%5,55)	Surfactant, cleanser [31]	Mild irritant, moisturizing [31]
Glucose Oxıdase	1 (%5,55)	Antibacterial agent, preservative [32]	Skin irritation and allergic reactions[32]
Glucosıde	2 (%11,11)	Non-ionic surfactant [33]	Mild irritation [33]
Glkyceryl Caprylate	1 (%5,55)	Emulsufier [34]	Rare allergic reactions [34]
Glycerin	10 (%55,55)	Humectant [32]	Toxic effect on kidney and liver[35]
Guar gum	2 (%11,11)	Thickening agent [35]	No specific side effects listed
Hydrated Silica	12 (%66,66)	Abrasive [29]	Gastrointestinal irritation [29]
Hydrogenated Starch Hydrolysate	4 (%22,22)	Humectant, sweetener [36]	Mild digestive issues [36]
Hydroxy Ethyl Cellulose	3 (%16,66)	Thickener, stabilizer [37]	Rare skin irritation [37]
Lauryl Glucosıde	2 (%11,11)	Gentle cleansing [38]	Skin or eye irritation [38]
Lımonene	2 (%11,11)	Antibacterial properties[39]	Rare allergic reactions [39]
Magnolıa Officinalis Bark Extract	1 (%5,55)	Antibacterial, antioxidant[40]	Skin irritation [40]

Table 2. Ingredients in children's Fluoridated Toothpastes (continue)

Ingredient Type	Occurrence in Flouridated Toothpastes (n)	Function in Toothpaste	Possible Side Effects
Magnesium Oxide	2 (%11,11)	Abrasive, pH adjuster [41]	Mild irritation [41]
Metylparaben	3 (%16,66)	Prevents microbial growth [42]	Affects the endocrine system by acting estrogen-like [42]
Nicotinyl Alcohol HF	2 (%11,11)	Vasodilator [43]	Skin flushing and mild irritation [43]
PEG-6	1 (%5,55)	Emulsifier, solubilizer[44]	No study in the literature
PEG-12 Allyl Ether	6 (%33,33)	Surfactant [45]	Mild skin irritation [45]
PEG-12 Dimethicone	7 (%38,88)	Emollient, conditioning agent [46]	No study in the literature
PEG 600	1 (%5,55)	Humectant, solubilizer [47]	No study in the literature
Pentylene Glycol	1 (%5,55)	Humectant, antimicrobial stabilizer [48]	Rare allergic reactions [48]
Phosporic Acid	2 (%11,11)	pH adjuster, tartar control agent [49]	Corrosive to tooth enamel and irritant [49]
Polylysine	1 (%5,55)	Antimicrobial agent, preservative [50]	Skin irritation [50]
Polysorbate-20	3 (16,66)	Solvent [51]	Irritant to epithelial cells in the digestive system [51]
Polysorbate-80	2 (%11,11)	Solvent [51]	Irritant to epithelial cells in the digestive system [51]
Potassium Hydroxide	3 (%16,66)	pH adjuster, solvent [51]	Irritant, corrosive [50,51]
Potassium Sorbate	3 (%16,66)	Antimicrobial effect [52]	Mild skin irritation and allergic reactions [52]
Proplene Glycol	2 (%11,11)	Solvent [53]	Skin irritation, allergic contact dermatitis [53]
Propyl Gallate	1 (%5,55)	Antioxidant, preservative[54]	Allergic reactions [54]
Propyl P-Hydorxybenzoate	9 (%49,95)	İnhibiting bacterial and fungal growth [55]	Potential endocrine disruptor [55]
Silica	3 (%16,66)	Abrasive [29]	Gastrointestinal irritation [29]
Silicon Dioxide	2 (%11,11)	Abrasive, anti-caking agent [56]	Lung irritation [56]
Stevia Rebaudiana Extract	2 (%11,11)	Sweetener, antioxidant properties [57]	Bloating, mild digestive issues [57]
Steviol Glycosides	1 (%5,55)	Sweetener [58]	No specific side effects listed
Sodium Benzoate	8 (%44,44)	Foaming, anti-staining activity and Anti-ginvitis effect [59]	Cytotoxic effect of human gingival fibroblasts [63]
Sodium Carboxymethyl Cellulose	1 (%5,55)	Thickener, stabilizer [61]	No specific side effects listed
Sodium Chloride	1 (%5,55)	Thickener, flavor enhancer [62]	Dryness or irritation[61]
Sodium Flouride	15 (%83,34)	Cariostatic activity [16]	Skeletal, dental and some systemic problems [15]
Sodium Propionate	3 (%16,66)	Preservative, antifungal agent [64]	Mild irritation [64]
Sodium Saccarin	11 (%61,11)	Sweetener [65]	Carcinogenic, allergen [65]

Table 2. Ingredients in children's Fluoridated Toothpastes (continue)

Ingredient Type	Occurrence in Flouridated Toothpastes (n)	Function in Toothpaste	Possible Side Effects
Sodium lauryl Sarconsinate	3 (%16,66)	Surfactant, foaming agent[66]	Mild skin and mucosal irritation [66]
Sodium lauryl sulphate	1 (%5,55)	Surfactant [67]	Toxic effect on oral cells [67]
Sodium Metyl Cocoyl Taurate	1 (%5,55)	Surfactant, foaming agent[68]	No specific side effects listed
Sorbitol	8 (%44,44)	Sweetener [69]	No specific side effects listed
Sucralose	1 (%5,55)	Sweetener [70]	Alter gut microbiota with excessive consumption [70]
Tetrasodium Pyrophospate	1 (%5,55)	Tartar control [71]	Mild mucosal irritant [71]
Tetrasodium EDTA	3 (%16,66)	Chelating agent [72]	Skin irritation, rare allergic reactions [72]
Titanium dioxide	5 (%27,77)	Whitening agent, colorant[73]	Potential toxicity with prolonged use[73]
Trisodium Phosphate	2 (%11,11)	pH adjuster, cleansing agent [74]	Irritating to gums and oral tissues [74]
Xanthan gum	3 (%16,66)	Thickening agent, Stabilizer [75]	Mild digestive discomfort if ingested in high amounts [75]
Xylitol	8 (%44,44)	Sweetener, anti-cavity agent [76]	Bloating or diarrhea in excessive amounts [76]
Zinc Oxide	2 (%11,11)	Antibacterial, remineralization agent [77]	Irritation [77]

As indicated in Table 2, fluoride compounds (Sodium Fluoride - 83.34%, Amine Fluoride - 16.66%) were the primary active agents responsible for cavity prevention.[80,81] However, only 9.78% of the analyzed toothpastes contained the EAPD-recommended 1000 ppm fluoride concentration, with another 9.78% falling below the optimal threshold (500-990 ppm F).[82] The overwhelming availability of fluoride-free toothpastes (80.44%) may potentially influence parents toward choosing 'natural' alternatives, possibly due to concerns over fluoride toxicity or marketing practices. However, this observation is based on product availability and does not directly reflect consumer purchasing behavior.[83,84] This imbalance could contribute to an increased risk of early childhood caries (ECC), particularly in children without access to fluoride from other sources (e.g., drinking water or professional treatments).[85]

Beyond fluoride, the widespread use of abrasives (Hydrated Silica - 66.66%, Calcium Carbonate - 5.55%) highlights a strong emphasis on mechanical plaque removal.[86] While these ingredients are effective for stain and plaque control, excessive abrasiveness may pose risks for enamel erosion in young children.[87,88] Furthermore, preservatives and stabilizers were heavily represented, with Sodium Benzoate (44.44%) and Propyl P-Hydroxybenzoate (49.95%) being among the most frequently used.[89,90] Table 1 highlights concerns regarding Sodium Benzoate's cytotoxicity to human gingival fibroblasts, while paraben derivatives like Propyl P-Hydroxybenzoate may act as endocrine disruptors.[91,92] Additionally, foaming agents such as Sodium Lauryl Sulfate (5.55%) and PEG-based surfactants were common, yet some of these compounds are known mucosal irritants and have potential toxicity concerns in long-term exposure.[93,94] The presence of Titanium Dioxide (27.77%), widely used for toothpaste whitening, further introduces concerns related to potential nanoparticle absorption and systemic toxicity risks.[95,96] Given the diverse and complex formulation of fluoridated toothpaste products, these findings emphasize the need for improved consumer awareness, regulatory oversight, and market interventions to ensure safe and effective pediatric oral care options.[97] While fluoride remains the most scientifically validated anti-caries ingredient, its low availability in the market suggests a disconnect between clinical recommendations and parental purchasing behaviors.[98] To bridge this gap, future efforts should focus on increasing fluoride toothpaste accessibility, ensuring formulations minimize

potentially harmful preservatives and irritants, and educating parents on evidence-based oral health practices.[99,100]

DISCUSSION

Fluoride-containing children's toothpastes are widely recommended for their anti-caries benefits, yet concerns remain regarding their potential toxicity, systemic effects, and ingredient safety. In this study, we identified a total of 146 distinct ingredients in fluoride-containing children's toothpastes, some of which have documented toxicological risks (Table 1). While fluoride remains the primary cariostatic agent, excessive exposure in young children has been associated with dental fluorosis and potential systemic toxicity.[101] Furthermore, there is growing concern about the cumulative systemic burden of chronic fluoride exposure, especially considering multiple sources such as drinking water, dietary intake, and dental products.[101,107]

In this study, only fluoride-containing children's toothpaste products underwent detailed compositional analysis. This decision was based on current evidence-based guidelines issued by major pediatric dental associations, including the European Academy of Paediatric Dentistry (EAPD), Australian Research Centre for Population Oral Health (ARCPOH) which advocate the use of fluoride-containing toothpaste for effective caries prevention in children.[7,14] Fluoride-free toothpaste formulations, although available in the market, were excluded from detailed analysis due to their lack of established caries-preventive efficacy.

One of the major concerns regarding fluoride use in pediatric oral care is the risk of ingestion, especially in children aged 0-6 years, who have a higher tendency to swallow toothpaste during brushing.[102] If ingested in excessive amounts, fluoride can accumulate in bones and soft tissues, potentially leading to skeletal fluorosis or neurotoxic effects.[103] This raises the question of whether fluoride-free remineralization alternatives, such as hydroxyapatite and calcium phosphate, could provide a safer yet effective alternative to traditional fluoride formulations.[104] Although current fluoride safety thresholds are primarily based on skeletal outcomes, emerging studies suggest that neurodevelopmental risks may arise at lower exposure levels than previously recognized.[102-104]

Beyond fluoride toxicity, several commonly used excipients in these toothpastes also pose potential health risks. Our study found that 44.44% of the analyzed fluoridated products contained Sodium Benzoate, a preservative with cytotoxic effects on human gingival fibroblasts, which may compromise oral tissue health with prolonged exposure. Sodium Benzoate has been demonstrated to induce oxidative stress and mitochondrial dysfunction in oral cell cultures, suggesting that chronic exposure may impair tissue repair mechanisms.[105] Similarly, Sodium Lauryl Sulfate (SLS), identified in 5.55% of the samples, is a known mucosal irritant, linked to increased prevalence of aphthous ulcers.[106] Additionally, Titanium Dioxide (27.77%), frequently used as a whitening agent, has raised concerns regarding potential nanoparticle absorption and carcinogenicity in recent toxicological studies. Particularly concerning is the increasing evidence that nano-sized Titanium Dioxide particles may translocate across mucosal barriers and accumulate systemically, raising concerns over cumulative toxic effects in children.[107]

In addition to fluorosis, emerging research suggests that excessive fluoride exposure may have neurotoxic effects, particularly in developing children. Several epidemiological studies have reported an inverse relationship between high fluoride intake and cognitive function, raising concerns about fluoride's potential impact on neurodevelopment.[108] While the majority of fluoride toxicity research has focused on skeletal effects, the possible neurodevelopmental consequences warrant further investigation. This is particularly important for young children, as their developing nervous system may be more vulnerable to fluoride accumulation.[109] Current regulatory standards focus primarily on dental health outcomes, yet there is a need to incorporate neurotoxicological evaluations into fluoride safety assessments.

An alternative approach to fluoride-based caries prevention is the incorporation of biocompatible remineralization agents, such as hydroxyapatite, calcium phosphates, and bioactive glass.[110] While these compounds have been studied for their ability to promote enamel remineralization, their long-term efficacy compared to fluoride remains inconclusive. However, hydroxyapatite has demonstrated promising results in reducing demineralization, repairing early carious lesions, and providing an antimicrobial effect without systemic toxicity risks. For instance, randomized clinical trials have demonstrated that nano-hydroxyapatite toothpaste can achieve remineralization rates comparable to fluoride toothpaste in early enamel lesions, offering a potentially safer alternative for young children.[111] If fluoride toxicity concerns continue to grow, the development of fluoride-free yet equally effective remineralization strategies could redefine pediatric oral care standards. Further clinical research is needed to evaluate whether hydroxyapatite and other biomimetic alternatives can serve as a safer substitute for fluoride in children's oral hygiene products.

Several ingredients commonly found in children's fluoridated toothpastes, such as Sodium Benzoate and Titanium Dioxide, have been associated with potential cytotoxic or systemic effects. Additionally, although polyethylene glycol (PEG) compounds are generally

regarded as safe in cosmetic products, specific toxicological studies are limited, and further research is warranted to fully evaluate their long-term safety in pediatric oral care products.[44,45] Although some types of PEG (such as PEG/PPG-17/6, PEG-40, and PEG-60) have been reported to have low levels of toxicity. However, PEG products are generally considered safe for use in cosmetic and personal care products. Specific studies are needed for further evaluation.[78] These findings highlight the necessity for more rigorous safety evaluations of non-fluoride excipients used in children's toothpaste formulations.

Our study's strength lies in its comprehensive evaluation of the fluoride-containing children's toothpaste products available within the Turkish market, offering valuable baseline data in a region where limited national surveys exist. Nevertheless, limitations must be acknowledged. Firstly, we did not evaluate the purchasing patterns or consumer behaviors associated with these products. Thus, our observations regarding potential parental misconceptions about fluoride are inferential and should be interpreted cautiously. Secondly, detailed compositional analysis was restricted to fluoride-containing formulations, excluding fluoride-free alternatives, which may offer additional insights regarding excipient safety profiles.

Future research should prioritize multi-faceted approaches: integrating chemical analysis with consumer behavior studies, investigating parental knowledge and perceptions of fluoride, and evaluating the clinical efficacy of both fluoride-based and fluoride-free remineralization strategies. Additionally, there is a pressing need for comprehensive toxicological assessments of all non-fluoride excipients commonly used in pediatric toothpaste formulations to ensure their biocompatibility and long-term safety.

In conclusion, while fluoride remains the gold standard for caries prevention, balancing its proven efficacy with emerging toxicity concerns is critical. Regulatory bodies should not only enforce optimal fluoride concentrations but also demand transparency and safety evaluations for auxiliary ingredients in pediatric oral care products. A coordinated effort among clinicians, researchers, regulatory agencies, and the industry is necessary to develop safer, evidence-based pediatric toothpaste formulations that align with evolving public health priorities.

CONCLUSIONS

This study highlights critical concerns regarding fluoride exposure, ingredient safety, and market trends in pediatric toothpaste formulations. The limited availability of fluoride-containing children's toothpaste products in Turkey may indicate a potential disconnect between clinical recommendations and the marketing trends influencing parental choices. However, further research including purchasing data would be necessary to confirm this hypothesis. The dominance of fluoride-free formulations (80.44%), despite EAPD recommendations for 1000 ppm fluoride-containing toothpaste, raises concerns about the effectiveness of marketed oral care products in preventing early childhood caries (ECC).

Beyond fluoride accessibility, this study also sheds light on potential health risks associated with commonly used excipients in fluoridated toothpaste products. The presence of Sodium Benzoate (44.44%), a known cytotoxic agent, along with Sodium Lauryl Sulfate (5.55%), a well-documented mucosal irritant, underscores the need for enhanced regulatory oversight on ingredient safety. Additionally, Titanium Dioxide (27.77%), frequently used as a whitening agent, has been flagged for its potential toxicity and nanoparticle absorption concerns, highlighting the necessity for further toxicological evaluations.

While fluoride plays an essential role in cavity prevention, increasing research suggests that excessive fluoride intake, particularly through accidental ingestion in children, may lead to systemic toxicity, neurodevelopmental concerns, and fluorosis. These findings align with emerging epidemiological evidence pointing to potential cognitive and developmental risks associated with high fluoride exposure. Given these concerns, future research should focus on identifying safer remineralization alternatives, such as hydroxyapatite and calcium phosphate-based.

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