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Araştırma/ Research Article

THE EFFECT OF SURFACE COATING AGENT ON THE SURFACE ROUGHNESS OF RESTORATIVE MATERIALS EXPOSED TO ACIDULATED PHOSPHATE FLUORIDE

ASİDÜLE FOSFAT FLUORİD UYGULANAN RESTORATİF MATERYALLERİN YÜZEY PÜRÜZLÜLÜĞÜNE YÜZEY ÖRTÜCÜ AJANININ ETKİSİ

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ABSTRACT

Aim: The purpose of this study was to assess the surface roughness of six different restorative materials when covered with surface coating agent prior to 1.23% acidulated phosphate fluoride gel application.
Materials and methods: Six restorative materials (Fuji IX, Amalgomer CR, Dyract XP, Beautifil II, ACTIVA, Filtek Z250) were used in this study. 28 specimens were prepared from each material and randomly divided into 4 groups (n=7) according to surface treatment regimens. Group C: control, no application, Group F: only acidulated phosphate fluoride gel application, Group S: only surface coating agent application, Group SF: acidulated phosphate fluoride gel application following the surface coating procedure. The surface roughness values for all specimens were measured using profilometer. The results were analyzed using analysis of variance (ANOVA), Newman Keuls and Tukey's tests ($p<0.05$).
Results: There were no statistically significant differences in surface roughness between group C and F for all analyzed materials, except for Amalgomer CR ($p>0.05$). The control group of Amalgomer CR showed greater surface roughness values than that of the group F ($p=0.001$). Group S produced significantly smoother surfaces than the group C for all restorative materials, except Dyract XP ($p=0.001$).
Conclusion: 1.23% acidulated phosphate fluoride gel application did not promote a significant increase on the surface roughness of restorative materials whether or not surface coated. However, surface coating was found to produce smoother surfaces.
Keywords: Fluoride gel, Glass ionomer cement, Surface roughness

ÖZ

Amaç: Bu çalışmanın amacı, %1,23 asidüle fosfat fluorid jel uygulamasından önce yüzey örtücü ajanı ile kaplanan altı farklı restoratif materyalin yüzey pürüzlülüğünün değerlendirilmesidir.
Gereç ve yöntem: Çalışmada altı restoratif materyal (Fuji IX, Amalgomer CR, Dyract XP, Beautifil II, ACTIVA, Filtek Z250) kullanıldı. Her bir materyalden 28 örnek hazırlandı ve yüzeye yapılan uygulamalara göre rastgele 4 gruba ayrıldı (n=7). Grup K: kontrol, herhangi bir uygulama yok, Grup F: sadece asidüle fosfat fluorid jel uygulaması, Grup S: sadece yüzey örtücü ajanı uygulaması, Grup SF: yüzey örtülemesini takiben asidüle fosfat fluorid jel uygulaması. Tüm örneklerin yüzey pürüzlülük değerleri profilometre ile belirlendi. Sonuçların analizi varyans analizi (ANOVA), Newman Keuls ve Tukey testi ile yapıldı ($p<0,05$).
Bulgular: Amalgomer CR dışında, değerlendirilen tüm materyallerin K ve F gruplarının yüzey pürüzlülüğü değerleri arasında istatistiksel olarak anlamlı farklılık görülmemiştir ($p>0,05$). Amalgomer CR'nin kontrol grubu, F grubuna göre daha yüksek yüzey pürüzlülük değeri göstermiştir ($p=0,001$). Dyract XP dışındaki tüm restoratif materyallerde grup S, grup K'ya göre anlamlı derecede daha pürüzsüz yüzey değeri vermiştir ($p=0,001$).
Sonuç: %1,23 asidüle fosfat fluorid jel uygulaması, yüzey örtücü uygulanmış ve uygulanmamış restoratif materyallerin yüzey pürüzlülük değerinde önemli bir artış sağlamamıştır. Ancak, yüzey örtücü uygulaması, materyallerin yüzey pürüzlülüğünü azaltmıştır.
Anahtar kelimeler: Fluorid jel, Cam iyonomer siman, Yüzey pürüzlülüğü

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INTRODUCTION

Glass ionomer cements (GICs) are crucial dental materials commonly used in pediatric dentistry due to their anti-cariogenic effects.[1,2] However, these materials have some clinical limitations such as long setting reaction time, moisture sensitivity and dehydration during initial setting, and rough surface texture, which makes them less resistant.[3,4] During the setting reaction, early water absorption causes swelling of the immature material and dissolution of reactive components, while dehydration may stop the acid-base reaction, resulting in surface crazing.[2,4,5] Furthermore, early moisture contamination diminishes the mechanical strength of GICs and makes their surface more prone to erosion and abrasion.[6] To avoid these problems, the surface of GICs can be covered with surface coating agents.[2,5] Surface coating may increase the resistance of the GICs and improve the marginal sealing and aesthetics of the restoration.[7] Moreover, few studies reported that surface coating application decreased the surface roughness.[8-10] However, it may severely impede the fluoride release from GICs.[11]

Topical fluorides are recommended as a preventive strategy for patients carrying a moderate or high risk of caries.[12] Furthermore, GICs have fluoride uptake ability when they are exposed to topical fluoride agents, so the GICs are also acting as a reservoir of fluoride.[13,14] However, topical fluoride agents may lead to surface deterioration on restorative materials.[15,16] Especially, acidulated phosphate fluoride (APF) gels which contain a strong acid can increase the surface roughness of restorative materials,[17] thereby enhancing the surface area available for bacterial adhesion.[18,19] This may decrease the clinical durability of the restorative materials.[15,20] A surface coating may protect the surface of restorative materials against the erosive effects of APF gels. According to a study, application of a glass ionomer varnish prior to an APF gel application protected the GICs from the erosive effects of the APF gel.[20]

The current study aimed to determine the effects of surface coating agent used before 1.23% APF gel application on the surface roughness of six restorative materials. The three null hypotheses tested were (1) surface coating would decrease the surface roughness of the restorative materials; (2) APF application would increase the surface roughness of the restorative materials; (3) the surface roughness of the coated restorative materials would not be increased by APF gel.

MATERIALS AND METHODS

A high-viscosity conventional GIC, a ceramic-reinforced GIC, a compomer, a giomer, a bioactive resin-modified GIC, and a composite resin were used in this study. The type and ingredient of these materials are listed in Table 1.

Table 1. The type and ingredient of restorative materials according to manufacturer data

Materials	Type	Ingredient	Average particle size	Manufacturer
Fuji IX GP® Capsule	High-viscosity GIC	Polyacrylic acid, water, fluoroaluminosilicate glass, polybasic carboxylic acid, polyacrylic acid powder	10 µm	GC Corp., Tokyo, Japan
Amalgomer™ CR	Ceramic-reinforced GIC	Fluoroaluminosilicate glass, polyacrylic acid powder, tartaric acid powder, and ceramic reinforcing powder, Polyacrylic acid and distilled water	5-10 µm	Advanced Health Care Ltd., Kent, UK
Dyract®XP	Compomer	Strontium-fluoro-silicate glass, strontium fluoride, TCB resin, UDMA, photoinitiator and stabilizers	0.8 µm	Dentsply, DeTrey, Konstanz, Germany
BEAUTIFIL®II	Giomer	BISGMA, Triethylene glycol dimethacrylate, Inorganic glass filler, aluminum oxide, silica, prereacted glass ionomer filler and Camphoroquinone	0.8 µm	Shofu Co, Kyoto Japan
ACTIVA™ Bioactive-Restorative	Bioactive resin modified GIC	Blend of diurethane and other methacrylates with modified polyacrylic acid, Amorphous silica, Sodium fluoride	Submicron - 4 µm	Pulpdent, Watertown, USA
Filtek Z250	Microhybrid Composite resin	Bis-GMA, UDMA, Bis-EMA Zirconia/silica	0.01-3,5 µm	3M ESPE, St. Paul, MN, USA

Sample preparation

A total of 168 disc samples (8mm x 2mm), 28 from each restorative material, were prepared. Each material was placed in a standard plastic mold, covered by Mylar strips, and tightly compressed between two glass slides to remove excess material. The conventional GIC and ceramic-reinforced GIC discs were left undisturbed at room temperature for 10 min. The compomer, giomer, bioactive resin modified GIC and composite resin were photopolymerized using a halogen curing unit (Optilux 501, Kerr, CA, USA) according to the manufacturer-recommended exposure time of 40 s on the top and bottom of each sample. Each specimen was removed from the mold and stored in deionized water at 37°C for 24 hours, followed by wet-grounding with a 1200-grit silicon carbide paper for 1 min before using the polishing system. Then, each specimen was subjected to a polishing system (Sof-Lex, 3M-ESPE, St. Paul, MN, USA).

Surface treatments

The specimens were randomly assigned to four groups (n = 7) and prepared as follows:

Group C: The specimens received no surface treatments.

Group F: The specimens were exposed to 1.23% APF gel (Nupro APF, Dentsply, York, USA) with microbrush for 4 min recommended by the manufacturer. Then, the samples were rinsed with deionized water until there were no remnants of APF gel.

Group S: Each specimen was coated with Equia Coat (GC Corporation, Tokyo, Japan) using a microbrush, then lightly air dried for 5 seconds, and light-cured for 20 seconds according to the manufacturer's instructions.

Group SF: Equia Coat was applied to the specimens as in group S before APF gel application. 1.23% APF gel (Nupro APF, Dentsply, York, USA) was applied with microbrush for 4 min and the samples were rinsed with deionized water until there were no remnants of APF gel.

Surface roughness measurement

The average surface roughness (Ra) values of the specimens were determined using a surface profilometer (Mahr Perthometer, Germany) with a 0.25-mm cut off (λc) at 0.1 mm/s. Three successive measurements were recorded for each surface, and the average Ra value was obtained for each specimen. Results were statistically analyzed by ANOVA for intergroup comparison, with the level of significance set at $p<0.05$. When ANOVA revealed a significant difference, Newman Keuls and Tukey multiple comparison tests were used to compare the subgroups.

RESULTS

The mean and standard deviation Ra values (µm) obtained in the groups of each restorative material, the comparisons among the materials and the groups are displayed in Table 2 and summarized in Figure 1.

In all materials except Amalgomer CR and Beautifil II, group F had the roughest Ra value. The lowest surface roughness was determined in group S for all materials. Surface coating significantly decreased the surface roughness in all restorative materials.

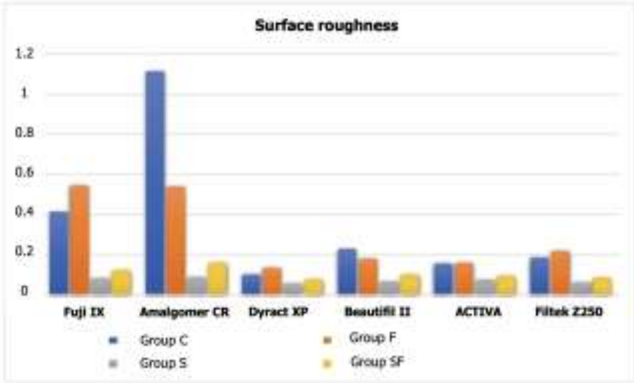

Figure 1. Mean surface roughness values measured in the subgroups for all restorative materials

Table 2. Mean values and standard deviations of surface roughness for each material group (Ra)(µm)

Material (n=7)	Group C	Group F	Group S	Group SF	$p^{\#}$
Fuji IX	$0.414\pm0.068^{a,A}$	$0.548\pm0.208^{a,A}$	0.084 ± 0.024^{b}	0.124 ± 0.028^{b}	**0.0001**
Amalgomer CR	$1.116\pm0.037^{a,B}$	$0.539\pm0.124^{b,A}$	0.09 ± 0.019^{c}	0.161 ± 0.203^{c}	**0.0001**
Dyract XP	$0.104\pm0.022^{a,C}$	$0.136\pm0.063^{a,B}$	$0.059\pm0.023^{a,b}$	$0.078\pm0.040^{a,b}$	**0.011**
Beautifil II	$0.229\pm0.077^{a,D}$	$0.182\pm0.020^{a,B}$	0.068 ± 0.025^{b}	0.102 ± 0.019^{b}	**0.0001**
ACTIVA	$0.158\pm0.017^{a,C,D}$	$0.161\pm0.024^{a,B}$	0.072 ± 0.010^{b}	0.095 ± 0.023^{b}	**0.0001**
Filtek Z250	$0.190\pm0.049^{a,D}$	$0.219\pm0.031^{a,B}$	0.064 ± 0.013^{b}	0.083 ± 0.007^{b}	**0.0001**
$p^{\#}$	**0.0001***	**0.0001***	0.055	0.492	

$P^{\#}$ (p<0.05) one-way analysis of variance (ANOVA).
**** Tukey multiple comparison test***
-Different superscript lower case letter in each row indicate significant difference according to Newman Keuls multiple comparison test (p<0.05).
-Same superscript capital letter in each column for Group C and Group F indicates no significant difference according to Tukey multiple comparison test (p>0.05).

The intergroup comparisons between the groups in each material according to Newman Keuls test revealed that mean Ra values obtained in group F were significantly higher than group SF in all materials ($p<0.05$), showing that surface coating prior to APF application decreased surface roughness when compared to APF application alone. Nevertheless, the difference between group C and F was insignificant in all tested materials except Amalgomer CR, which showed mean surface roughness values in group F lower than group C. Application of APF did not significantly increased surface roughness in any of the materials tested ($p>0.05$).

The intergroup comparisons between the restorative materials tested in each group using Tukey multiple comparison test showed that the differences between mean surface roughness values of all materials in groups C and F were found statistically significant (*p*=0.0001). In both groups the lowest surface roughness was obtained in Dyract XP; however the highest values were determined in Amalgomer CR for group C and in Fuji IX for group F.

DISCUSSION

GICs are sensitive to early moisture contamination and dehydration during the initial setting period, which may negatively affect the physical and aesthetic properties of these materials.[21] To protect GICs from detrimental effects, immediate application of a surface coating agent is recommended.[11] Moreover, surface coating treatment may decrease the surface roughness of the materials.[9] According to several *in vitro* studies, surface coating application was not found to be effective in decreasing the surface roughness of restorative materials. However, finishing and polishing procedures were not carried out before applying surface coating agent in these studies.[22,23] Unlike the previous studies, it was stated in other studies that the use of surface coating improved the surface smoothness of restorative materials, but all samples were finished and polished prior to the surface coating.[9,24] Similarly, in the current study, finishing and polishing procedures were performed on all samples before the application of the surface coating. For all restorative materials except Dyract XP, the group S demonstrated significantly lower Ra value than the group C (*p*<0.05). Various studies reported that finishing and polishing procedures deteriorated the smooth surfaces produced with Mylar strip.[25-27] Therefore, in light of these studies, the smoothing effects of surface coating may be more visible on the finished and polished surfaces. However, in this study, there was no significant difference in surface roughness between the group C and S of the compomer. It may be attributed to the content of the compomer which showed smoothest Ra values for the group C. Hence, surface coating might not have promoted a significant decrease in surface roughness on the group C of the compomer. Based on the results of the present study, there is a valid reason to accept the first null hypothesis.

The critical surface roughness value for bacterial colonization on restorative materials is determined to be 0.2 µm. Above this value, plaque accumulation, gingivitis, and staining can be observed, and all these may reduce the longevity of the restoration.[28] In the current study, the Ra values of the groups S and SF for all materials were lower than this critical value, which implies that surface coating improved the surface smoothness of the restorative materials considerably. On the other hand, since the group F of the Dyract XP, Beautifil II and ACTIVA demonstrated Ra values below 0.2, it may not be necessary to apply surface coating for these materials before APF application. However, topical fluoride applications are perfomed many times clinically. Therefore, the disruptive effects of the APF gel on the surface of the materials may not be seen because the APF gel was applied only once in this study.

Topical fluoride application is an important part of preventive dentistry. Unfortunately, APF gel includes hydrofluoric and phosphoric acids that have the ability to accelerate the degradation of the glass particles and can enhance the surface roughness of restorative materials.[29-31] In contrast, Botta et al.[16] reported that APF gel decreased the surface roughness of microhybrid composite resin and resin-modified GIC. Also, the surface roughness of the nanofilled composite resin was not influenced by APF gel. In accordance with the previous study, in the current study, for all restorative materials except Amalgomer CR, there were no statistically significant differences between the group C and F regarding the surface roughness (*p*>0.05). For Amalgomer CR, the group F showed a significantly smoother surface than the group C (*p*=0.001). Papagiannoulis et al.[32] demonstrated that zirconium-containing materials were not susceptible to APF agents. Considering the results of the previous study, it can be suggested that ceramic-reinforced particles in Amalgomer CR may be resistant to acid attacks. Another study claimed that APF could chemically attack the inorganic particles of the material, reducing the surface roughness.[16] Moreover, it has been reported that the removal of only the resin matrix by finishing and polishing causes the filler particles to protrude from the surface, thereby increasing the surface roughness.[25,33] In a study, after finishing and polishing processes, a significant increase in surface roughness was found in Amalgomer CR.[27] Therefore, in this study, the decrease in surface roughness after APF application in the Amalgomer CR may be due to the chemical attack of APF on glass particles other than zirconium particles, which become prominent on the surface after finishing and polishing. Based on the results of the present study, the second null hypothesis, that APF would increase the surface roughness of the restorative materials was rejected.

Many studies have suggested that conventional GICs result in high surface roughness values owing to the large particle sizes of their formulation.[25,26] Consistent with these studies, the higher Ra values of Fuji IX and Amalgomer CR before and after APF treatment can be attributed to their compositions consisting of large size particles. Besides, the size and shape of the filler particles as well as the composition of the material play an important role in the behaviour of restorative materials when exposed to topical fluoride applications.[34,35] It has been observed that APF gel application increases the surface roughness of GICs compared to resin composites.[36] Also, Soeno et al.[30] reported that microfilled material surfaces were not sensitive to the APF gel agent compared to macroinorganic-filled material surfaces. According to another study, APF gel significantly increased the surface roughness of Fuji IX and Vitremer with large particles. However, nano-sized filler particle containing materials showed negligible alteration in surface roughness after APF gel application.[29] Contrary to those studies, the surfaces of the Fuji IX containing large particles and Dyract XP, Beautifil II, ACTIVA and Filtek Z250 containing small particles were not modified by APF gel in the present study. For Amalgomer CR with large particles, the control group showed rougher Ra values than group F. On the other hand, the resin matrix may act as a barrier to prevent the surface degradation of restorative materials caused by topical fluoride applications.[17,29,37] In the current study, APF did not significantly increase the surface roughness of the non-resin based materials. Therefore, regarding the results of this study, it does not seem reasonable to claim that the effect of APF gel on surface roughness depends on the particle size and resin content of the materials.

A coating agent may be able to protect the surfaces of the restorative materials against acid attacks. Previous studies demonstrated that a glaze application protected the surface of GICs from the APF gel.[38,39] Similarly, Reddy et al.[40] observed that the surface textures of the GICs protected with G-coat Plus (GC Corporation, Tokyo, Japan) were not affected by acids. In addition, Khosla et al.[20] stated that surface coat application prior to using 1.23% APF gel prevented the surface alteration in GICs. Likewise, in this study, APF did not notably increase the Ra values of the coated materials tested. The results of the current study support the third null hypothesis. However, it cannot be claimed that surface coating protects the surface texture of restorative materials from APF gel since APF gel application did not increase the surface roughness of the non-coated restorative materials tested. This result might be attributed to the short-term application of APF gel. The prolonged exposure time may lead to surface alterations.[41] Therefore, additional *in vivo* and *in vitro* studies are required to evaluate the long-term effects of APF agents on surfaces of various restorative materials.

CONCLUSION

APF gel application did not cause remarkable degradation on the surface of the coated and non-coated restorative materials. The surface coating decreased the surface roughness of the restorative materials. Although APF gel did not modify the surfaces of the materials, surface coating treatment before applying an APF gel could be suggested to enhance the surface smoothness of dental materials.

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Conflicts of interest statement
The authors declare no conflict of interest.

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