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SURFACE ROUGHNESS OF RESTORATİVE MATERİALS- AN AFM STUDY İN DENTİSTRY

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ABSTRACT
Objective: This study's objective was to evaluate the surface roughness of the five restorative materials. **Materials and Methods:** Five materials were used to construct the specimens: a high viscosity GIC (Fujı IX GP; GC, Tokyo, Japan), an RMGIC (Fujı II LC; GC, Tokyo, Japan), a giomer (Beautifil II; Shofu, Kyoto, Japan) a nano-filled resin composite (Estelite Σ Quick; Tokuyama, Tokyo, Japan) and a micro-hybrid resin composite (Charisma Smart; Heraeus Kulzer, Hanau, Germany). In a teflon mold, fifteen bar-shaped specimens of each material were created (n=15). Each group was stored in distilled water at 37°C for 24 hours before testing. The specimens' mean surface roughness values (Ra) were calculated using atomic force microscopy (AFM). The Kolmogorov-Smirnov test was applied to verify if the data were normally distributed. One-way ANOVA and Tukey HSD posthoc analyses were used to compare the groups' mean surface roughness values ($P = 0.05$). **Results:** The highest surface roughness value was found in the high viscosity GIC ($p<0.05$). The lowest surface roughness values were obtained from the giomer, the nanohybrid resin composite, and the micro-hybrid resin composite ($p<0.05$). The surface roughness values of the giomer, the nanohybrid resin composite, and the micro-hybrid resin composite were not statistically different ($p>0.05$). The resin-modified glass ionomer showed statistically a lower surface roughness value than the high viscosity glass ionomer ($p<0.05$). **Conclusion:** While the addition of resin to glass ionomer cement improves the surface roughness properties of the material, there is no difference between the surface roughness values of resin composites and the giomer.

KEYWORDS: High viscosity glass ionomer cement, resin-modified glass ionomer cement, giomer, surface roughness.

INTRODUCTİON
Currently, resin materials and polyalkenoate-based materials—of which glass-ionomer cement is the most biomimetic—are the two main direct dental materials that are accessible for use in oral health. Glass-ionomer cements (GICs) are the only restorative material capable of chemically adhering to the tooth structure, and they offer interesting qualities such as biocompatibility, bioactivity, fluoride release, good coefficient of linear thermal expansion/contraction, and modulus of elasticity. To improve the wear resistance of GICs to occlusal stresses, enhance their subpar mechanical qualities, and increase their gauge range, producers have developed high-viscosity GICs. However, although there are currently studies to improve the low mechanical properties of glass ionomer cements, their mechanical properties are weaker than composite resins and they are not aesthetic materials.[1–3] In addition, a new class of hybrid aesthetic restorative materials termed giomers has recently been introduced. Giomers have been produced to combine the biological properties of glass ionomer cements with the mechanical properties of resin composites. The glass-ionomer in the restorative material is developed using pre-reacted glass-ionomer (PRG) technology.[3] The important features of composite resins are their superior mechanical, good aesthetics, and handling qualities, which all help to shorten the time needed for operations.[4]

In addition to its mechanical properties, the aesthetic qualities of the restoration also play a role in how long it will last. In other words, the longevity of restoration is affected by its aesthetic qualities. One of the desired properties of the restorative material is to be evaluated in terms of aesthetics and to preserve its aesthetic properties not only at the time of restoration but also over time. Surface properties are a factor affecting the aesthetic success of restorations. Surface roughness analysis is one of the techniques used to evaluate the surface properties of materials. Surface roughness is a factor that affects the long-term aesthetic performance of the material. Because the excess surface roughness will increase the formation of biofilm on the material, affecting the formation of secondary caries under the restorative material and the adhesion of coloring pigments on the surface of the restorative material, thus negatively affecting the long-term success of the restoration.[5,6]

Surface roughness has been given a maximum acceptable threshold value of 0.2 µm (200 nm), which will depend on technical advancements in dental restorative materials. Above this point, increasing bacterial growth on material surfaces is a challenge for biomaterials.[7] Surface roughness can be assessed quantitatively using profilometry or qualitatively with scanning electron microscopy up to the nanoscale. Atomic Force Microscopy (AFM) has been increasingly utilized in dentistry in recent years to examine the properties of various materials. AFM does not require working in a vacuum or any specimen preparation, and it enables three-dimensional (3D) imaging with a nanometric resolution.[8,9]

New materials for restoration are constantly being developed. However, more studies on this material are needed to assist physicians in the selection of restorative materials. The surface roughness values of the materials are also a feature that will affect the physicians' material selection. Therefore, this study aims to evaluate the surface roughness of different restorative materials by AFM.

MATERİALS AND METHODS

In the present study, the surface roughness of five different restorative materials was tested. The restorative materials were a high viscosity GIC (Fujı IX GP; GC, Tokyo, Japan), a resin-modified GIC (Fujı II LC; GC, Tokyo, Japan), a nano-filled resin composite (Estelite Σ Quick; Tokuyama, Tokyo, Japan) and a micro-hybrid resin composite (Charisma Smart; Heraeus Kulzer, Hanau, Germany), a giomer (Beautifil II; Shofu, Kyoto, Japan) were used. Table 1 contains a list of the components, composition, producer, and lot number.

Table 1: The composition of the materials according to the manufacturers' data.

Materials	Type	Composition	Manufacturer	Lot
Fujı IX GP	High viscosity GIC	Polyacrylic acid, fluoroaluminosilicate glass, polybasic carboxylic acid	GC, Tokyo, Japan	180110A
Fujı II LC	Resin modified GIC	2-hydroxyethyl methacrylate, Polyacrylic acid, water and fluoro-aluminosilicate glass	GC, Tokyo, Japan	2010051
Beautifil II	Giomer	BIS-GMA, TEGDMA, inorganic glass filler, aluminium oxide, silica, prereacted glass ionomer filler, camphoroquinone	Shofu, Kyoto, Japan	111787
Estelite Σ Quick	Nano-filled resin composite	Bis-GMA, TEGDMA, silica zirconia fillers, silica-titania fillers, photoinitiators	Tokuyama, Tokyo, Japan	E699
Charisma Smart	Micro-hybrid resin composite	Bis-GMA, Barium Aluminum Fluoride glass, silicon dioxide	Heraeus Kulzer, Hanau, Germany	K010516

Bis-GMA: Bisphenol A diglycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate

Specimen preparation

For the surface roughness test, 15 specimens from each material were prepared, a total of specimens 75. The specimens for the surface roughness test had a diameter of 5 mm and a thickness of 2 mm. After the material had been put into the teflon molds, the polyester strips (Mylar strip; SS White Co., Philadelphia, PA, USA) were pressed into the mold surfaces to extrude superfluous material and create a flat surface. According to the manufacturer's instructions, an LED light-curing unit was used to polymerize the resin-modified GIC, the giomer, and the resin composites through the glass plate (Smartlite Focus; Dentsply, Milford, DE, USA). The Smartlite Focus curing light (Dentsply, Milford, DE, USA) was measured for intensity before and after application, and the output was never less than 1,000 mW/cm2. The specimens were removed from the molds after the cycle of light-curing and setting. To produce a flat surface, the specimens were gently polished by hand using 1,000- and 1,500-grit wet silicon carbide papers in a circular motion. Each specimen received a quick rinse with tap water in between each grit. All of the samples were made at room temperature (21±1 °C), with a relative humidity of 55 percent. Each group spent 24 hours before testing in distilled water at 37°C.

Surface Roughness

The specimens’ mean surface roughness values (Ra) were calculated using atomic force microscopy (AFM, ezAFM, NanoMagnetics Instruments, Ankara, Turkey). The specimens were assessed using a Si3N4 tip with a frequency of 1 Hz in contact mode. Three distinct locations were randomly chosen to determine the surface roughness values with a scan area of 5 x 5 m and a resolution of 512 x 512 pixels. NMI ezAFM v4.8.2.3 control software was used to analyze the surface roughness values and compute the mean roughness value for each specimen.

Statistical Analysis

Statistical analyses were performed with the SPSS Program, version 25.0 (Statistical Package for the Social Sciences; SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was applied to verify if the data were normally distributed. The mean surface roughness values of the groups were compared using one-way ANOVA and Tukey HSD posthoc tests. A p-value less than 0.05 was considered statistically significant.

RESULTS

The surface roughness values of the materials with standard deviations are presented in Table 2. The highest surface roughness value was found in the high viscosity GIC ($p<0.05$). The lowest surface roughness values were obtained from the giomer, the nanohybrid resin composite, and the micro-hybrid resin composite ($p<0.05$). The surface roughness values of the giomer, the nanohybrid resin composite, and the micro-hybrid resin composite were not statistically different ($p>0.05$). The resin-modified glass ionomer showed statistically a lower surface roughness value than the high viscosity glass ionomer ($p<0.05$). But, the surface roughness value of the resin-modified glass ionomer was statistically higher than the giomer, the nanohybrid resin composite, and the micro-hybrid resin composite ($p<0.05$).

Table 2: The mean surface roughness values (ηm) and standard deviations of the materials.

Materials	Surface roughness values
Fujı IX GP	121.35 ± 29.74^{a}
Fujı II LC	98.72 ± 24.85^{b}
Beautifil II	75.54 ± 19.58^{c}
Estelite Σ Quick	65.78 ± 15.63^{c}
Charisma Smart	71.42 ± 18.16^{c}

Same small superscript letter indicates no statistical difference in the column

DISCUSSION

The surface roughness of the restorative materials hurts their marginal integrity and tendency to abrasion. It also results in the coloring of the restoration, plaque buildup, and gingival irritation, all of which have a negative clinical impact.[10,11] The amount, type, size, shape, and distribution of filler particles, the type of resin matrix, the filler and matrix combination, the flexibility of finishing and polishing methods, the hardness of the abrasive, and the application techniques all affect how rough the surface is.[12] Depending on the factors mentioned above that determine surface qualities, the restoration's surface smoothness may change depending on the type of restorative materials.[13]

Five different restorative materials' surface roughness was evaluated in the current study. The high viscosity GIC was determined to have the greatest surface roughness value in the investigation. Surface roughness values for resin-modified GIC were less than those for high viscosity GIC. Additionally, giomer, nanohybrid resin composite, and micro-hybrid resin composite had the lowest surface roughness values.

In the present study, the values of average Ra for all tested materials were within the range of 0.12-0.07 µm range, respectively. This indicates that these differences could be the result of the materials' composition. The essential surface roughness (Ra) for bacterial colonization is 0.2 µm, according to research by Bollen et al. on the relationship between titanium implant Ra values and bacterial adhesion. Surface roughness greater than 0.2 µm is probably going to dramatically increase bacterial adhesion, dental plaque development, and acidity, which act on material surfaces and raise the risk of caries. In this study, each material had surface roughness below this threshold.[14]

In the present study, the surface roughness value of RMGIC was lower than the high viscosity GIC. The result is similar to previous studies.[5,15,16] As reported in previous studies, the result may be due to the structural features of RM-GIC. The surface roughness differences between the two tested glass ionomer cement materials in this study, as observed in other studies, can be attributed to their distinctive structure.[17,18] The production of conventional GICs, or GICs in their original, classical form, begins with a powder-liquid mixture and an acid-base reaction.[1] These are complex substances that have compositions that vary greatly depending on the formulation. In addition to water, the liquid mostly comprises polyacrylic acid. The liquid is represented schematically as an aqueous solution of polyacrylic acid with many ionized carboxyl functional -COOH groups, which are consequently in the form of COO-. Some formulations directly include the lyophilized acid groups in the powder. The liquid, which is almost entirely composed of water, serves as a secondary activator for these groups. The powder has fundamental reactive FAS fillers in it. This term is deceptive, though, as other substances like strontium, phosphate, zinc, calcium, or sodium may be included, depending on the composition selected by the producer. These FAS fillers contribute significantly to the acid-base reaction that sets the material and also influence the material's ultimate mechanical characteristics. The FAS fillers used in commercially available traditional GICs are not silanated to retain their reactivity due to the lack of a resin in their formulation.[1,19,20] Even though the name "HV-GIC" is frequently used in international literature, some authors still classify these medicines as traditional GICs. Small FAS fillers are added to the other materials in these HV-GICs to speed up the reaction. The latter gain from a surface modification, which raises their responsiveness. Both the molecular weight of polyacrylic acid and the powder-to-liquid ratio rise.[21,22]

RM-GICs combine a radical polymerization reaction involving methacrylate monomers with the same acid-base reaction as GICs. The liquid is used with monomers, commonly 2-hydroxyethyl methacrylate (HEMA), and photoinitiators as camphorquinone. With resin addition, setting time is sped up, mechanical characteristics are improved, and the material is less sensitive to aqueous or saliva contamination than with standard GICs. Silanated FASs are used as fillers. Manufacturers have not adequately explained the silanization process for reactive fillers, which theoretically enables the attachment of these FAS particles to the resin matrix, increasing the cross-linking of the resin network, enhancing the material's final mechanical properties, and modifying the solubilization of the reactive fillers.[1,23]

In this study, the surface roughness was no different among the three tested materials, giomer, and two different resin composites, attributed to their similar chemical structure.

In contrast to a micro-hybrid composite, where the particle sizes may range between 0.01 and 2.0 μm, the average size of the filler particles in a micro-filled composite is roughly 0.04 μm. New filler materials have recently been created with diameters ranging from 5 to 100 nm. The purpose of applying nanotechnology to resin composites is to develop resins with superior mechanical and aesthetic properties since the fillers are distributed more widely and are smaller in size. There are variations in the organic compositions of these nano-filled composites as well, which could produce different mechanical properties. As a result, the mechanical properties of these new materials, such as their polymerization shrinkage, tensile strength, compressive strength, resistance to fracture, and reduced wear, may be improved. The smaller size and widespread distribution of the nano-fillers may increase the filler load. According to previous studies, nanocomposites enhance translucency and polish and maintain that polish similarly to micro-filled composites while having physical characteristics and wear resistance on par with hybrid or universal composites.[8,24]

The sizes and distributions of filler particles have improved in recent years, along with advancements in composite resin restorations in dentistry, and new products with enhanced mechanical and esthetic qualities have been released on the market.[25] Giomer is composed of three primary parts: a resin matrix, fillers, and a coupling agent. As such, it has a composite structure. According to the manufacturer's data, the micro-filled composite's fillers are made up of silicon dioxide and ytterbium trifluoride. This type of "inhomogeneous" micro-filled composite resin has two different types of fillers, including silicone particles that range in size from 0.04-0.2 m and larger organic filler particles that are designed to fill the resin matrix to its maximum capacity and produce better mechanical properties. In this regard, the composite resin's resin content drops. This type of composite resin has a filler content of 46 vol% and 66.7 wt%. Bis-GMA, UDA, and TEGDMA make up the resin component of Beautifil II giomer. Beautifil II, on the other hand, is the second generation of fluoride-releasing light-cured giomers. Its fillers are composed of discrete nanofillers, pre-reacted glass fillers with surface reactivity, and glass particles. Glass-ionomer powder particles that have been activated by polyacrylic acid on the surface compensate for S-PRG fillers. Even after eight years of clinical service, using this class of materials has produced a good aesthetic appearance and color matching. Additionally, Beautifil II giomer has discrete nanofillers (10–20 nm) in addition to bigger particles up to 4 m in size, allowing for a filler concentration of 68.6 vol% and 83.3 wt%.[26,27]

In their study, Ruivo et al. evaluated the surface roughness of five different restorative materials (two micro-hybrid resin composites, nano-filled resin, supra-nanofilled resin composite, and giomer and found similar surface roughness values between the materials after finishing the polishing processes. These findings are in agreement with the result of our study.[28] Borges et al., in another study in which they examined the surface roughness of five different composite resins, stated that there was no difference between the surface roughnesses after finishing and polishing processes.[29] Likewise, Giacomelli et al., in a study in which they examined the surface roughness values using three micro-hybrid resin composites, two nano-hybrid resin composites, and one nano-fil resin composite found that there was no difference between the control groups' surface roughness values.[30] In another study, the surface roughness values of micro-hybrid and giomer were examined and no statistical difference was found between the values.[27]

In addition, besides the surface roughness values of giomer and resin composites were not different in this study, the surface roughness of these three materials was lower than both the glass ionomer cements. Similar to the results of this study, as an of conclusion Guler and Unal's study, the surface roughness of five different restorative materials was evaluated and it was stated that the giomer had a lower surface roughness than RM-GIC.[11] According to a study by Mohammed-Tahir et al., the giomer's surface roughness value was lower than that of high viscosity GIC.[31]

The limitations of this study are that only the surface roughness values are considered among the factors used to test the clinical life of five different restorative materials. The values after 24 hours of aging were also looked at in this review. Restorative materials are subjected to acid from diet or abrasion from brushing in the dynamic oral environment. In consideration of these, in vitro and in vivo investigations are needed to evaluate the material's performance.

CONCLUSİON

Within the limitations of this investigation, the surface roughness of giomer, nano-filled resin composite, and micro-hybrid resin composite was the lowest. The highest surface roughness value was found in the high-viscosity GIC. The surface roughness of RM-GIC is lower than the high-viscosity GIC.

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