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Surface Roughness of Bulk Fill Composite after Simulated Toothbrushing with Different Dentifrices

Ahmed Mohamed Elmarakby[1,2]*, Mahmoud Darwish[3,4], Yasser R Souror[5,6], Ahmed Waly[5,7]

[1]Department of Restorative Dental Sciences, Al-Farabi College for Dentistry and Nursing, Riyadh, KSA; [2]Department of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Assiut, Egypt; [3]Department of Prosthetic Dental Sciences, Al-Farabi College for Dentistry and Nursing, Riyadh, Saudi Arabia; [4]Department of Prosthodontics, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt; [5]Department of Pediatric Dentistry and Dental Public Health, Faculty of Dentistry, Al-Azhar University, Assiute. Egypt; [6]Department of Pediatric Dentistry, Batterjee Medical College, Jeddah, KSA; [7]Department of Pediatric Dentistry, AlFarabi Dental College, Jeddah, Saudi Arabia

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***Correspondence:** Ahmed Mohamed Elmarakby, Assistant Professor, Department of Restorative Dental Sciences, Al-Farabi College for Dentistry and Nursing, Riyadh, Kingdom of Saudi Arabia. Lecturer, Department of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Assiut, Egypt. Mobile: +966506676440. E-mail: drahmedmarakby@gmail.com
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Abstract

AIM: The aim of the current *in vitro* study was to evaluate the changes in surface roughness of bulk fill composites after simulated toothbrushing with different dentifrices.

MATERIALS AND METHODS: Three types of bulk fill resin composites were used in this study; 27 specimens of each composite resin were randomly divided into three main groups (n = 9). Each main group was further subdivided into three subgroups (n = 3). Each group was subjected to simulated toothbrushing with three different dentifrices. One-way analysis of variance was used to evaluate the effect of brushing using dentifrices on the surface roughness of each type of composite resin, followed by Tukey's test at a significance level of $p \leq 0.5\%$.

RESULTS: Results revealed that different effects on composite surface roughness were detected after simulating toothbrushing with different dentifrices. Lacalut toothpaste abrades more with Filtek Bulk Fill, Tetric N-Ceram then Bulk Fill SDR. Crest 3D toothpaste abrades more with Tetric N-Ceram, Bulk Fill SDR then Filtek Bulk Fill. BlanX toothpaste abrades more with Tetric N-Ceram, Bulk Fill SDR then Filtek Bulk Fill.

CONCLUSION: Chemical composition of both resin composites and dentifrices plays an important role in influencing the degree of surface roughness of bulk fill composite resin restorations.

Introduction

The drawbacks of amalgams, in particular the lack of esthetics and presence of mercury have largely contributed to the popularity and increased use of resin-based composites (RBCs) for tooth restorations [1]. The RBCs have undergone tremendous research and development in the last 40 years to improve their performance, mechanical properties, and clinical handling [2]. These developments have primarily focused on improving the mechanical properties such as hardness, compressive strength, flexural strength, fracture toughness, and reducing polymerization shrinkage [3]. Bulk-fill composite resin is among the recent development in dental composites. These types of resin composite can be placed in a 4 mm thick bulk in the cavities and cured in one step instead of the current incremental fill technique where the increments of 2 mm is placed and cured [4]. Bulk-fill composite seems to improve the bad effect of the polymerization shrinkage, improve the cavity adaptation, and degree of conversion (DC %). It was also reported that bulk fill composites have superior physical and mechanical properties to resist high masticatory forces in oral cavity [5], [6]. Many studies have focused on the mechanical properties of the bulk-fill composites [4], [6], [7], [8] and there were little literatures focused on the behavior of these composites when subjected to tooth brush abrasion. Like enamel and dentin [9], restorative materials are also subjected to wear especially in the posterior occlusal surfaces. The degree of wear depends on the type of restorative material [8], [9]. The wear and abrasion of the restorative materials in the oral environment can be a result of different factors. These include direct contact between the tooth and the restorations during mastication, oral habits, toothbrushing with abrasive particles, and also due to chemicals in the dietary form [10]. The wear and abrasion can lead to an adverse effect on the mechanical properties of the materials and also leads to an increased surface

roughness [11]. The surface roughness may increase the coefficient of friction and the rate of wear [12]. Rough surface can also predispose for accumulation of dental biofilms, residues, and stains that may lead to gingival irritation, risk of secondary caries, diminishing the gloss of the restoration, and giving rise to discoloration and/or surface degradation [13], [14]. Despite the fact that toothbrushing plays an important role in oral hygiene, their ongoing action might damage the surface of resin composite restoration, making it rougher and consequently prone to staining, plaque accumulations, soft tissue inflammation, and recurrent caries [15], [16]. The amount of wear caused by toothbrushing depends mainly on toothbrushing habits, type of the tooth brush (hard, medium, or soft), and the dentifrice abrasive material used [17]. The toothbrushing abrasion that causing changes in surface conditions of restorative materials in any experimental situations can be helpful in predicting the clinical behavior of such materials [18]. The wear and surface roughness may also have a negative impact on the longevity of the restoration in the oral environment. The surface roughness of the composite is usually dictated by size, hardness and quantity of particles load which influence the mechanical properties of composites [19]. Dentifrices have different components such as detergents, fluoride, therapeutic ingredients, flavors, and abrasives. Among the abrasives, the most common are calcium carbonate and silica [20]. These abrasives have an important role in cleaning teeth, removing bacteria and stains from the tooth surface. However, the best dentifrices material should promote optimal tooth surface cleaning with minimal abrasive action [21]. Dentifrices with high amounts of abrasives can damage hard tissues, soft tissues, and restorations causing gingival recession, cervical abrasion, dentin hypersensitivity, and increased surface roughness of restorative materials [22], [23]. Some studies have been conducted to evaluate the surface roughness of composite resins caused by the abrasivity of some dentifrices. Amaral *et al*. [24] evaluated the action of abrasive dentifrices on esthetic restorative materials after simulated toothbrushing cycles. They found a significant difference between the abrasivity of dentifrices, but not among the composite resins. The dentifrices that used silica and carbonate were less abrasive compared to the ones containing bicarbonate. Some studies [25], [26] have shown that the surface roughness of composite resins has a direct influence on susceptibility to staining and need for restoration replacement. Others have reported no correlation between surface roughness and staining susceptibility [6], [27]. Hence, it becomes necessary to study the effect of toothbrushing on composite wear and roughness. The aim of the current *in vitro* study was to evaluate the changes in surface roughness of bulk fill composites after simulated toothbrushing with different dentifrices.

Materials and Methods

Before starting this *in vitro* study, the ethical approval was obtained from the Scientific Research Unit of Al-Farabi College for Dentistry and Nursing. The research proposal was approved by Institutional Review Board (IRB) at Al-Farabi College for Dentistry and Nursing in Riyadh, Saudi Arabia under no. (IRB No.: Alf. dent-2020023).

Selection of composite resin

Three types of resin composites were used in this *in vitro* study. Selection criteria for the composite brands include that they could be of bulk fill category with same curing time and same depth of cure.

1. The Bulk Fill SDR Posterior Bulk Fill Flowable Based composite (Dentsply Caulk 38 West Clarke Avenue Milford, DE 19963, USA).
2. Tetric N-Ceram Bulk Fill (Ivoclar Vivadent AG Bendererstrasse 2. FL-9494 Schaan Principality of Liechtenstein).
3. Filtek Bulk Fill Posterior Restorative (3M, ESPE, Elipar, Filtek Scotchbond. Canada).

The specifications of each composite resin brand are described in Table 1.

The composite resin specimens were made using a silicone matrix with orifices of 5 mm in diameter and height. The matrix was positioned on a glass plate and filled with composite resin. A polyester strip was then placed on the composite resin followed by a glass plate to obtain a flat surface. The composite resin was then light cured with the light emitting diode unit Radii-cal (SDI, Australia) for 20 s at a distance of 1 mm from the surface of the specimen. Toothbrushing with dentifrices was applied on the composite resin surface that was in contact with the polyester strip. Twenty-seven specimens

Table 1: Specifications and manufacturers of bulk fill resin-based composites

Composite resin	Composition	Manufacturer
SDR Posterior Bulk Fill Flowable Base	• Barium-alumino-fluoro-borosilicate glass • Strontium alumino-fluoro-silicate glass • Modified urethane dimethacrylate resin • Ethoxylated Bisphenol A dimethacrylate (EBPADMA) • Triethyleneglycol dimethacrylate (TEGDMA) • Camphorquinone (CQ) Photoinitiator • Photoaccelerator • Butylated hydroxy	Dentsply Caulk 38 West Clarke Avenue Milford, DE 19963, USA.
Tetric N-Ceram bulk fill	Urethane dimethacrylate, ytterbium, trifluoride, ethyoxylated bisphenol A dimethacrylate, and Bis-GMA	Ivoclar Vivadent AG Bendererstrasse 2 FL-9494 Schaan Principality of Liechtenstein. China
Filtek Bulk Fill Posterior Restorative	Non-agglomerated/non-aggregated 20 nm silica filler, a non-agglomerated/ non-aggregated 4–11 nm zirconia filler, an aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4–11 nm zirconia particles) and a ytterbium trifluoride filler consisting of agglomerate 100 nm particles	3M, ESPE, Elipar, Filtek, Scotchbond. Canada.

of each resin composite type where fabricated and stored in distilled water at room temperature for 24 h to complete the polymerization and simulate conditions of the oral cavity environment.

Experimental groups

The 27 specimens of each composite resin were randomly divided into three main groups (n = 9). Each main group was further subdivided into three subgroups (n = 3). Each group was subjected to simulated toothbrushing with three different dentifrices: BlanX sensitive teeth toothpaste, Crest 3D white Brilliance toothpaste, and Lacalut aktiv medical toothpaste. The composition of each dentifrice is listed in Table 2.

Evaluation of surface roughness

The initial surface roughness of each specimen was measured with a contact profilometer device (MarSurf PS1-Mahr GmbH. GÖttingen-Germany). Three consecutive measurements of the specimen were taken in different regions (one central, one right, and one left) for obtaining the mean average from the three measurements. The roughness of the surfaces was measured again after surfaces of resin composites subjected to simulated toothbrushing.

Simulated toothbrushing

The simulated toothbrushing was done manually by one operator using (Oral-B 40) rotary toothbrushing machine. This is done throughout the experiment to ensure proper standardization and decrease variables. Operator's errors were avoided by excluding any major changes in readings. Each specimen was fixed in the center (orifice) of an acrylic plate (55 mm × 25 mm × 4 mm), respectively, for the diameters and height, enabling the test surface to remain 1 mm beyond the edge of the orifice which housed the specimen. Utility wax was applied to fix the specimens. Each plate was placed in an acrylic tank which was attached to the brushing machine by metal pins. The acrylic tank was filled with a mixture composed of 1 g of dentifrice paste per 1 ml of distilled water. Medium bristle classic rotary toothbrush was used for simulated toothbrushing that continued once daily for approximately 6 months. The dentifrice pastes were changed every cycle. Rotary toothbrushes were changed every 6 days. After every brushing cycle, the specimens were washed in running tab water, cleaned in distilled water for 10 min and drying with compressed air. The roughness of the surface was measured again. Surface roughness readings were measured perpendicular to the brushing direction of the rotary toothbrush bristles. For the correct positioning of the specimen in the brushing machine and to always ensure readability in the same direction (perpendicular to the brushing), a mark with a diamond bur mounted in a high-speed hand piece was made on the border of each specimen.

Statistical analysis

The values of surface roughness were collected, organized, and tabulated. One-way analysis of variance was used to evaluate the effect of brushing using dentifrices on the surface roughness of each type of composite resin, followed by Tukey's test at a significance level of $p \leq 0.5\%$.

Results

Results revealed that different effects on composites surface roughness were detected after simulating toothbrushing with different dentifrices. Regarding The Bulk Fill SDR Posterior Bulk Fill Flowable Based composite (Dentsply) results revealed that the mean differences in surface roughness after simulating toothbrushing using different toothpastes were as follow: Lacalut toothpaste (0.33), Crest 3D White (0.39), and BlanX (0.58). There was no statistical significant difference between values of Lacalut toothpaste (0.33) and Crest 3D White (0.39), but there was a statistical significant difference between them and BlanX (0.58) as $p \leq 0.5\%$. Regarding Filtek Bulk Fill Posterior Restorative composite (3M, ESPE, E) results revealed that the mean differences in surface roughness after simulating toothbrushing were as follow: Lacalut toothpaste (0.78), Crest 3D White (0.33), and BlanX (0.30). There was no statistical significant difference between values of

Table 2: Specifications and manufacturers of toothpastes

Toothpaste	Composition	Manufacturer
BlanX Sensitive Teeth Toothpaste	Hydroxyapatite, Potassium Chloride, Sodium Fluoride, Arctic Lichen, Aqua, Glycerin, Hydrated Silica, Sorbitol, Potassium BlanX Sensitive Chloride, Silica, PEG-32, Cellulose Gum, Zinc Hydroxyapatite, Xylitol, *Cetraria islandica* extract, Usnea barbata extract, Eugenia Teeth Caryophyllus Flower Oil, Mentha Piperita Oil, Mentha Viridis Leaf Toothpaste Oil, Sodium Monofluorophosphate, Sodium Myristoyl Sarcosinate, Sodium Methyl Cocoyl Taurate, Zinc Citrate, Sodium Fluoride, Sodium Saccharin, Menthol, Titanium Dioxide, Benzyl Alcohol, Phenoxyethanol, Sodium Benzoate, Eugenol, Limonene.	Sensodyne, UAE
Crest 3D White Brilliance	Sodium fluoride 0.243%, glycerin, hydrated silica, sodium hexametaphosphate, water, PEG-6, flavor, trisodium phosphate, sodium lauryl sulfate, carrageenan, cocamidopropyl betaine, sodium g saccharin, PEG-20M or PEG-23M, xanthan gum, sucralose, mica, titanium dioxide.	The Procter and Gamble Manufacturing Company, USA
Lacalut Aktiv Medical Toothpaste	Aqua, Hydrogenated Starch Hydrolysate, Aluminum Hydroxide, Lacalut Medical Hydrated Silica, Silica, Poloxamer 188, Sodium Lauryl Sulfate, Aroma, Hydroxyethyl cellulose, Aluminum Lactate, Titanium Dioxide, Toothpaste Allantoin, Aluminum Fluoride, Sodium Saccharin, Chlorhexidine Digluconate, Bisabolol, Limonene.	Lacalut, China

Crest 3D White (0.33) and BlanX (0.30), but there was a statistical significant difference between them and Lacalut toothpaste (0.78) as p ≤ 0.5%. Regarding Tetric N-Ceram bulk fill (Ivoclar Vivadent) results revealed that the mean differences in surface roughness after simulating toothbrushing were as follow: Lacalut toothpaste (0.59), Crest 3D White (0.81), and BlanX (0.81). There was no statistical significant difference between values of Crest 3D White (0.81) and BlanX (0.81), but there was a statistical significant difference between them and Lacalut toothpaste (0.59) as p ≤ 0.5%. Regarding the effect of Lacalut toothpaste on the surface roughness of different bulk fill resin composites, results revealed that mean difference values vary according to type of composite used as follow: Bulk Fill SDR (0.33), Filtek Bulk Fill (0.78), and Tetric N-Ceram (0.59). These results are shown in Table 3.

Table 3: Effect of Lacalut toothpaste on surface roughness on the 3 types of composite

SDR	Sample no.						Mean		Difference
	1		2		3				
SDR	Pre	0.270	Pre	0.391	Pre	0.697	Pre	0.45	0.33
	Post	0.856	Post	0.594	Post	0.894	Post	0.78	
Filtek Bulk Fill	Pre	0.741	Pre	0.408	Pre	0.493	Pre	0.54	0.78
	Post	1.311	Post	1.780	Post	0.884	Post	1.32	
Tetric N-Ceram	Pre	0.249	Pre	0.707	Pre	0.486	Pre	0.48	0.59
	Post	1.027	Post	1.164	Post	1.021	Post	1.07	

Regarding the effect of Crest 3D White toothpaste on the surface roughness of different bulk fill resin composites, results revealed that mean difference values were as follow: Bulk Fill SDR (0.39), Filtek Bulk Fill (0.33), and Tetric N-Ceram (0.81). These results are shown in Table 4.

Table 4: Effect of crest 3D white toothpaste on surface roughness on the 3 types of composite

SDR	Sample no.						Mean		Difference
	1		2		3				
SDR	Pre	0.278	Pre	0.589	Pre	0.339	Pre	0.40	0.39
	Post	0.731	Post	0.629	Post	1.038	Post	0.79	
Filtek Bulk Fill	Pre	0.600	Pre	0.530	Pre	0.419	Pre	0.51	0.33
	Post	0.745	Post	0.839	Post	0.957	Post	0.84	
Tetric N-Ceram	Pre	0.511	Pre	0.279	Pre	0.619	Pre	0.46	0.81
	Post	1.843	Post	0.980	Post	1.000	Post	1.27	

Regarding the effect of BlanX toothpaste on the surface roughness of different bulk fill resin composites, results were as follow: Bulk Fill SDR (0.58), Filtek Bulk Fill (0.30), and Tetric N-Ceram (0.81). These results are shown in Table 5.

Table 5: Effect of BlanX toothpaste on surface roughness on the 3 types of composite

SDR	Sample no.						Mean		Difference
	1		2		3				
SDR	Pre	0.213	Pre	0.313	Pre	0.399	Pre	0.3	0.58
	Post	1.024	Post	0.780	Post	0.844	Post	0.88	
Filtek Bulk Fill	Pre	0.249	Pre	0.607	Pre	0.504	Pre	0.45	0.30
	Post	0.580	Post	0.640	Post	1.049	Post	0.75	
Tetric N-Ceram	Pre	0.268	Pre	0.259	Pre	0.410	Pre	0.31	0.81
	Post	1.129	Post	1.021	Post	1.215	Post	1.12	

Statistical significant differences among all variables are summarized in Table 6 and illustrated in Figure 1.

Table 6: Differences (D) between variables

Toothpaste	Composite		
	SDR	Filtek Bulk Fill	Tetric N-ceram
Lacalut	0.33	0.78	0.59
Crest 3D white	0.39	0.33	0.81
BlanX	0.58	0.30	0.81

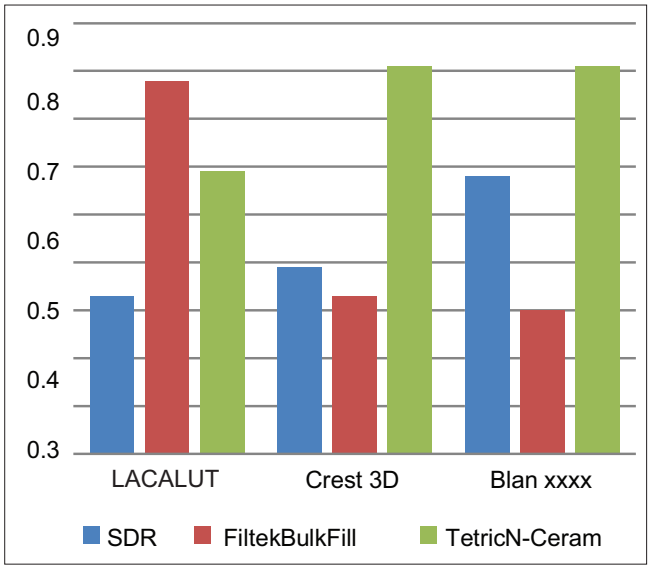

Figure 1: Bar chart showing statistical significant differences among all variables

Discussion

The present study evaluated the influence of toothbrushing abrasion on the surface roughness of three commercial bulk fill composite resins. Restorative material surfaces in the oral environment are subjected to various factors, which can modify the surface roughness. Toothbrushing using dentifrices is one of the oral hygiene procedures that play a significant role in reducing plaque and caries among other benefits. Previous studies have reported that amount of wear by toothbrush dentifrice abrasion depends on toothbrush quality, toothbrushing habits, type of dentifrices used, the load applied, slurry dilution, and oral temperature [28]. It is also reported that wear resistance of a composite depends mainly on shape, size, load of inorganic filler, and to little extent on the organic matrix components [29]. The mechanical characteristics of the composite resins can be evaluated by surface roughness measurements after they subjected to simulated toothbrushing [30]. In the present study, a medium type of rotary toothbrush was selected with different dentifrices and the results revealed statistical significant differences in the values of composite resin surface roughness. This result disagreed with the study of Oliveira *et al*. where they reported that toothbrush type did not affect the resin composite wear or surface roughness when used with a wet medium type [30]. In addition, some authors reported that soft type toothbrushes abrade more when compared to medium or hard types of brushes [31]. In the present study and regarding influences of surface roughness, a significant difference was observed among all groups of tested bulk fill resin composites. Results of the present study are in agreement of other studies that reported that Filtek Bulk Fill Posterior Restorative (3M, ESPE) are more resistant to wear and surface roughness than The Bulk Fill SDR Posterior

and Bulk Fill Flowable Based composite (Dentsply). Although the mentioned later two types of composite fillers have same average cluster size, it is clear that the non-aggregated zirconia/silica cluster filler presented in Filtek Bulk Fill Posterior Restorative (3M, ESPE) can resist the toothbrushing abrasion more effectively than triethylene glycol dimethacrylate (TEGDMA) presented in Bulk Fill SDR (Dentsply) [32]. Notably, in the present study, the Tetric N-Ceram bulk fill (Ivoclar Vivadent) demonstrated more statistical significant differences in surface roughness compared to other two types of composites. This finding was in agreement with the results of Mitra *et al*. [33]. They clarified that urethane dimethacrylate (the main composition of Tetric N-Ceram bulk fill) showed less resistant to wear and surface roughness among the tested composite groups. This could be better explained due to the fact that mean distance between adjoining particles is less than coarse filler particles. This structure favors protection against wear of the matrix and ensures better performance of the material [34]. Quirynen and Bollen [35], [36] reported that surface roughness values in composite materials should be below 0.4 μm to prevent adhesion of plaque and microorganisms. The roughness of the restoration can be detected by tongue if the surface roughness value is above 0.7 μm [37]. In the current study, the initial Ra values of all the tested composites were around the threshold limit of 0.4 μm but after final brushing cycles, most of the tested groups exhibited values above 0.7 μm. Although the filler loading in all types of composites used in this study was 82% by weight, it was clear that chemical composition and arrangement of fillers answer why Tetric N-Ceram bulk fill (Ivoclar Vivadent) demonstrated more statistical significant differences in surface roughness values (less resistance to wear and surface roughness) compared to other two types of bulk fill resin composite. There was a clear correlation between surface roughness and chemical composition for all composite types and dentifrices used in the present study. In previous studies by Kanter *et al*. [38] and Mandikos *et al*. [39], they were concluded that composites which wear more showed increased surface roughness. This was in agreement with the findings of our study but was conflicting with the outcomes of the studies by Wang *et al*. [28] and Garcia *et al*. [15] where they concluded that there was no significant relationship between the degree of wear resistance of resin composite and their surface roughness.

Conclusion

Under limitation of the present study, the results revealed that chemical composition of bulk fill resin composites and abrasive materials incorporated within the dentifrices plays an important role in influencing the degree of surface roughness of bulk fill composite restorations. The degree of toothbrush abrasion depends on variety of factors such as type of resin composite, the chemistry and method of polymerization, type of toothpaste, and the nature of the toothbrush used. Further studies should be done to clarify the relation between wear resistance and surface roughness of different esthetic restorative materials.

Recommendations

Under limitation of the present study, the results revealed that:

1. Lacalut toothpaste abrades more with Filtek Bulk Fill then Tetric N-Ceram and finally Bulk Fill SDR so it is not recommended that patient of Filtek Bulk Fill composite restoration to use Lacalut toothpaste for rotary toothbrushing using medium type of toothbrush.
2. Crest 3D White toothpaste abrades more with Tetric N-Ceram then Bulk Fill SDR and finally Filtek Bulk Fill so it is not recommended that patient of Tetric N-Ceram composite restoration to use Crest 3D White toothpaste for rotary toothbrushing using medium type of toothbrush.
3. BlanX toothpaste abrades more with Tetric N-Ceram then Bulk Fill SDR and finally Filtek Bulk Fill so it is not recommended that patient of Tetric N-Ceram composite restoration to use Crest 3D White toothpaste for rotary toothbrushing using medium type of toothbrush.

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