ORIGINAL RESEARCH

Comparative Evaluation of Abrasiveness among Three Dentifrices: An *In Vitro* Study

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Abstract

Aim: A lot of herbal and medicated toothpastes having natural and antisensitivity properties are creating niches for themselves in the market. However, toothpaste containing high content of abrasives can be harmful to the teeth. The present *in vitro* study was conducted to assess the abrasiveness of three commercially available dentifrices on human-extracted anterior teeth on sound and demineralized enamel.

Materials and methods: A total of 42 freshly extracted teeth were mounted on acrylic resin and randomly divided into three groups (group I, Colgate; II, Glister; and III, Dant Kanti). Each group consisted of one test tooth (partially) and one control tooth (completely) covered with nail varnish. The study had two phases. Phase 1—baseline average roughness (Ra) value was assessed with a profilometer of all the samples. Phase 2—further, teeth were immersed in the demineralizing solution for 4 days to allow the formation of an artificial carious lesion. Tooth brushing was performed by a customized automated toothbrushing model on all the teeth for 28 days. Ra value was again evaluated with Profilometer.

Result: Data were analyzed, and a statistically significant result was observed with demineralized teeth in all three groups (p = 0.005). The intragroup comparison showed a significant difference with demineralized teeth of Colgate and Dant Kanti, (p =0.018) and (p =0.027), respectively. However, there was no significant difference in demineralized teeth of glister and sound teeth of all three groups.

Conclusion: Glister was found to be the least abrasive of all three toothpastes, followed by Dant Kanti and Colgate.

Clinical relevance: The particle size of the ingredients used in manufacturing toothpaste can lead to abrasion of the teeth.

This, in combination with the hard bristles, can cause more harm to the teeth than good. The current study has compared the abrasive potential of three commercially available kinds of toothpaste. Hence daily use of these commercially available dental products should be used cautiously.

Keywords: Abrasivity, Dentifrices, Human enamel.

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Introduction

The insoluble ingredients known as abrasives are added to dentifrices to help with the actual removal of stains, plaque, and food particles. The two abrasives that are most frequently used are silica and calcium carbonate.[1] Although a high-quality dentifrice contains silica,[2,3] its use raises the price; thus, low-quality calcium carbonate and iron oxide are utilized to reduce the price.[1]

As per the report seen in the previous study, adequate results while toothbrushing could be achieved if there is a certain amount of abrasives present in the toothpaste.[4,5] There are various kinds of toothpaste available in the market that are highly abrasive and could result in irreversible damage to tooth enamel. The teeth may become sensitive when tooth enamel is worn away. There are some abrasives (alumina, calcium pyrophosphate, and hydrated silica) considered to be inactive abrasives in toothpaste;[6] however, Sodium bicarbonate is the most multifunctional of all abrasives used in dentifrices.[7]

On the other hand, several investigations have shown that toothpaste has little role in the mechanical eradication of plaque.[8] Also, as per the previously reported studies, consistent use of toothpaste results in gingival recession and tooth wear.[9,10] Dental professionals must make sure they are well informed about the effectiveness of these products as these dentifrices gain more and more popularity.[11]

Hence, this study was designed to compare three different kinds of toothpaste available in the Indian market, which are Colgate, Dant Kanti, and Glister, for their abrasiveness.

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Materials and Methods

An *in vitro* study was designed to test the effect of three commercially available kinds of toothpaste to assess their abrasiveness. The study was done from January–April 2018 in the Department of Public Health Dentistry, VK Institute of Dental Sciences, KLE Academy of Higher Education and Research (Deemed to be University), Belagavi, Karnataka, India. The study was ethically approved.

According to Cohen's d formula, the estimated sample size was 14 in each group, the p-value fixed at 0.05, that is, $\alpha = 0.05$ with power = 80% and the assumed effect size was at 0.8. Hence a total number of 42 extracted teeth were taken.[12]

A pilot study was conducted prior to the main study to know the feasibility of the study on six extracted teeth. Extracted macroscopically caries-free human permanent anterior teeth were included in the study, whereas teeth having intrinsic stains, dental caries, gross surface defects like pits and cracks (on the buccal, lingual, and proximal surfaces), and gross hypoplasia were excluded.

A total of 42 freshly extracted human anterior teeth were divided into a test group (partly) and a control group (completely). Acid-resistant nail varnish was applied over (Fig. 1) to produce an artificial subsurface lesion only in the test group, which was left uncovered for the reference area.

Study Procedure

Construction of Customized Brushing Model

Under the direction of experts, a brushing model that could produce force unidirectionally in a uniform manner was created. It comprises a motor (Adraxx 100 RPM and 12-volt DC geared motor), a handle, and a wooden base (Fig. 2). The apparatus had a screw and wedge design that facilitates easy replacement of one type of toothbrush with another.

Preparation of Enamel Specimen

Freshly extracted 42 teeth were fixed on a base of acrylic (Meliodent Cold; Heraeus Kulzer, Hanau, Germany). All the teeth were cleaned with an ultrasonic scaler tip for any stains, food debris, and calculus deposits adhering to the specimens. Subsequently, the enamel specimen was grind using 6000 grit water-cooled carborundum discs and polished using diamond spray to flatten the enamel surfaces by removing approximately 150 µm of the outer enamel. This method was continued to prepare the opposite surface of the specimen using (600 grit), parallel to the established plane.

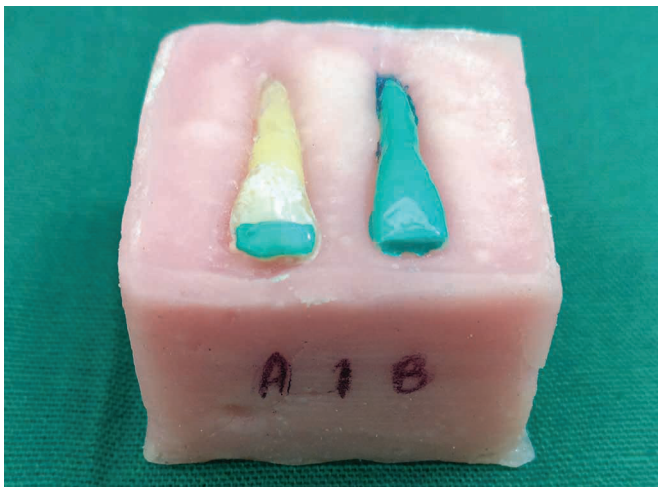

Fig. 1: Test and control tooth

Fig. 2: Customized automated toothbrushing model

All the teeth were divided into a test group and a control group, which were further grouped as groups I, II, and III. Each test and control group consisted of 14 mounted specimens. Groups I, II, and III specimens were brushed using Colgate, Glister, and Dant Kanti toothpaste, respectively.

Formation of Artificial Caries Lesions

Demineralization was performed on all 42 teeth using 3 L of demineralizing solution (containing 2.2 mM $CaCl_2$, 2.2 mM NaH_2PO_4, 0.5 M CH_3COOH, pH was adjusted to 4.4 with 1 M KOH) to produce artificial carious lesion for the period of 4 days. Once the lesion depth reached 60–100 µm,[13] demineralizations were finished, and using a cotton pellet with acetone nail varnish was removed.

This procedure resulted in a sample, each containing a pair of test and control groups from the same block (group I: artificial subsurface lesions; group II; sound enamel).

Toothbrush Abrasion

Dentifrices slurry was prepared with three different kinds of toothpaste. An artificial salivary substitute was taken, and to prepare abrasive media, 5 gm of three different toothpaste were mixed with 15 mL of artificial salivary substitute using an electromagnetic stirrer at 100 rpm until a homogenous suspension resulted (ratio 1:3) at KLE's Dr Prabhakar Kore BSRC, Belagavi, Karnataka.

Brushing abrasion was performed with a customized automated toothbrushing machine along with abrasive media in the Department of Public Health Dentistry, KLE VK IDS, Belagavi, Karnataka, for 1 month. Colgate Toothbrush (head: 275 g, Medium) was attached to the machine's rod, and the toothbrush was enabled for defined contact pressure. Two aluminum vials with a central indentation (30 mm in diameter) were equipped in the machine for inserting the samples.

The sample containing the two specimens was centered on the bristle head so that it would brush with the sample along its entire length. The brush was moved along the longitudinal axis of the tooth, and each sample was subjected to 16,000 brushing strokes at a rate of 200 strokes/minute. Total brushing time 80 minutes for each specimen for 1 month.

The sample was covered with 15 mL abrasive slurry using a measuring tool. After 5,000 and 10,000 brush strokes, the toothpaste/artificial saliva mixture was renewed twice for each sample. Also, the toothbrush was replaced after brushing each tooth.

Profilometric Analysis

Baseline evaluation of Ra (average surface roughness) was done at KLS Gogte Institute of Technology, Belagavi, Karnataka. Profilometer (Taylor Hobson, Surtronic S128) was calibrated as per the manufacturer's instructions. After all the specimens were brushed, all specimens of the three groups were again taken to the laboratory, and Ra values were recorded.

The average surface loss was calculated, which gives the Ra value (average surface roughness), and the variation in the Ra value before and after brushing the teeth gives a surrogate measure for determining surface abrasion. After computing the differences

between the mean values of the profilometric measurements taken before and after brushing, the results were compared.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) for Windows, Version 21; SPSS Inc. (Chicago, Illinois, United States of America). Descriptive statistics were used to calculate frequencies, mean values, and standard deviation. The intergroup and intragroup comparison was done using Kruskal–Wallis and Wilcoxon signed-rank tests, respectively.

Results

Baseline values of the test and control group are shown in Table 1, whereas Table 2 shows the values after toothbrushing.

Table 1: Baseline values for brushing abrasion; roughness [µm; mean ± standard deviation (SD)] of test and control group among three kinds of toothpaste

	Phase-1 (Baseline value of all the samples)					
	Groups	*N*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Colgate	Abrasivity at baseline (test group)	7	0.75	0.28	0.40	1.10
	Abrasivity at baseline (control group)	7	0.72	0.28	0.40	1.10
Glister	Abrasivity at baseline (test group)	7	0.70	0.37	0.30	1.50
	Abrasivity at baseline (control group)	7	0.95	0.82	0.40	2.80
Dant Kanti	Abrasivity at baseline (test group)	7	0.64	0.16	0.50	0.90
	Abrasivity at baseline (control group)	7	0.61	0.25	0.40	1.10

Table 2: Values for brushing abrasion (µm; mean ± SD) of test and control group among three kinds of toothpaste after toothbrushing

	Phase-2 (after toothbrushing)					
	Groups	*N*	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Colgate	Abrasivity after brushing (test group)	7	3.14	1.38	0.70	4.60
	Abrasivity after brushing (control group)	7	0.71	0.30	0.40	1.20
Glister	Abrasivity after brushing (test group)	7	0.68	0.29	0.40	1.10
	Abrasivity after brushing (control group)	7	0.67	0.30	0.40	1.10
Dant Kanti	Abrasivity after brushing (test group)	7	1.78	1.12	0.50	3.60
	Abrasivity after brushing (control group)	7	0.88	0.65	0.40	2.30

Table 3: Intergroup comparison of abrasivity (roughness) among three kinds of toothpaste

	Groups	*N*	*Mean rank*	χ^2	*Degree of freedom*	*p-value*
Abrasivity at baseline (test group)	I (Colgate)	7	12.36	0.543	2	0.762
	II (Glister)	7	10.57			
	III (Dant Kanti)	7	10.07			
	Total	21				
Abrasivity at baseline (control group)	I (Colgate)	7	11.79	0.914	2	0.633
	II (Glister)	7	12.00			
	III (Dant Kanti)	7	9.21			
	Total	21				
Abrasivity after brushing (test group)	I (Colgate)	7	16.21	10.71	2	0.005*
	II (Glister)	7	5.43			
	III (Dant Kanti)	7	11.36			
	Total	21				
Abrasivity after brushing (control group)	I (Colgate)	7	11.00	0.276	2	0.871
	II (Glister)	7	10.14			
	III (Dant Kanti)	7	11.86			
	Total	21				
Pairwise comparison between three groups for abrasivity (roughness)	Comparison of groups	1–2		10.786		0.001*
		1–3		4.857		0.141
		2–3		–5.929		0.072

*p- value of <0.05: statistically significant
The test applied: Kruskal–Wallis test
χ^2: Chi-square coefficient

An intergroup comparison of three toothpastes for abrasive using the Kruskal–Wallis test is shown in Table 3. When three groups were compared for abrasive at baseline (test group) and (control group), there was no statistically significant result ($p = 0.762$) and ($p = 0.633$), respectively. Whereas, after toothbrushing, a statistically significant result from the test group was ($X^2 = 10.715$, $p = 0.005$) seen.

As Kruskal–Wallis was found to be significant, a *post hoc* test (pairwise comparison) was performed, which showed Gp1 and Gp2 as highly significant results with *p*-value (0.001).

An intragroup comparison was done for abrasivity at baseline and abrasivity after brushing for the test group of Colgate and Dant Kanti using the Wilcoxon signed-rank test; the *p*-value was found to be statistically significant (0.018) and (0.027), respectively. Similarly, abrasivity at baseline and abrasivity after brushing for the test group of Glister and the control group of Colgate, Glister, and Dant Kanti did not differ significantly with *p*-values (0.670), (0.892), (0.833), and (0.684), respectively (Table 4).

Discussion

The present study compared the abrasivity of three commercially available kinds of toothpaste, namely Colgate, Glister, and Dant Kanti, in an *in vitro* model using 42 extracted human anterior teeth. The abrasivity among the three pastes differed significantly, and Glister was the least abrasive of all, followed by Dant Kanti.

The baseline Ra value of all 42 teeth was assessed using a profilometer, which was followed by the formation of an artificial caries lesion. According to studies, a variety of factors affect toothbrush wear. These factors include the way you brush, how hard you brush, how long you brush, how often you brush, and the kind of toothbrush you use, depending on the stiffness of the bristles.[14] Soft, medium, and hard toothbrushes are available in the market according to bristle stiffness. In the present study, a medium toothbrush is used as this is the most commonly used brush by the Indian population.[15]

The samples were immersed in a demineralizing solution for 4 days, followed by toothbrushing using dentifrice slurry and a customized automated toothbrushing machine for 2 minutes two times a day for 28 days (total 112 minutes, i.e., 1.86 hours.). The force was maintained at 180 ± 20 gm; similarly, as Fraleigh et al.[16] The above force limit was chosen due to being comparable to the usual force that people use to brush their teeth by hand, as was done in the research by Kumar et al.,[14] the Dontrix gauge was used to adjust the tension on a periodic basis.

There was no significant difference found for abrasivity at baseline in both the test and control groups. However, after toothbrushing was performed, the test group showed a significant result. Glister was the least abrasive of all, followed by Dant Kanti. We did a thorough review of the literature but failed to retrieve similar studies. Hence comparison with other studies was not possible. Because Glister includes sylodent, a polishing

Table 4: Intragroup comparison for abrasivity (roughness) among three toothpastes

Groups			*N*	*Mean rank*	*Sum of ranks*	*z*	*p-value*
Colgate	Abrasivity after brushing–Abrasivity at baseline (test group)	Negative ranks	0	0.00	0.00	−2.366	0.018*
		Positive ranks	7	4.00	28.00		
		Ties	0				
		Total	7				
	Abrasivity after brushing–Abrasivity at baseline (control group)	Negative ranks	3	2.67	8.00	−0.135	0.892
		Positive ranks	2	3.50	7.00		
		Ties	2				
		Total	7				
Glister	Abrasivity after brushing–Abrasivity at baseline (test group)	Negative ranks	5	3.30	16.50	−0.426	0.670
		Positive ranks	2	5.75	11.50		
		Ties	0				
		Total	7				
	Abrasivity after brushing–Abrasivity at baseline (control group)	Negative ranks	3	3.83	11.50	−0.210	0.833
		Positive ranks	3	3.17	9.50		
		Ties	1				
		Total	7				
Dant Kanti	Abrasivity after brushing—abrasivity at baseline (test group)	Negative ranks	0	0.00	0.00	−2.207	0.02*
		Positive ranks	6	3.50	21.00		
		Ties	1				
		Total	7				
	Abrasivity after brushing–Abrasivity at baseline (control group)	Negative ranks	3	2.00	6.00	−0.406	0.684
		Positive ranks	2	4.50	9.00		
		Ties	2				
		Total	7				

* *p*-value of <0.05: statistically significant
Test applied: Wilcoxon signed-ranks test

agent that effectively polishes and whitens teeth without using too much abrasion, it may be the least abrasive option.[17] The minimal abrasivity of Glister can be attributed to the presence of sylodent, which is absent in other toothpaste used in the present study.

A pairwise comparison between the three kinds of toothpaste showed that Colgate had significant differences, thus, establishing Colgate as the most abrasive among all three. This could be due to the fact that the Colgate contains hydrated silica, which is more abrasive than calcium carbonate, which is present in Dant Kanti.[18] Though hydrated silica is also present in Glister, it is an inactive ingredient, and hence Sylodent is added as a polishing agent. A similar result was reported by Aggarwal et al.[19] in which Himalaya HiOra and Patanjali Dant Kanti toothpaste were found to be less abrasive on tooth surfaces compared to Colgate and Dabur Red. Another study reported that SHY-NM was the least abrasive in comparison to GC Tooth Mousse Plus, Remin Pro, and Colgate on demineralized human teeth.[20]

In addition to other polishing agents, toothpaste contains a wide range of the abrasive system, including hydrated silica, alumina, dicalcium phosphate dihydrate, insoluble metaphosphate, and calcium carbonate toothpaste.[21] The most frequently employed are silica derivatives,[22] of which are included to guarantee the elimination of bacterial plaque and prevent the accumulation of other superficial deposits on tooth structure.[18] How abrasive toothpaste depends on a variety of factors, including the hardness of the dentin compared to the abrasive, the material and microstructure of the abrasives, and the concentration, size, and form of the abrasives.[23]

However, in the present study, Colgate showed in comparison to Dant Kanti and Glister. Surprisingly both Colgate and Glister have similar relative dentine abrasivity (RDA) values of 70. Colgate presented approximately similar RDA as Glister with a value of 70. The RDA value of Dant Kanti is not available in the literature; however, calcium carbonate is present as a base material (38–42%) along with hydrated silica.

When intragroup comparison was done in the Colgate group with respect to abrasivity, a significant difference was seen in the test group, as Colgate has hydrated silica as an abrasive agent. A significant abrasive effect was seen in the enamel sample. A similar result was reported by Aggarwal et al.[19] This is explained by the fact that there are mainly two types of abrasives found in dentifrice; calcium carbonate and hydrated silica; out of these two, hydrated silica was found to be more abrasive, which is present in Colgate Total toothpaste.[18]

Similarly, abrasivity was assessed for Glister; we failed to get any significant difference between baseline abrasive value and postbrushing abrasive value. This shows that Glister is the least abrasive toothpaste, and it could be attributed to the fact that Sylodent is a polishing agent which effectively polishes and whitens teeth without excessive abrasion. However, we could not compare our result with another study as the present study is the first of its kind where Glister toothpaste has been assessed.

Abrasivity assessment for Dant Kanti showed a significant difference at baseline and postbrushing, which was similar to the study done by Aggarwal et al.[19] Ideally, a toothpaste should have 10–40% of the abrasive agent,[24] but in Dant Kanti, calcium carbonate, which is an abrasive, is used as a base material, and hence the total composition of abrasive is in the range of 41–47%. Thus, this may have led to a more abrasive value postbrushing.

Conclusion

Reduced abrasion can be observed when Glister is applied to sound enamel as well as when applied to the enamel with lesions. Based on the present study, abrasivity was found least in Glister, followed by Dant Kanti and Colgate.

Clinical Relevance

The particle size of the ingredients used in manufacturing toothpaste can lead to abrasion of the teeth.

This, in combination with the hard bristles, can cause more harm to the teeth than good. The current study has compared the abrasive potential of three commercially available kinds of toothpaste. Hence daily use of these commercially available dental products should be used cautiously.

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