Child Toothbrush Abrasion Effect on Ionomeric Materials

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ABSTRACT

The purpose of the study was to evaluate the abrasive effect of different toothbrushes—soft-cross bristles (CB), extra-soft-parallel bristles (ES), and soft-parallel bristles (S)—on the surface roughness of conventional (C) and resin-modified (V) glass ionomer cements in vitro. Eight specimens of each material were prepared for each group: (1) V and CB; (2) V and ES; (3) V and S; (4) C and CB; (5) C and ES; and (6) C and S. Specimens were stored at 37°C/24 hours and 100% humidity, polished, and initially analyzed with a surface roughness-measuring device. Next, they were fixed to the tooth-brushing device and abraded via toothbrushes, using a dentifrice slurry, performed at 250 cycles/minute with a 200 g load. The specimens were washed, dried, and analyzed identically with the same device. There was no significant interaction between material and toothbrush types. After tooth-brushing, V showed significantly higher surface roughness than C and CB and created higher surface roughness than S. No difference was observed between these toothbrushes and ES. Regardless of the toothbrush type used, resin-modified glass ionomer cement showed the highest roughness values. (**J Dent Child 2008;75:112-6**)

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KEYWORDS: GLASS IONOMER CEMENT, TOOTH-BRUSHING ABRASION, SURFACE ROUGHNESS

Glass ionomer cements (**GIC**) have been used in pediatric restorative dentistry for 20 years. GICs are preferred to other materials because of their fluoride release, biocompatibility, chemical adhesion to tooth structure, applicability in a variety of clinical procedures, and relatively lower cost.[1-4]

GICs are available in 2 major categories: (1) conventional GIC (**CGIC**) and resin-modified GIC (**RMGIC**). RMGICs were developed partly to overcome problems with CGICs, such as brittleness and sensitivity to moisture during initial setting.[2,3,5] Although RMGICs have increased physicomechanical cement strength,[1,6,7] doubt persists about this material's surface characteristics because different studies have shown both lower and higher wear resistance and hardness when compared with CGIC.[2,3,5,8,9]

Toothbrushes and toothpastes are the items most associated with oral hygiene procedures performed to clean teeth and restorations surfaces. It is known that these items can abrade these surfaces, with major abrasion resulting from the toothpaste on the toothbrush.[10] Previous studies testing adult toothbrushes have indicated different abrasion levels produced by higher or lower filament/toothpaste contact areas with the substrate surface.[11,12] A variety of child toothbrushes present different bristle arrangements, densities, and stiffnesses to facilitate and improve oral hygiene. Nevertheless, no study was found in the dental literature that evaluated the abrasive effect that child toothbrush bristles produced on dental material surfaces.

This study's purpose was to compare, in vitro, the surface roughness of two glass ionomer cements (conventional and

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resin-modified) before and after a tooth-brushing test, using 3 types of child toothbrushes and analyzing the surface substrate morphology by scanning electronic microscopy (SEM). The null hypothesis was that the toothbrush type had no influence on the surface roughness of GICs.

METHODS

This study used two glass ionomers, CGIC (Chem-Flex, Dentsply Caulk, Mildford, Del) and RMGIC (Vitremer, 3M ESPE Dental Products, St. Paul, Minn) and 3 child toothbrushes:

(1) soft-cross bristles (Oral-B Stage 4, Oral B Laboratories, Iowa City, Iowa); (2) extra-soft-parallel bristles (Sorriso Kolynos Master Infantil, Colgate Palmolive Ind e Com Ltda, SB Campo, São Paulo, Brazil); and (3) soft-parallel bristles (Tek Jr, Johnson e Johnson Ltda, SJ Campos, São Paulo; Figure 1). Twenty-four samples (8 for each group; Table 1) were produced for each material.

Each glass ionomer cement was handled according to the manufacturers' instructions and cylindrical specimens were prepared in stainless steel molds (4 x 2 mm). The glass ionomer surfaces were covered with a polyester matrix strip (Probem Ltda, Catanduva, Brazil) that was pressed using glass slab. Vitremer was light cured (Elipar Tri-light, ESPE America Co, Seefeld, Germany) for 40 seconds on each side of the mold, and its surface was protected with Finishing Gloss (3M ESPE Dental Products). The CGIC, meanwhile, was pressed for 5 minutes during its setting time and covered by nail varnish (Colorama, CEIL Coml Exp Ind Ltda, São Paulo). All samples were maintained at 100% relative humidity and 37°C for 24 hours. The surfaces were wet-ground with abrasive disks (Sof-Lex Pop On, 3M Dental Products) and ultrasonically cleaned (Ultrasonic Cleaner, model USC1400, Unique Ind e Com Ltda, São Paulo) in distilled water for 10 minutes to remove polishing debris.

Before the abrasion test, the specimens were analyzed using a Surfcorder SE1700 surface roughness-measuring instrument (Kosaka Corp, Tokyo, Japan). The surface roughness measurements were made in the opposite direction of the tooth-brushing movement. Three readings from each specimen were taken and considered to be baseline measurements.

Tooth-brushing test was conducted at 250 cycles/minute (up to 30,000 cycles) with a 200 g load. Tandy dentifrice (Colgate Palmolive Ind e Com Ltda) diluted in distilled water (6:6) was used. Next, samples were washed in an ultrasonic bath, cleaned for 10 minutes, and gently dried. Three final surface roughness readings were taken from each specimen at the same sites.

One representative specimen of each group was observed by SEM (model Jeol JSM 5600 LV, Tokyo, Japan) to illustrate the effect of tooth-brushing. Additional specimens from each material were taken as baseline to compare unbrushed surfaces to abraded surfaces.

Statistical analysis was performed with the factorial analysis of variance (ANOVA) test to compare the influence between materials and toothbrushes. The paired t test was used to analyze the difference in surface roughness before (baseline) and after the tooth-brushing test. A P=.05 level of significance was used.

RESULTS

There was no significant interaction between material and toothbrush types by Factorial ANOVA test (P=.87). The surface roughness before and after tooth-brushing was evaluated separately for materials and toothbrushes.

Table 1. Group Distribution

Group	Glass ionomer x toothbrush
1	Vitremer (3M) x soft-cross bristles (Oral-B)
2	Vitremer (3M) x extra-soft-parallel bristles (Kolynos)
3	Vitremer (3M) x soft-parallel bristles (Johnson e Johnson)
4	Chem-Flex (Dentsply) x soft-cross bristles (Oral-B)
5	Chem-Flex (Dentsply) x extra-soft-parallel bristles (Kolynos)
6	Chem-Flex (Dentsply) x soft-parallel bristles (Johnson e Johnson)

Table 2. Surface Roughness Values of Ionomeric Materials Before and After Tooth-brushing

Ionomeric materials	Roughness values (µm)±(SD)		
	Initial	Final	Mean
Vitremer	0.39±0.15[a]	0.49±0.20[b]	0.49*
Chem-Flex	0.30±0.23[a]	0.36±0.18[a]	0.36

** Same symbols are not significantly different when comparing the surfaces of the same material before and after tooth-brushing (paired t test; P<.05). Same letters are not significantly different when comparing the same material's surfaces before and after tooth-brushing (paired t test; P<.05).*

Table 3. Surface Roughness Values of Ionomeric Materials Before and After Tooth-brushing According to Toothbrush Type

Toothbrushes	Roughness values (µm)±(SD)		
	Initial	Final	Mean
Soft-cross	0.39±0.19[a]	0.53±0.24[b]	0.53*
Extra-soft-parallel	0.29±0.13[a]	0.38±0.18[a]	0.38*†
Soft-parallel	0.35±0.25[a]	0.36±0.12[a]	0.36*†

** Same symbols are not significantly different when comparing the surfaces of ionomeric materials for the same toothbrush before and after tooth-brushing (paired t test; P>.05). †Same letters are not significantly different when comparing the surfaces of ionomeric materials for the same toothbrush before and after tooth-brushing (paired t test; P>.05).*

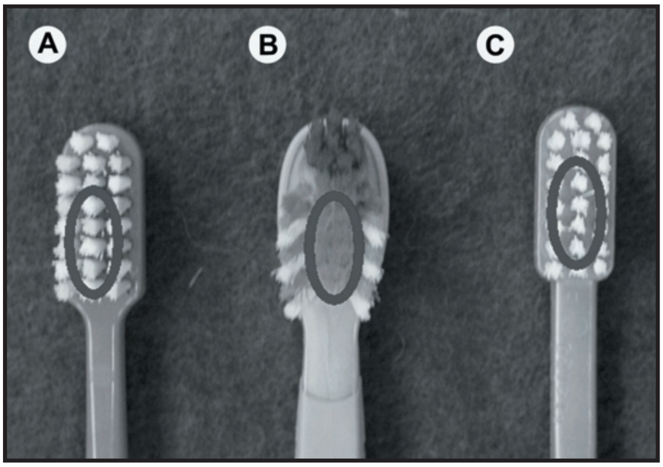

Figure 1. Toothbrushes used in this study: (a) extra-soft-parallel bristles; (b) soft-cross bristles; and (c) soft-parallel bristles.

Roughness values for ionomeric materials tested are given in Table 2. No difference was observed between the surface roughness before and after tooth-brushing for Chem-Flex (P=.13), but for Vitremer the surface roughness was higher after tooth-brushing (P=.001). Vitremer showed higher surface roughness than Chem-Flex.

For the different toothbrush types, there was a statistically significant difference between surface roughness before and after tooth-brushing only for soft-cross bristles (P=.001;Table 3). Soft-cross bristles created a higher surface roughness than soft-parallel bristles, but there was no statistically significant difference between these toothbrushes and the extra-soft-parallel bristles.

Figures 2 and 3 are representative SEM images depicting GIC surfaces before and after tooth-brushing. When comparing the surface morphology of the studied materials, RMGIC was shown to be more irregular than CGCI before and after tooth-brushing with the same toothbrush type. The Vitremer particles appeared to be exposed to a higher degree by soft-parallel bristles than by extra-soft-parallel bristles toothbrushes (Figure 2b-d). For Chem-Flex, the soft-parallel bristles showed a higher abrasion than the other toothbrushes and presented a protrusion of particles (Figure 3c). Both cements' surfaces showed less abrasion when brushed with extra-soft-parallel bristles and had a matrix that prevented surface irregularity (Figures 2d and 3d).

DISCUSSION

GICs have been used in primary tooth restorations since the early days of their development. GIC's main pediatric dentistry advantages are fluoride ion release, the ability to form a chemical bond to tooth structure, efficacy in young patients, high susceptibility to dental caries, and little to no postoperative tooth sensitivity. Adding a resin component to RMGIC decreased initial hardening time and handling difficulties and made restorative treatment of pediatric patients easier.[4] Nevertheless, CGIC and RMGIC undergo abrasion by daily tooth-brushing that increases their surface roughness, which justifies studies about the abrasive resistance of different restorative materials. Investigations of these 2 cement types are contradictory.[2,3,5,8,13,14]

This study's results showed that Vitremer had higher surface roughness values than Chem-Flex (Table 2), corroborating other studies.[2,3,5,8] Possible explanations for these values is the inherent resistance of the major constituents (polymer matrix and glass particles), size and shape of the glass particles, adhesion between particle and matrix at the interface, and setting reaction of both materials.[5]

RMGIC is mainly composed of fluoroaluminosilicate glass, polyalkenoic acid, and 2-hydroxiethylmethacrylate (HEMA). During the setting reaction, crosslinks are formed, often via a HEMA molecule, between the polyacid chains. The crosslink has a certain length and may prevent the 2 joined polyacid chains from coming close together in the vicinity of the crosslink. In this region, carboxylate groups in the 2 polyacid chains will be too far apart to be crosslinked via Ca $^{\text{and } 2}$, as will normally happen without the crosslink.

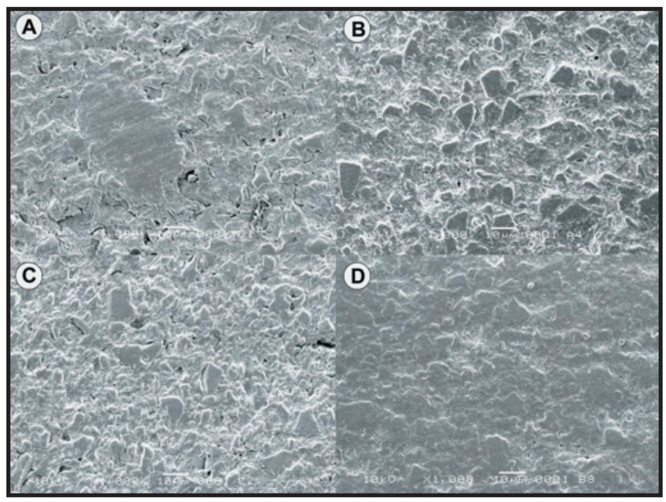

Figure 2. Vitremer surface before abrasion (a) and after abrasion with a soft-cross bristle toothbrush (b), soft-parallel bristle toothbrush (c), and extra-soft-parallel bristle toothbrush (d).

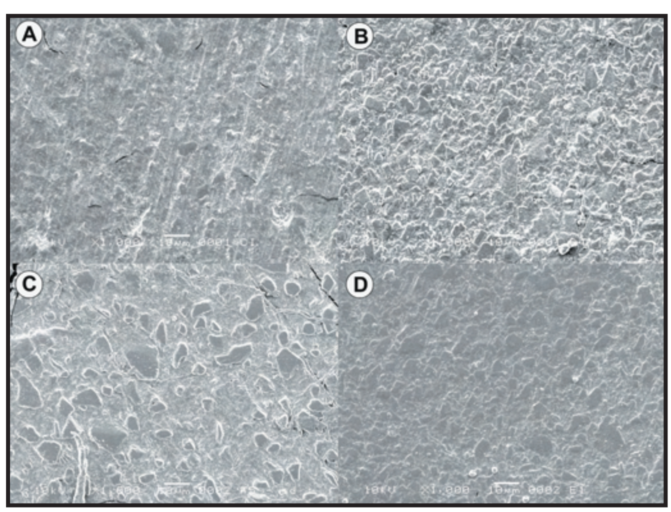

Figure 3. Chem-Flex surface before abrasion (a) and after abrasion with a soft-cross bristle toothbrush (b), soft-parallel bristle toothbrush (c), and extra-soft-parallel bristle toothbrush (d).

This destabilizing effect of methacrylate crosslinking consequently will decrease wear resistance.[5] It is possible for this set cement to have 2 different matrixes—a polyacid chain and poly-HEMA chain with different abrasion resistances—without interpenetration, forming separate phases inside a single substrate. This characteristic would make RMGIC susceptible to different abrasion levels and higher roughness on same surface compared with the homogenous CGIC matrix.

Moreover, the partial replacement of the rigid polyalkenoate network by the flexible polymer chains in RMGIC increased the surface's deformation caused by tooth-brushing. Also, it could lead to microcrack formation in an ionic crosslinked polyalkenoate matrix, with a subsequent loss of particle adherence, leading to higher wear.[8] The affirmation that the polymer matrix is more flexible than the polyalkenoate network was confirmed by Xie et al (2000) through the compressive stress-strain curve. Additionally, RMGIC showed appreciable permanent deformation prior to fracture in contrast with CGIC, which exhibited a small amount of permanent deformation, although both are considered completely brittle materials. The high proportion of functional hydrophilic groups contained within the RMGIC matrix could absorb a large quantity of water from abrasive slurry, producing a plasticizing effect resulting in increased abrasion.[15]

Different child toothbrush bristle directions, concentrations, and stiffnesses were tested in this investigation. Based on the results, it should be noted that there was no statistically significant difference between surface roughness produced by the extra-soft-parallel and the other toothbrushes. This demonstrates that different bristle stiffnesses (soft and extra-soft) are unlikely to represent clinical significance regarding the studied abrasion materials. Dye et al (2000) published data indicating that, when used with toothpaste, soft bristles caused more abrasion than hard bristles, perhaps because soft filaments are capable of holding toothpaste better and flexing on the substrate, thus increasing the filament/toothpaste area in contact with the substrate. This study, however, did not test extra-soft toothbrushes.

The present study's findings showed higher surface roughness values produced by soft-cross toothbrushes than by soft-parallel toothbrushes. The difference in bristle direction (angle to the head) between these toothbrushes could not be tested, due to small specimen size. The discs were abraded only by a central area of soft-cross toothbrush filaments, which also were parallel. Nevertheless, the soft-cross toothbrush presented a higher concentration of filaments per test area during machine movement (Figure 1). This influenced the filament/toothpaste surface area in contact with the substrate, increasing the quantity of toothpaste moved over the surface with each stroke, thus abrading materials more intensely. In the SEM images of specimens brushed by soft-cross toothbrushes (Figure 2b and 3b), an irregular surface texture was observed where the matrix was worn down, resulting in the exposure of glass particles.

Although some investigations[3,6] have related RMGIC's improved mechanical properties, this study showed a higher susceptibility to abrasion of this material, resulting in higher surface roughness values than for CGIC. Clinically, such roughness may decrease the wear resistance of the restorative material and make this surface significantly more prone to an increased deposition of bacterial biofilm. This inherently leads to a greater incidence of secondary caries and aesthetic damage. Therefore, further investigations are needed to analyze the true clinical significance of the detrimental effects produced by different types of child toothbrushes on restoration integrity.

Despite this study's limitations, the null hypothesis was accepted: The toothbrush type had no influence on glass ionomer cement's surface roughness. The material surface roughness was shown to be an inherent characteristic of the material.

CONCLUSIONS

Based on this study's findings, and within the limitation of an in vitro investigation, the following conclusions can be made:

1. The toothbrush type had no influence on glass ionomer cement's surface roughness.
2. The surface roughness was higher for Vitremer than for Chem-Flex after the tooth-brushing test, irrespective of the toothbrush type used.
3. Soft-cross bristle toothbrushes created higher surface roughness values than soft-parallel bristle toothbrushes, but there was no statistically significant difference between these toothbrushes and extra-soft-parallel bristles.

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