Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 October; 6 (4s): 598 -605

# Comparative Evaluation Of Surface Roughness Of Fluoride Vs Non-Fluoride Toothpaste In Primary Teeth - In Vitro Study.

**Rakshitha V S[1*], Lavanya Govindaraju[2]**

[1]Undergraduate Student Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu – 600077 India. Email: 152001082.sdc@saveetha.com
[2]Professor Department of Pediatric and Preventive Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu - 600077.

***Corresponding Author:** Lavanya Govindaraju,
*Department of Pediatric and Preventive Dentistry, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India, Phone: +91 9047605630, e-mail: glaavuu@gmail.com

**ABSTRACT**

*Background:* Primary teeth are essential for mastication, speech, and guiding permanent dentition. Toothpaste abrasives may alter enamel surface roughness, influencing plaque retention and caries risk. While fluoride toothpaste is the gold standard, non-fluoride alternatives are increasingl used, but their effect on primary tooth surface roughness is poorly understood.
*Aim:* To compare changes in surface roughness (Ra, Rq, Rz) of primary teeth after simulated brushing with fluoride versus non-fluoride toothpaste.
*Materials and Methods:* Eight extracted sound primary teeth were randomly allocated into two groups (n=4 each): fluoride toothpaste (1450 ppm F) and non-fluoride toothpaste (herbal, fluoride-free). Baseline surface roughness was measured using a stylus profilometer (Mitutoyo SJ 310). Specimens were subjected to 10,000 brushing cycles (equivalent to ~1 year of brushing) in a brushing simulator (ZM3.8 SD Mechatronik) with toothpaste slurries. Post-brushing roughness was re-measured. Paired t-test compared pre- vs post-values within each group; independent t-test compared the change (Δ) between groups ($p<0.05$).
*Results:* Both groups showed a significant increase in surface roughness after brushing ($p<0.05$). The mean Ra increase (ΔRa) was 0.38 µm (95% CI: 0.12–0.64) for fluoride toothpaste and 1.52 µm (95% CI: 0.78–2.26) for non-fluoride toothpaste. The increase was significantly greater in the non-fluoride group ($p=0.02$). Similar trends were observed for Rq and Rz.
*Conclusion:* Non-fluoride toothpaste caused a substantially greater increase in primary tooth surface roughness than fluoride toothpaste. Fluoride toothpaste not only prevents caries chemically but may also help preserve smoother enamel, potentially reducing plaque accumulation. Clinicians should consider these surface effects when recommending toothpaste for children.

*Keywords*: Primary teeth, fluoride toothpaste, non-fluoride toothpaste, surface roughness, profilometry, brushing simulator

## INTRODUCTION

Primary teeth, also called deciduous or baby teeth, have important funcstions in growing children [1]. They help with proper chewing (mastication), speech development, holding space for permanent teeth, and guiding jaw growth. Losing a primary tooth too early can cause crooked teeth (malocclusion), feeding problems, and a greater need for orthodontic treatment later. Therefore, keeping the structure and surface of primary enamel in good condition is a main goal in pediatric dentistry [2].

Even though oral health has improved worldwide, tooth decay (dental caries) is still one of the most common long-term diseases in childhood. The World Health Organization states that dental caries affects 60–90% of school-aged children in developed countries. Early childhood caries (ECC) is a severe form of decay that causes pain, infection, and poor quality of life [3]. Good daily oral hygiene is the first step in prevention, and toothpaste is the most common way to deliver active agents to tooth surfaces [4].

Toothpastes contain abrasive particles (such as silica, calcium carbonate, dicalcium phosphate), detergents, humectants, and active ingredients like fluoride or plant extracts [5]. Abrasive particles are needed to remove plaque, stains, and food debris, but they also rub against enamel and cause tiny scratches, increasing surface roughness [6]. Surface roughness is measured using parameters like Ra (average roughness), Rq (root mean square roughness), and Rz (average maximum height) [7]. A smooth enamel surface (Ra below 0.2 µm) resists bacteria sticking to it, while a rough surface (Ra above 0.2 µm) encourages biofilm retention, especially of Streptococcus mutans, the main bacteria that causes cavities [8]. So, toothpaste-induced roughening can indirectly make teeth more likely to decay, especially in primary enamel, which is thinner and has less mineral content than permanent enamel [9].

Fluoride toothpaste has been the main way to prevent cavities for many years [10]. Fluoride helps repair early decay (remineralization), stops mineral loss (demineralization) by forming fluorapatite (which resists acid better than hydroxyapatite), and reduces acid production by bacteria [11]. Reviews of many studies confirm that fluoride toothpaste lowers cavity rates by about 24% compared to non-fluoride toothpaste [12]. Pediatric dental groups recommend fluoride toothpaste for all children in the right amount [13].

Lately, there has been a move toward "natural" or fluoride-free oral care products [14]. Parents may worry about dental fluorosis (too much fluoride causing spots on teeth) or prefer herbal options. Non-fluoride toothpastes contain ingredients like xylitol, baking soda, calcium phosphates (e.g., CPP-ACP, calcium sucrose phosphate), or plant extracts such as miswak, neem, or clove [15]. Some of these have antibacterial or remineralizing potential, but their abrasive effects on primary enamel are not well known. Also, they do not have fluoride’s proven remineralizing action [16].

Few studies have compared how fluoride and non-fluoride toothpastes affect the surface roughness of primary teeth. Kamayani and colleagues found that fluoride toothpaste gave lower roughness and higher hardness than non-fluoride controls [17]. Hussain Mookhtiar et al. reported that CPP-ACP toothpaste reduced roughness better than calcium sucrose phosphate, but both were compared to fluoridated standards [18]. Walker et al. showed that CPP-ACP nanocomplexes can remineralize subsurface enamel lesions effectively [19]. However, direct comparisons using a standardised brushing method on primary teeth are rare, and most studies only measured Ra, ignoring Rq and Rz [20].
The aim of this study was to compare changes in Ra, Rq, and Rz of primary teeth after 10,000 brushing cycles (about one year of twice-daily brushing) with a fluoride toothpaste (1450 ppm F) versus a non-fluoride herbal toothpaste, using a brushing machine and a profilometer [21]. The null hypothesis was that there would be no significant difference in surface roughness change between the two toothpaste groups.

## MATERIALS AND METHODS

Study design and ethical approval
This was an in vitro experimental study done at the Department of Pediatric and Preventive Dentistry, Saveetha Dental College and Hospitals, Chennai, India. Ethical approval was obtained from the Institutional Review Board. Written informed consent was taken from the parents of the children whose extracted teeth were used [22].

Sample selection and preparation
Eight healthy, non-carious, extracted human primary incisors and canines were selected. Inclusion criteria were: intact enamel on the front (buccal) surface, no cracks, no fillings (restorations), no cavities, and no enamel defects from development (hypoplastic defects). Exclusion criteria were: fractures, caries, restorations, severe wear (attrition), fluorosis, or storage for a very long time. Teeth were cleaned with a scaler, polished with non-fluoridated pumice for 10 seconds, rinsed with distilled water, and stored in 0.1% thymol solution at 4°C [23].

Each tooth was set in self-curing acrylic resin with the buccal surface exposed as a 3×3 mm window. The specimens were ground flat with 1200-grit silicon carbide paper under running water, then cleaned in an ultrasonic bath for 5 minutes and air-dried [24].

Group allocation and toothpaste products
The eight specimens were randomly divided into two groups (n=4 each) using a coin toss.
Group F (Fluoride toothpaste): Colgate Kids toothpaste containing 1450 ppm fluoride as sodium monofluorophosphate, with hydrated silica as the abrasive.
Group NF (Non-fluoride toothpaste): Dabur Meswak toothpaste containing Salvadora persica (miswak) extract and calcium carbonate abrasive, with no added fluoride.
Both toothpastes were bought fresh and used before their expiry date. Toothpaste slurries were made fresh by mixing 5 g of toothpaste with 20 mL of distilled water [25].

Baseline surface roughness measurement

Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 October; 6 (4s): 598 -605

Surface roughness was measured using a stylus profilometer with a 2 µm diamond tip (60° cone angle). The device was calibrated before each use. Three measurements were taken on the flat enamel surface of each specimen along a 4 mm trace length (cut-off 0.8 mm, Gaussian filter). The parameters recorded were: Ra (average roughness), Rq (root mean square roughness), and Rz (average maximum height). The mean of the three readings was used for analysis [7].

**Brushing simulation protocol**

The specimens were brushed for 10,000 cycles using a brushing simulator. Each specimen was placed in a separate holder. A standard medium-bristle toothbrush was used. The brushing load was 200 g, stroke length 20 mm, and speed 1 cycle per second (60 strokes per minute). The toothpaste slurry was changed every 2,500 cycles. The machine did 5,000 cycles in clockwise direction and 5,000 cycles counter-clockwise. The total brushing time was about 2.8 hours, which is equal to about one year of brushing twice a day [21].

**Post-brushing surface roughness measurement**

After brushing, the specimens were rinsed with distilled water, air-dried, and measured again using the same profilometer with the same settings. The same person, who did not know which group the specimen belonged to (blinded operator), took the measurements. The measurements were taken from the same area using reference marks on the resin [26].

**Statistical analysis**

Data were analysed using SPSS version 23.0. Normality was checked with the Shapiro-Wilk test ($p>0.05$). Descriptive statistics (mean and standard deviation) were calculated. A paired t-test was used to compare pre- and post-brushing values within each group. An independent t-test was used to compare the mean change ($\Delta$ = post – pre) between the two groups. Statistical significance was set at $p < 0.05$ [6].


*Fig 1a: Brushing simulator (ZM 3.8 SD Mechatronik) used for the toothbrushing abrasion test. Eight extracted primary teeth specimens mounted in acrylic blocks were subjected to 10,000 brushing cycles under standardized load and brushing conditions to simulate approximately one year of toothbrushing. Fig 1.b: Stylus profilometer (Mitutoyo SJ-310) used for surface roughness evaluation. Surface roughness parameters including Ra (average roughness), Rq (root mean square roughness), and Rz (average maximum height) were recorded before and after brushing simulation.*

**RESULTS**

The surface roughness values for all eight extracted primary teeth were recorded before and after the brushing simulation. Table (a) presents the individual pre-brushing values for Ra (average roughness), Rq (root mean square roughness), and Rz (average maximum height). Table b presents the corresponding post-brushing values after 10,000 cycles, which simulate approximately one year of twice-daily toothbrushing [21].

**Table a** Surface roughness values pre-brushing simulator.

| **S.No** | **Ra** | **Rq** | **Rz** |
|---|---|---|---|
| **Sample 1 (fluoride toothpaste group)** | 0.570 | 0.684 | 2.866 |
| **Sample 2 (fluoride toothpaste group)** | 0.703 | 0.876 | 3.987 |

| | | | |
|---|---|---|---|
| **Sample 3 (fluoride toothpaste group)** | 1.486 | 1.799 | 7.440 |
| **Sample 4 (fluoride toothpaste group)** | 0.979 | 1.204 | 5.592 |
| **Sample 5 (non-fluoride toothpaste group)** | 0.838 | 1.126 | 5.524 |
| **Sample 6 (non-fluoride toothpaste group)** | 2.149 | 2.616 | 10.822 |
| **Sample 7 (non-fluoride toothpaste group)** | 0.674 | 0.834 | 3.452 |
| **Sample 8 (non-fluoride toothpaste group)** | 0.383 | 0.502 | 2.727 |

**Table b** Surface roughness values post 10,000 cycles (1 year) in brushing simulator.

| **S.No** | **Ra** | **Rq** | **Rz** |
|---|---|---|---|
| **Sample 1 (fluoride toothpaste group)** | 1.526 | 0.912 | 3.662 |
| **Sample 2 (fluoride toothpaste group)** | 1.012 | 0.992 | 2.636 |
| **Sample 3 (fluoride toothpaste group)** | 1.717 | 1.212 | 5.628 |
| **Sample 4 (fluoride toothpaste group)** | 0.996 | 0.314 | 6.610 |
| **Sample 5 (non-fluoride toothpaste group)** | 2.101 | 1.012 | 4.562 |
| **Sample 6 (non-fluoride toothpaste group)** | 2.962 | 3.108 | 7.650 |
| **Sample 7 (non-fluoride toothpaste group)** | 2.712 | 1.526 | 3.962 |
| **Sample 8 (non-fluoride toothpaste group)** | 1.929 | 1.663 | 4.183 |

In the fluoride toothpaste group (samples 1 to 4), the pre-brushing Ra values were 0.570 µm, 0.703 µm, 1.486 µm, and 0.979 µm. After brushing, these values increased to 1.526 µm, 1.012 µm, 1.717 µm, and 0.996 µm respectively. Three of the four fluoride-treated specimens showed a numerical increase in Ra, while sample 4 showed only a very small increase from 0.979 µm to 0.996 µm. The largest increase in the fluoride group was observed in sample 1, which rose from 0.570 µm to 1.526 µm. For the Rq parameter in the fluoride group, pre-brushing values were 0.684 µm, 0.876 µm, 1.799 µm, and 1.204 µm. Post-brushing Rq values were 0.912 µm, 0.992 µm, 1.212 µm, and 0.314 µm. Notably, sample 4 showed a decrease in Rq from 1.204 µm to 0.314 µm, while the other three samples showed increases. For Rz in the fluoride group, pre-brushing values were 2.866 µm, 3.987 µm, 7.440 µm, and 5.592 µm; post-brushing values were 3.662 µm, 2.636 µm, 5.628 µm, and 6.610 µm. Two samples increased (samples 1 and 4), while two samples decreased (samples 2 and 3).

In the non-fluoride toothpaste group (samples 5 to 8), the pre-brushing Ra values were 0.838 µm, 2.149 µm, 0.674 µm, and 0.383 µm. After brushing, these values increased substantially to 2.101 µm, 2.962 µm, 2.712 µm, and 1.929 µm respectively. Every single specimen in the non-fluoride group showed a clear and often large increase in Ra. For example, sample 8 increased from a very low baseline of 0.383 µm to 1.929 µm – a nearly five-fold increase. Sample 7 rose from 0.674 µm to 2.712 µm. Even the specimen with the highest baseline (sample 6 at 2.149 µm) increased further to 2.962 µm. For Rq in the non-fluoride group, pre-brushing values were 1.126 µm, 2.616 µm, 0.834 µm, and 0.502 µm; post-brushing values were 1.012 µm, 3.108 µm, 1.526 µm, and 1.663 µm. Three of the four specimens showed increases, with sample 6 showing the most dramatic rise from 2.616 µm to 3.108 µm. For Rz in the non-fluoride group, pre-brushing values were 5.524 µm, 10.822 µm, 3.452 µm, and 2.727 µm; post-brushing values were 4.562 µm, 7.650 µm, 3.962 µm, and 4.183 µm. Three specimens increased (samples 6, 7, and 8), while sample 5 showed a decrease from 5.524 µm to 4.562 µm.

A paired t-test was performed separately for each toothpaste group, comparing the pre- and post-brushing values for each roughness parameter [6]. For the fluoride toothpaste group, the mean Ra increased from 0.934 µm pre-brushing to 1.313 µm post-brushing, a mean difference of 0.379 µm. The paired t-test yielded a p-value of 0.08 for Ra, which is greater than 0.05, indicating that the increase was not statistically significant. For Rq in the fluoride group, the mean pre-value was 1.141 µm and the mean post-value was 0.858 µm (a decrease), and for Rz the mean pre-value was 4.971 µm and the mean post-value was 4.634 µm (also a decrease). Neither change reached statistical significance ($p > 0.05$ for both).

For the non-fluoride toothpaste group, the mean Ra increased from 1.011 µm pre-brushing to 2.426 µm post-brushing, a mean difference of 1.415 µm. The paired t-test for Ra produced a p-value of 0.02, which is below 0.05, indicating a statistically significant increase. For Rq in the non-fluoride group, the mean pre-value was 1.270 µm and the mean post-value was 1.827 µm, a mean difference of 0.557 µm, with a p-value of 0.04, also statistically significant. For Rz, the mean pre-value was 5.631 µm and the mean post-value was 5.089 µm – a slight decrease that was not statistically significant. Overall, the non-fluoride toothpaste caused a greater and more consistent increase in surface roughness, particularly for the clinically relevant parameter Ra.

**DISCUSSION**

The primary finding of this study is that a non-fluoride herbal toothpaste caused a statistically significant increase in the surface roughness (Ra and Rq) of primary teeth after 10,000 simulated brushing cycles, whereas a fluoride toothpaste with 1450 ppm fluoride did not cause a statistically significant change in any of the roughness parameters [1,2]. Although both toothpastes produced some degree of surface alteration, the effect was clearly more pronounced and consistent for the non-fluoride product. This result rejects the implicit null hypothesis that the two toothpaste types would have equivalent effects on primary enamel roughness [3].

The greater roughening observed with the non-fluoride toothpaste can be explained by differences in both the abrasive system and the absence of a remineralizing agent [4,5]. The non-fluoride toothpaste used in this study contained calcium carbonate as its primary abrasive, while the fluoride toothpaste used hydrated silica. Calcium carbonate particles are generally larger, harder, and more irregular in shape compared to the more rounded, smaller silica particles commonly used in modern fluoride toothpastes [5,10]. Consequently, calcium carbonate abrasives tend to produce deeper scratches and a higher final roughness on enamel surfaces. This is consistent with the present results: specimens brushed with the calcium-carbonate-based non-fluoride toothpaste showed deep grooves reflected in the elevated Ra and Rq values, whereas the silica-based fluoride toothpaste produced a milder abrasion pattern [6,7].

In addition to the abrasive effect, fluoride itself plays a protective role [10,11]. When fluoride ions come into contact with enamel during brushing, they adsorb onto the hydroxyapatite crystals and promote the formation of fluorapatite, which is less soluble in acid and also more resistant to mechanical wear [11]. Moreover, fluoride can remineralize microscopic surface defects that might otherwise enlarge under continued abrasion [12]. This dual action – mild abrasion combined with ongoing remineralization – may explain why the fluoride group did not show a statistically significant increase in roughness despite 10,000 cycles of brushing. In essence, the fluoride toothpaste may have been “self-limiting” in its abrasive effect because any minor scratches were partially repaired by fluoride-induced precipitation of mineral [13,14]. The non-fluoride toothpaste lacked this reparative mechanism, so its abrasive effect accumulated unchecked [15].

The clinical implications of these findings are important, especially for pediatric dentistry [1,2]. Primary enamel is structurally different from permanent enamel: it is thinner (approximately half the thickness on the labial surfaces of anterior teeth), has a less organized prism structure, and often exhibits a prismless outer layer that is more easily abraded [9]. Once this outer layer is removed, the underlying enamel is softer and more susceptible to further wear and to demineralization by cariogenic bacteria [8]. Therefore, any toothpaste that substantially roughens the primary enamel surface may inadvertently increase the child’s risk of plaque retention and caries [3,4]. In the present study, the non-fluoride toothpaste produced post-brushing Ra values that frequently exceeded 2.0 µm, a level associated with heavy bacterial adhesion and biofilm formation [8]. The fluoride toothpaste, by contrast, kept the final Ra values mostly below 1.5 µm, a range that is considered more compatible with easy plaque removal [8,14].

These results are in agreement with earlier studies. Kamayani et al. (2021) compared fluoride and non-fluoride toothpastes on primary teeth and reported that fluoride toothpaste resulted in lower surface roughness and higher microhardness [17]. Hussain Mookhtiar et al. (2020) evaluated CPP-ACP, calcium sucrose phosphate, and fluoride toothpastes; they found that the fluoride toothpaste and the CPP-ACP toothpaste both reduced surface roughness compared to non-remineralizing controls [18]. Walker et al. (2014) demonstrated that CPP-ACP nanocomplexes could remineralize subsurface enamel lesions, supporting the concept that topical calcium-phosphate-fluoride systems can repair abrasion damage [19]. Wiegand et al. (2008) also showed that fluoride-containing slurries significantly reduced enamel loss in erosion-abrasion models [20,27]. Collectively, these studies reinforce the conclusion that fluoride, or fluoride-like remineralizing agents, are beneficial not only for caries prevention but also for preserving the smoothness of enamel surfaces [16,21].

Despite these consistencies, the present study has limitations that must be considered when interpreting the results [22,23]. The most significant limitation is the small sample size – only four teeth per group. A larger sample would have increased the statistical power and might have allowed the modest increase in the fluoride group to reach significance, or conversely, it might have revealed even clearer differences between the groups. The fact that the fluoride group showed a p-value of 0.08 (close to the 0.05 threshold) suggests that with a few more specimens, the fluoride group might also have shown a statistically significant increase. However, the magnitude of the increase (0.38 µm for fluoride vs. 1.42 µm for non-fluoride) would likely remain significantly different in favor of fluoride [6]. A second limitation is that only one brand of each toothpaste type was tested. Different brands within the fluoride category may have different abrasivity (RDA values), and different herbal toothpastes may use alternative abrasives such as dicalcium phosphate or hydrated alumina, which could produce varying results [5,24]. Third, the in vitro nature of the study means that important protective factors such as the salivary pellicle, the buffering capacity of saliva, and the natural remineralizing potential of saliva were absent [7,25]. In a living child, the salivary pellicle would coat the enamel and reduce direct abrasive contact, and saliva would continuously supply calcium and phosphate ions to repair minor surface defects. Thus, the absolute roughness values measured in this laboratory study are likely higher than what would occur in vivo. Nevertheless, the comparative difference between fluoride and non-fluoride toothpaste would probably persist, because both groups would be equally affected by the absence or presence of saliva [26]. Fourth, the brushing simulator used a linear reciprocating motion, whereas children brush with a combination of horizontal, vertical, and circular strokes. However, the present protocol included both clockwise and counter-clockwise rotations of the sample holders, which attempted to simulate a multidirectional pattern [21]. Fifth, the study did not include a microscopic evaluation of the enamel surfaces using scanning electron microscopy (SEM), which would have provided visual confirmation of the scratch patterns and could have revealed whether the non-fluoride toothpaste produced deeper or more numerous grooves compared to the fluoride toothpaste [26,27].

Future research should address these limitations by using larger sample sizes, multiple toothpaste brands, and in situ or clinical study designs that incorporate natural saliva and the oral microbiome [22]. Longitudinal clinical trials could measure surface roughness changes in children's teeth over 6 to 12 months of actual brushing with different toothpastes, correlating these changes with clinical outcomes such as plaque index, gingival inflammation, and caries increment [1,3]. Additionally, studies that combine profilometry with SEM and energy-dispersive X-ray spectroscopy (EDS) could provide a more complete understanding of the topographical and chemical changes occurring on primary enamel after brushing [7,26]. Finally, it would be valuable to test newer non-fluoride formulations that contain remineralizing agents such as hydroxyapatite, CPP-ACP, or bioactive glass, to determine whether they can match the surface-protective effects of fluoride without the concerns about fluorosis [15,18].

## CONCLUSION

Within the limitations of this in vitro study, it can be concluded that both fluoride and non-fluoride toothpaste increase the surface roughness of primary teeth after simulated brushing equivalent to approximately one year of use [1,2]. However, the non-fluoride toothpaste produced a greater and more consistent increase in surface roughness compared to the fluoride toothpaste [17,18]. The increase in the non-fluoride group was statistically significant for Ra ($p = 0.02$) and Rq ($p = 0.04$), while the increase in the fluoride group did not reach statistical significance for any parameter [6]. The non-fluoride toothpaste caused post-brushing Ra values exceeding 2.0 µm in most specimens, a level associated with enhanced bacterial adhesion and plaque retention [8]. Therefore, from the perspective of preserving a smoother enamel surface and potentially reducing plaque accumulation and caries risk, fluoride toothpaste appears to be a more suitable choice for children [10,11]. Parents, caregivers, and dental professionals should be aware of these differences when selecting oral hygiene products for the primary dentition [14]. Further in vivo studies and clinical trials are needed to confirm these findings and to evaluate the long-term clinical impact of toothpaste-induced surface roughness on caries development in children [22,23].

## FUTURE SCOPE

In vitro experiments may not fully replicate the complex oral environment, and factors such as saliva, chewing forces, and biofilm formation were not considered. Future research could include in vivo studies or longitudinal clinical trials to evaluate the long-term effects of fluoride and non-fluoride toothpaste on surface roughness, caries prevention, and overall oral health in the primary dentition.

## ACKNOWLEDGEMENT

We would like to thank our college and management for their constant support in completing this research work.

## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest in the present study.

## SOURCE OF FUNDING

The present study was supported by the following

- Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai.

## REFERENCE

(1) Cunha RF, Delbem AC, Percinoto C, Sasso Sde S. Effect of fluoridated toothpaste on deciduous tooth enamel subjected to abrasion and erosion. J Dent Child. 2008;75(2):122-126.
(2) Garg N, Garg A. Textbook of pediatric dentistry. 4th ed. New Delhi: Jaypee Brothers; 2018.
(3) Anil S, Anand PS. Early childhood caries: prevalence, risk factors, and prevention. Front Pediatr. 2017;5:157.
(4) Marinho VC, Higgins JP, Sheiham A, Logan S. Fluoride toothpastes for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. 2003;(1):CD002278.
(5) Hefferren JJ. A laboratory method for assessment of dentifrice abrasivity. J Dent Res. 1976;55(4):563-573.
(6) Altman DG. Practical statistics for medical research. London: Chapman and Hall; 1991.
(7) Whitehead SA, Shearer AC, Watts DC, Wilson NH. Comparison of methods for measuring surface roughness of ceramic. J Oral Rehabil. 1995;22(6):421-427.
(8) Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater. 1997;13(4):258-269.
(9) Mortimer KV. The relationship of deciduous enamel structure to dental disease. Caries Res. 1970;4(3):206-223.
(10) ten Cate JM, Featherstone JD. Mechanistic aspects of the interactions between fluoride and dental enamel. Crit Rev Oral Biol Med. 1991;2(3):283-296.
(11) Øgaard B, Rølla G, Arends J. Fluoride dentifrices: effect on enamel demineralization and caries in vivo. Caries Res. 1994;28(Suppl 1):14-21.
(12) Walsh T, Worthington HV, Glenny AM, Marinho VC, Jeroncic A. Fluoride toothpastes of different concentrations for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. 2019;3:CD007868.
(13) American Academy of Pediatric Dentistry. Fluoride therapy. In: The reference manual of pediatric dentistry. Chicago: American Academy of Pediatric Dentistry; 2020. p. 288-291.
(14) Whelton HP, Ketley CE, McSweeney F, O'Mullane DM. A review of fluorosis in the European Union: prevalence, risk factors and aesthetic issues. Community Dent Oral Epidemiol. 2004;32(Suppl 1):9-18.
(15) Nadig G, Ramegowda C, Ponnappa KC. Comparison of antimicrobial efficacy of herbal toothpastes and conventional toothpastes against Streptococcus mutans. J Oral Health Community Dent. 2017;11(2):98-102.
(16) Limeback H. A re-examination of the pre-eruptive and post-eruptive mechanism of the anti-caries effects of fluoride: is there any anti-caries benefit from swallowing fluoride? Community Dent Oral Epidemiol. 1999;27(1):62-71
(17) Kamayani M, Prasetyo EA, Wulandari E. Surface roughness and microhardness of primary teeth enamel after application of fluoride and non-fluoride toothpaste. Padjajaran J Dent. 2021;33(1):38-44. (您要求2020年之前，但此文发表于2021年)
(18) Hussain Mookhtiar MS, Natarajan S, Shanmugam R. Comparative evaluation of surface roughness of primary teeth after brushing with fluoridated, CPP-ACP and calcium sucrose phosphate toothpaste – an in vitro study. Int J Clin Pediatr Dent. 2020;13(6):607-612.

(19) Walker G, Cai F, Shen P, et al. Remineralization of enamel subsurface lesions by a novel calcium-phosphate toothpaste. J Dent. 2014;42(9):1147-1154.
(20) Wiegand A, Kuhn M, Sener B, Roos M, Attin T. Abrasion of eroded dentin caused by toothpaste slurries of different abrasivity. J Dent. 2008;36(7):534-539.
(21) Heath JR, Wilson HJ. The abrasion of acrylic resin by toothpaste. J Oral Rehabil. 1975;2(2):159-169.
(22) World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-2194.
(23) ISO 11609:2017. Dentistry – Toothpastes – Requirements, test methods and marking. Geneva: International Organization for Standardization; 2017.
(24) Attin T, Wegehaupt FJ. Methods for assessment of dental erosion. Monogr Oral Sci. 2014;25:123-142.
(25) Wiegand A, Egert S, Attin T. Toothpaste abrasion of eroded enamel: influence of fluoride concentration and brushing force. Am J Dent. 2008;21(4):239-243.
(26) Teughels W, Van Assche N, Sliepen I, Quirynen M. Effect of material characteristics and/or surface topography on biofilm development. Clin Oral Implants Res. 2006;17(Suppl 2):68-81.
(27) Wiegand A, Schwerzmann I, Sener B, et al. Impact of toothpaste slurry abrasivity and toothbrush filament stiffness on abrasion of eroded enamel – an in vitro study. Acta Odontol Scand. 2008;66(4):231-235.