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Effect of topical fluoride application on toothbrushing abrasion of resin composites

Thomas Attin[a,*], Wolfgang Buchalla[a], Elmar Hellwig[b]

[a]*Department of Operative Dentistry, Preventive Dentistry and Periodontology, Georg-August-Universität Göttingen, Robert-Koch-Str. 40, D-37075 Göttingen, Germany*
[b]*Department of Operative Dentistry and Periodontology, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany*

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Summary *Objectives*: This in vitro study assesses toothbrushing abrasion of a microfill (Heliomolar® Radioopaque) and a hybrid composite (Herculite® XRV) after application of two acidic fluoride agents.
Methods: Thirty-six specimens of each resin composite were fabricated, ground flat and polished. Subsequently the 36 samples of each material were evenly assigned to three groups. In the first group, samples were treated with the fluoride varnish Bifluorid 12® (5.5% F, pH 5.6), in the second group with Elmex Fluid® (1.25% F, pH 4.3). In the third group, specimens remained unfluoridated (controls). After 8 h, the samples were subjected to toothbrushing abrasion (2000 brushing strokes, load: 250 g) in an abrasive slurry. Fluoridation and brushing abrasion were repeated twice. Afterwards, abrasion of the materials was quantitatively determined with a laser profilometer and statistically analyzed (ANOVA).
Results and Significance: With Herculite® both, Bifluorid 12® ($P=0.0001$) and Elmex Fluid® ($P=0.0001$) led to a significant increase of brushing abrasion compared to the non-fluoridated group. However, no significant difference was observed between the two fluoridation regimes. Heliomolar® showed a tendency towards higher abrasion after treatment with Elmex Fluid® compared to Bifluorid 12® ($P=0.0496$) and the non-fluoridated group ($P=0.0496$), whereas treatment with Bifluorid 12® yielded no significant difference compared to the non-fluoridated Heliomolar® specimens. Fluoridation of Herculite® resulted in a 106–121% increase of abrasion, whereas Heliomolar® only showed an increase by 5–30%. Application of the acidic fluoride products used led to an increase in toothbrushing abrasion of the tested composite restorative materials. However, clinical long-term studies are needed to determine the effect of topical fluoride regimes on resin composite materials.

* Corresponding author. Tel.: +49 551 392884; fax: +49 551 392037.
E-mail address: thomas.attin@med.uni-goettingen.de (T. Attin).

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Introduction

It was shown that the physical properties of resin-based materials might be deteriorated by various chemical influences, such as contact to alcoholic or acidic solutions [1-9]. Even mouthrinses may exert a material dependent effect on physical properties of composites [10]. Also, acidic fluoride regimes, such as acidulated phosphate fluoride gels lead to increased surface roughness not only of glass ionomer cements (GIC) or resin-modified GICs, but also of resin composite materials [11-14]. Acidic fluoride regimes might damage the surface of composite materials [15-21].

Wear resistance has been used as an important criterion to assess the quality and predicted clinical success of resin-based materials [22]. In this sense wear resistance of restorative materials is mostly evaluated by two-or three-body wear experiments [23], which simulate intraoral tooth-to-tooth contact situations (two-body-wear) or mastication or toothbrushing (three-body-wear).

Depending on the kind of toothbrushing movements performed by patients, such as horizontal brushing techniques, especially cervical restorations may be jeopardized by wear due to toothbrushing abrasion. Therefore, it is important that restorative materials used for cervical lesions, such as resin composites, are able to withstand degradation due to toothbrushing abrasion. In preventive programs fluorides are applied in various forms such as dentifrices, mouthrinses, gels, fluids and varnishes. Varnishes are widely used, having the advantages of long-term release of fluoride during the dissolution of the varnish in the mouth, the need for only few applications per year (every third to sixth month) [24,25] and the deposition of a calcium fluoride-like layer, which releases fluoride over a long period [26,27]. The calcium fluoride constitutes a fluoride reservoir, which releases fluoride when pH drops [28]. This globular calcium fluoride-like layer is usually formed on dental hard tissues following the application of ionically bound fluorides or in an acidic environment [29]. Due to this reason, the pH of some fluoride varnishes is adjusted to (slightly) acidic values.

As mentioned above, some studies have evaluated the impact of topical fluoride regimes on restorative composite materials. Thereby, the investigation performed by Kula et al. [19] could prove that application of daily topical fluoride gels (APF gels) might reduce wear resistance of composite materials in a pin-on-disc apparatus simulating two-body-wear-conditions. However, little is known about the impact of acidic fluoride varnishes or liquids under three-body-wear-conditions, such as toothbrushing abrasion, on resin composites.

Hence, the aim of the present study was to assess toothbrushing abrasion of different composite restorative materials (one microfill and one hybrid composite) after application of different acidic fluoride varnishes.

Material and methods

Data for the materials used in the study are given in Table 1. The microfill resin composite Heliomolar® Radioopaque and the hybrid composite Herculite® XRV were investigated in the study. Thirty-six specimens of each material were fabricated. Cavities (6 mm in diameter, 1 mm in depth) were prepared in disc-shaped molds made of an acrylic resin (Technovit 4071®, Kulzer, Wehrheim, Germany). These cavities were filled with the restorative materials and light-cured for 40 s (Optilux 400, Demetron Research Corp., Danburry, USA). The specimens were ground flat

Table 1 Manufactures' data for materials used.

	Manufacturer	Composition
Restorative materials		*Resin, filler type (mean particle size). % filler*
Heliomolar® Radio-opaque	Vivadent, Schaan, Liechtenstein	BisGMA, UDMA, Decandiol-DMA, highly dispersed pyrolytic SiO_2 (0.04 μm), prepolymerized copolymers (15 μm) containing SiO_2 particles, YbF_3 (0.24 μm). 64 vol%, 77 wt%
Herculite XRV®	Kerr, Romulus, MI, USA	BisGMA, Ba-Al-Borosilicate (1.0 μm), pyrolytic SiO_2 (0.04l μm). 59 vol%, 79 wt%
Fluoride varnishes		*Matrix, % fluoride, pH*
Bifluorid 12®	Voco, Cuxhaven, Germany	Synthetic resins, teflon particles, organic solvent, 2.71% fluoride as NaF 2.92% fluoride as CaF_2, pH-value: 5.6
Elmex Fluid®	Gaba, Therwil, Switzerland	Water-based (85%) solution, flavour, saccharin, 1.25% fluoride as amine fluoride, pH-value: 4.3

with water-cooled carborundum discs (500–4000 FEPA; Water Proof Silicon Carbide Paper, Struers, Willich Schiefbahn, Germany) and polished with diamond spray (3 and 1 μm; DP-Spray P3, Struers). After the preparation steps the polished surfaces of the tested materials were flush with the acrylic molds.

The specimens were covered with tape (Tesa®, Beiersdorf, Hamburg, Germany) exposing an area of 1.8×10.0 mm across the centre of the restorative materials. This procedure ensures reference surfaces when measuring the depth of the abrasion grooves.

The 36 samples of each material were evenly assigned to three groups and treated according to pretreatment. In group 1 the specimens were covered with Bifluorid 12® and in group 2 with Elmex Fluid® for 8 h. In the third group the specimens were not fluoridated.

The specimens were covered with 50 μl of the respective fluoridation product and stored in a humid atmosphere at 37 °C. The specimens were then subjected to brushing abrasion without having removed the fluoride agents before. Pretreatment and brushing was repeated three times. Brushing abrasion of the specimens was performed with an automatic toothbrushing machine (VDD Elektronik, Freiburg; Germany) described in detail previously [7,30]. Toothbrushes with medium bristle stiffness were used (Clips Wechselkopf Medoral®, Diedenhofen, St Augustin, Germany) and renewed after brushing of five specimens of the same experimental group. In each brushing sequence the exposed areas of the specimens, which were not covered with the tape, were submitted to 2000 brushing strokes (200 strokes/min) at a load of 250 g in 20 ml of an abrasive slurry. The abrasive slurry was prepared by mixing 2 ml distilled water with 1 g dentifrice (Blend-a-med® Klassisch, Blend-a-med, Schwalbach, Germany) and 1.2 g medium grit pumice. For each specimen the slurry was renewed.

After final brushing the tapes were removed from the specimens and the abrasion of the material in the brushing groove was quantitatively determined with a laser profilometer (Microfocus; UBM Messtechnik, Ettlingen, Germany). For profilometrical measurements the laser moved across the brushing groove and the unbrushed area perpendicularly to the direction of the toothbrushing movement. Five measurements were performed in the center of each specimen at intervals of about 100 μm and averaged. The average depth of the abraded part of the specimens relative to the nonabraded surface areas was calculated by a software program (UBM Messetchnik).

Analysis of variance were applied to the abrasion data additionally followed by the closed test procedure with corrected level of significance. Level of significance was set at $P \leq 0.05$.

Results

Table 2 presents the average depth of the brushing grooves in the respective experimental group. Analysis of variance revealed a significantly different wear due to brushing abrasion among the two composite materials ($P=0.0001$). Abrasion of Heliomolar® was higher compared to Herculite® after fluoridation with Elmex Fluid® ($P=0.0061$) and without fluoridation ($P=0.0001$). No significant difference between the two composites was observed after fluoridation with Bifluorid 12® ($P=0.0647$). With Herculite® both, Bifluorid 12® ($P=0.0001$) and Elmex Fluid® ($P=0.0001$) led to a significant increase of brushing abrasion compared to the non-fluoridated group. However, no significant difference was observed between the two fluoridation regimes. Heliomolar® showed a tendency towards higher abrasion after treatment with Elmex Fluid® compared to Bifluorid 12® ($P=0.0496$) and the non-fluoridated group ($P=0.0496$), whereas treatment with Bifluorid 12® yielded no significant difference compared to the non-fluoridated Heliomolar® specimens.

Considering all composite samples, fluoridation of Herculite® resulted in a 106–121% increase of abrasion, whereas Heliomolar® only showed an increase by 5-30%.

Table 2 Mean abrasion (μm) and SD in the experimental groups.

Fluoridation	Composite material	
	Herculite®	Heliomolar®
No fluoridation	3.46 (1.18)	8.86 (5.34)
Bifluorid 12®	7.18 (2.18)^{A,1}	9.30 (4.15)^{B,1}
Elmex Fluid®	7.87 (2.93)^{A}	11.58 (3.09)^{B}

Values with same superscript letter (digit) in one column (line) were not significantly different.

Discussion

In the oral cavity, restorative materials are not only subjected to masticatory or occlusal forces, but also to toothbrushing which might be held responsible especially for wear of cervical restorations. In the present study the fluoride products were left on the surfaces of the composite materials for eight hours before brushing was performed. This was done, since fluoride varnishes and liquids are mostly applied on buccal surfaces of teeth where they sometimes will retain for some hours until being removed during subsequent toothbrushing. Therefore, the brushing abrasion test used in the present study was regarded as a suitable instrument to evaluate the wear resistance of materials used for cervical restorations after prolonged contact with fluoride varnishes or liquids.

However, it has to be stated that the specimens were subjected to a total of 4000 brushing strokes. These extensive numbers of brushing strokes were necessary in order to achieve a brushing groove with a sufficient depth allowing for profilometrical evaluation, as evaluated in pilot experiments. It has been documented that patients perform toothbrushing with a frequency of 4.5 strokes/s [31]. Taking into account that each sextant is approximately brushed for 20 s, it may be assumed that during a single implementation of toothbrushing about 90 brushing strokes are applied. Hence, the amount of material removed with 4000 strokes is certainly higher compared to a single implementation of toothbrushing by a patient. In the present study abrasivity of the dentifrice slurry was enlarged by adding pumice to the slurry. However, other studies evaluating impact of toothbrushing on composite restorative materials also subjected the materials to very severe conditions either by using high number of brushing strokes (up to 120,000) or by enlarging the abrasivity of the toothpaste slurry [32].

Despite these severe and exaggerated conditions, the composite materials behaved differently in toothbrushing abrasion and the treatment of the different fluoride regimes resulted in different abrasion values for the respective composite. The composite materials Heliomolar® Radioopaque and Herculite® XRV were chosen as typical representatives for a microfill and a hybrid composite, respectively. Elmex fluid® and Bifluorid 12® represent fluoride varnishes with different fluoride concentration and different pH values. However, formulation of the bases of these fluoride products is also different. Therefore, the present study provides only limited information for the reason of the increased brushing abrasion of the fluoride varnish treated composites. Nevertheless, both fluoride agents did not lead to statistically significantly different brushing abrasion for either Heliomolar® Radioopaque or Herculite® XRV, although the two agents were different with respect to both fluoride concentration and pH. To clarify the impact of the fluoride concentration and the pH, a study is presently running in which abrasion of composites is evaluated which are treated with different experimental fluoride agents only different in pH and fluoride concentration but not in formulation of the base.

Brushing abrasion of the two composite materials was statistically significantly different for the unfluoridated samples with microfill composite Heliomolar® showing lower abrasions resistance. The performed toothbrushing with a dentifrice slurry as abrasive medium represented a three-body-wear-situation. In previous three-body-wear-studies, higher abrasion wear of Heliomolar® compared to some hybrid composites was also recorded [2,33]. As a rule, microfill composite resins are reported to be less susceptible to generalized wear than to localized wear where the amount of wear can be appreciably greater than in areas immediately adjacent to it [34,35]. Moreover, under two-body-wear-conditions or in clinical studies, microfill resin composites were equally or even more resistant to abrasive loss than hybrid composite materials [36–41].

Treatment of the two composites with the acidic fluoride agents led to an increase in abrasion which was more pronounced for the hybrid composite (106–121% increase) as compared to the microfill material (5–30%). This observation corresponds to the results of previous studies, which also showed that topical application of acidulated phosphate fluoride gels (APF gels) might damage surfaces of composites with glass filler particles [15–21]. Glass particles, such as present in the hybrid composite Herculite® are more prone to stress corrosion when exposed to media of high or low pH, whereas pure silica fillers (Heliomolar®) are less affected by an acidic media [2]. Fillers containing alkaline earth metals, such as barium-aluminum-silicate (Herculite®) are more sensitive to stress corrosion especially under hydrogen ion influences resulting in leaching of filler components and facilitated filler plug-out under abrasive conditions [19]. Additionally to this direct influence of the acidic media on the fillers, fluoride may cause depolymerization of the matrix-filler interface and support filler loss from the matrix as reported by Bowen and Cleek [42]. It should also be taken into consideration that the fluoride agents might exert degradation of the composite matrix. It was shown that long-term storage of composite samples in alcoholic (e.g. ethanol) solutions might result in softening of the resin matrix and the matrix-resin interface [5,43]. However, there is no hint in the literature that acidic or fluoride containing substances may interact with the cured polymers of the composite matrix.

Due to the results of the present study it is concluded that application of the tested acidic fluoride agents led to an increase in toothbrushing abrasion of the tested composite restorative materials under the chosen in-vitro-conditions. However, clinical long-term studies are needed to determine the effect of topical fluoride regimes on resin composite materials.

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