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ORIGINAL ARTICLE

Effect of Water and Chlorhexidine with Different Pressures of Oral Irrigation Device on the Surface Roughness and Topography of Giomer

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ABSTRACT
Objective: To evaluate the effect of different pressures of an oral irrigation device (OID) and the irrigation solution type on the surface roughness of the giomer restorative material. **Material and Methods:** In this *in vitro* study, disk-shaped giomer samples were fabricated and assigned to 5 groups (n=23): Group 1, storage in distilled water (control); Group 2, OID #7 pressure/ water; Group 3, OID #10 pressure/ water; Group 4, OID #7 pressure/ 0.05% CHX; Group 5, OID #10 pressure/ 0.05% CHX. The samples' treatment simulated a one-year application of OID. Surface roughness (Ra) and topography of the giomer were evaluated using profilometry and scanning electron microscopy. The data were analyzed with Paired t-test, Tukey, and ANOVA tests (α=0.05). **Results:** The Ra of the samples increased significantly after treatment with OID ($p<0.001$). The roughness increase in groups with a pressure of 10 was higher than those with a pressure of 7 ($p<0.001$). The effect of pressure on surface changes was significant ($p<0.001$). However, the solution type and the cumulative effect of these two factors were insignificant ($p=0.08$ and $p=0.43$, respectively). **Conclusion:** Oral irrigation device with both solutions significantly increased the surface roughness and topographic changes of the giomer. The severity of these changes was related to the device's pressure.

Keywords: Surface Properties; Biguanides; Composite Resins; Pressure.

Introduction

Mechanical oral hygiene methods such as using a toothbrush and dental floss are the most common tools to eliminate microbial plaque from the available tooth surfaces [1,2]. However, more than these methods are required due to the inaccessibility of some dental areas [3]. Antibacterial mouthwashes have improved the efficacy of mechanical methods. Chlorhexidine digluconate (CHX) has a long history of inhibiting dental plaque and is considered the gold standard in decreasing microbial counts. The cationic nature of this material increases its absorption to different surfaces, including teeth, mucosa, pellicle, and plaque. Its low concentration (0.05%) can be used daily for a long time with minimal side effects [4-6].

Recently, oral irrigation devices (OIDs), also called water flossers and water jets, have become popular as adjunctive tools for oral hygiene and removing microbial plaque, especially in areas with limited access, such as proximal and gingival areas. The American Academy of Periodontology declared that supragingival irrigation with this device could be more effective in decreasing microbial plaque and gingivitis than toothbrushing alone [7].

The mechanism of action of OID relies on irrigation through pulsation and high water pressure. The applied water pressure creates shearing hydraulic pressure that can remove bacterial biofilms. A minimum pressure of 60 PSI is required for the clinical efficacy of oral irrigation, and higher pressures are safe [8]. Scanning electron microscope evaluations have shown that a 3 s application on each surface can remove 99.9% of biofilms from the area involved [9]. This device can be used several times a day depending on the patient's need, especially in patients with gingival problems or those with problems during flossing and toothbrushing [7].

Oral irrigation can be carried out with different solutions, such as water or antimicrobial agents. Using CHX instead of water has produced good antibacterial activity against subgingival pathogens as oral irrigation [10]. CHX in OIDs in its diluted solution (0.04% and 0.06% concentrates) has been accepted [7].

Studies on the effect of OID on gingival attachments have deemed it a safe device [11]. However, worries are related to the possible impact of the irrigation solution pressure on the surface of polymer-based restorative materials such as composite resins with lower hardness than the tooth enamel and a heterogeneous structure [12]. The surface topography of composite resins has a significant role in biofilm aggregation. Increased surface roughness increases biofilm aggregation, periodontitis, recurrent caries, and surface staining and discoloration over time [12,13], especially when surface roughness exceeds 0.2 µm [14].

Recently, a new generation of resin restorative materials, called giomer, has been introduced. Giomer is produced by combining pre-reacted glass-ionomer filler particles with the matrix of composite resin materials. Giomer materials have the double advantage of composite resin materials, such as esthetic and mechanical strength, and the benefit of glass-ionomer materials, including fluoride release and recharge and protection against caries [15]. Therefore, these materials have been recommended in all restorative cavities and direct veneers, especially in patients with caries risk [16].

Previous studies have evaluated the effects of adjunctive tools for oral hygiene, such as toothbrushes and mouthwashes, on abrasion and erosion of resin-based materials. However, contradictory results have been reported regarding the type of mouthwashes and composite resins [3,17,18].

Only a few studies are available on the effect of OID on restorative materials. A previous study reported that this device increased the surface roughness of micro-hybrid and nanohybrid bulk-fill composite resins [19]. Another study showed that increasing the OID pressure has significantly increased the surface roughness in composite resins with spherical particles [20].

Sufficient data are not available on the possible effect of this device on the surface of resin-based restorative materials, especially concerning giomer, whose use has increased to restore cervical lesions next to gingival tissues. These areas are more exposed to oral irrigation devices due to their position. Therefore, the present study evaluated the effect of two different pressures of the Waterpik WP-100 oral irrigation device and two irrigation solutions (water and 0.05% CHX) on the surface topography and roughness of giomer restorative material in a simulated one-year use. The null hypotheses were: (1) there would be no significant difference between different pressures, and (2) no significant difference among the effect of irrigation solutions.

Material and Methods

Ethical Clearance and Study Design

This research was approved by the Research Committee of the Guilan University of Medical Sciences (IR.GUMS.REC.1399.629). The present *in vitro* study used giomer (Beautifil II LS) restorative material with A3 shade. Table 1 presents the characteristics of this material.

Table 1. The characteristics of giomer used in the study.

Commercial Name	Composition	Filler
Beautifil II LS, Shofu Inc., Kyoto, Japan (LOT: 071959)	Bis-GMA, TEGDMA, S-PRG filler based on fluoro-boro-alumino-silicate glass, Polymerization initiator, Pigments	Size:0.01-5µm Average:0.8µm Loading: 83.3 weight %

Bis-GMA: Bisphenol A Glycol Dimethacrylate; TEGDMA: Triethylene Glycol Dimethacrylate; S-PRG: Surface Pre-Reacted Glass-Ionomer.

Sample Preparation and Treatment

A total of 115 disk-shaped samples of giomer were prepared using a round mold measuring 5 mm in diameter and 2 mm in height. The mold was filled with giomer, and a Mylar matrix was placed on the filled mold; then, the samples were light-cured through the matrix [21]. An LED light-curing unit (LED-F, Woodpecker, Medical Instrument, Guangxi, China) was used to light-cure the samples under 1100 mW/cm^2 (normal mode) light intensity, perpendicular to and very close to the material surface for 20 s. The light intensity was repeatedly checked with a radiometer (Woodpecker, Medical Instruments, Guangxi, China). The lower surface was marked to differentiate between each sample's upper and lower surfaces.

The samples were stored under 100% humidity at 37 °C for 24 hours. Afterward, the samples were polished using Sof-Lex (3M ESPE, Saint Paul, MN, USA) polishing disks, starting from medium to superfine. Each polishing disk was used for 30 seconds parallel to the surface. After these procedures, the giomer samples were rinsed with distilled water and randomly assigned to 5 groups (n=23) for the treatment procedures with OID:

- Group 1: Control (storage in distilled water);
- Group 2: OID with water; #7 pressure;
- Group 3: OID with water; #10 pressure;
- Group 4: OID with 0.05% CHX; #7 pressure;
- Group 5: OID with 0.05% CHX; #10 pressure.

The prepared 0.05% CHX solution for use with the OID, Vi-One alcohol-free 0.2% CHX mouthwash (Tabriz, Iran) was diluted to 1:3 proportion (mouthwash-to-water). The pH of the prepared CHX solution was determined with a pH meter (Jenway Model 3505, Cole-Parmer Instrument Company LLC, Vernon Hills, IL, USA) at 6.16.

The samples were treated in each group once a week for eight weeks to lengthen the process and better simulate the clinical condition. In groups 2 to 5, the OID was used for 5 minutes each time (40 minutes in eight weeks). This duration was estimated to be equal to a one-year use, twice daily, for three seconds each time [9] on each surface. The classic jet tip (suitable for supragingival irrigation) of the WP-100 Waterpik device (Waterpik Inc., Fort Collins, CO, USA) was placed perpendicular (according to the manufacturer's instructions) to the giomer material surface at a distance of 2 mm from the surface. To this end, the handle of the water-jet device was mounted in a fixed position. The pressure gauge in groups 2 and 4 was set to 7, which was almost equal to 63 PSI (the minimum pressure required for a proper clinical function of OID) [8], and to 10 in groups 3 and 5 (equal to 90 PSI, the device's maximum pressure). Then, each sample was rinsed with water for 10 s and stored in distilled water at room temperature until the next round of treatment. No intervention was made in group 1 samples stored in distilled water.

Evaluation of Surface Roughness Using Profilometry

Each sample's surface roughness (Ra) was determined using a contact probe of a profilometer (Hommel-Etamic Tester T8000, Hommelwerke GmbH, Germany) by carrying out three consecutive measurements in the middle area of each sample and calculating the mean Ra for each sample. The profilometer was adjusted to a 0.8-mm cut-off, mm tracing length of 4 mm, and mm stylus speed of 0.5 mm/s. The Ra of each sample was determined initially (after polishing) and at the end of the treatment period.

Observation of Surface Topography Using Scanning Electron Microscopy (SEM)

Two additional samples from each group were prepared for microscopic evaluations to assess the samples' surface quality before and after the study procedure. The samples were gold-sputtered and evaluated under a scanning electron microscope (Mira/LMU, Tescan, s.r.o, Brno, Czech). Surface micrographs were taken at ×500 and ×3000 magnifications.

Data Analysis

Shapiro-Wilk test was used to evaluate the normality of data, and Levene's test was used to assess the equality of variances. Paired t-test was used for intra-group comparisons of Ra before and after treatment. One-way ANOVA and post hoc Tukey tests were used to compare Ra changes between the groups. Two-way ANOVA was used to evaluate the effect of different factors and their cumulative effects. SPSS 26 (IBM Corp., Armonk, NY, USA) was used for statistical analyses at a significance level of $p<0.05$.

Results

Analysis of Surface Roughness

Table 2 presents the means and standard deviations of Ra in different groups. A paired t-test showed significant differences in Ra after treatment in the groups treated with OID ($p<0.001$). However, Ra decreased slightly in the control samples. There were significant differences in Ra changes between the groups ($p<0.001$, one-way ANOVA), with the most substantial changes in the OID groups with the pressure gauge on ten and water or CHX solution (Table 2). According to two-way ANOVA, only the effect of OID pressure on Ra changes of giomer was significant ($p<0.001$, df=1, F=1249.826). In contrast, the effect of solution (water vs. CHX) and the cumulative effect of the two factors were not significant ([IP=0.083, df=1, F=3.07] and [p=0.434, df=1, F=0.617] respectively).

Table 2. Means and standard deviations of surface roughness (µm) of giomer in terms of treatment types.

Groups	Ra (Before)	Ra (After)	ΔRa	p-value
Control	0.16±0.02	0.16±0.02	-0.003±0.01[a]	0.008*
OID#7/water	0.16±0.02	0.30±0.02	0.13±0.01[b]	<0.001*
OID#10/water	0.16±0.02	0.42±0.02	0.26±0.01[c]	<0.001*
OID#7/CHX	0.15±0.02	0.30±0.02	0.14±0.01[b]	<0.001*
OID#10/CHX	0.16±0.02	0.43±0.02	0.27±0.01[c]	<0.001*

OID: Oral Irrigation Device; CHX: Chlorhexidine; ΔRa: Ra (After) – (Before); Different superscript letters indicate statistically significant differences; *Statistically Significant;

Analysis of Surface Topography

After treatment, the photomicrographs of the control group were almost similar to those before treatment, with smoother surfaces than the other groups. The groups treated with OID exhibited changes in the surface topography, with pits or cavities on the material surface. These changes were more prominent under the higher pressure of OID (#10) (Figure 1). The effects of different OID solutions (water/CHX) were not distinguishable.

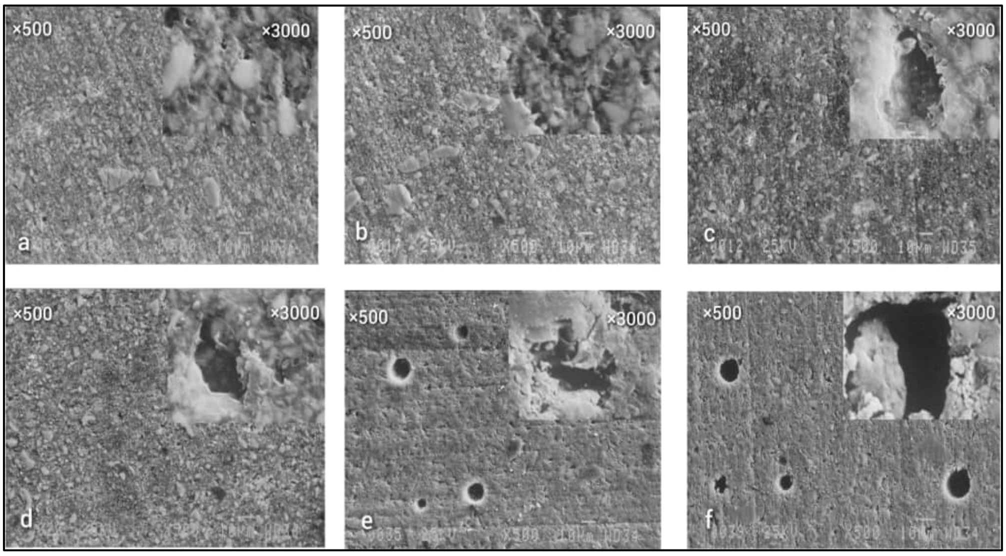

Figure 1. SEM images of giomer (×500, ×3000): (a) baseline, (b) control after eight weeks, (c) treated with OID#7/water, (d) treated with OID#7/CHX, (e) treated with OID#10/water, (f) treated with OID#10/CHX.

Discussion

Resin-based materials might undergo changes, including changes in surface roughness and surface texture, in the oral cavity under the effect of mechanical and chemical oral hygiene procedures. Increased surface roughness increases biofilm aggregation, dental caries, and periodontal diseases. The characteristics of filler particles, including their composition, concentration, size, and shape, are the most important factors in resistance against abrasion [22].

A new type of filler particle has been used to manufacture the giomer restorative material. Giomer (Beautifil II LS) has been manufactured by incorporating glass-ionomer filler particles in the form of S-PRG (surface pre-reacted glass-ionomer) measuring 0.01–5 µm into the resin matrix. These particles have been manufactured by the complete or partial reaction of fluoroaluminosilicate glasses with polyalkenoic acid [23].

The present study evaluated the effect of the WP-100 oral irrigation device with two different pressures (#7 and #10) and two irrigation solutions (water and 0.05% CHX) on the surface roughness and topography of the giomer restorative material. The results showed a significant increase in the surface roughness of the giomer material after applying the OID with a simulated use of one year.

In this study, the sample surfaces were polished under standard conditions to eliminate the weak resin-rich surface layer and the effect of this layer on the results [24]. On the other hand, the working conditions were similar to the clinical conditions. For the proper function of the Waterpik device, its tip was placed at a right angle to the sample surface in the cervical area according to the manufacturer's instructions. The pressure gauge of 7, equal to 63 PSI, and the maximum pressure of 10, equal to 90 PSI of the WP-100 device, were selected. The selection of the minimum pressure was based on a study by Jahn [8], who reported that a minimum pressure of 60 PSI is necessary for the clinical efficacy of OID and the removal of dental plaque. In addition, the maximum pressure was applied to evaluate the effect of high pressure on the surface of the restorative material because no range has been reported in this respect by the manufacturer, and high pressures might be applied under clinical conditions.

The mechanism of action of OID relies on the contact of high liquid pressure and creating shearing forces [20]. Therefore, the increased surface roughness of the giomer was probably due to the shearing forces transferred from the device during its continuous application, resulting in surface abrasion, the failure of the filler–matrix bond interface, and the separation of the fill from the resin matrix.

Resin materials display different behaviors in the face of other abrasive materials. In this line, hybrid composite resins with large filler sizes undergo more abrasion because larger filler particles are more prominent on the material's surface and serve as a cantilever, facilitating their detachment from the resin matrix. However, smaller and more uniform particles in nanofilled and microfilled composite resins are more resistant to abrasion [25]. Beautiful II giomer material has S-PRG filler particles with large sizes of up to 5 µm, with a filler content similar to hybrid composite resins. The large filler particles increase the material's microporosity, detrimental to its polishability, making it more susceptible to increased surface roughness by abrasive agents [26]. Therefore, in the giomer, large filler particles were possibly detached from the matrix more efficiently, creating surface porosities and increasing surface roughness as determined by the profilometer. This can be explained by evaluating the SEM images of the material surface and the presence of depressions, pits, and areas devoid of filler particles, possibly due to the detachment of particles from the matrix.

In the present study, applying the maximum pressure ((#10) of OID resulted in increased surface roughness of the giomer material compared to lower pressure ((#7), which might be explained by higher shearing forces, stress, and destruction, leading to more surface roughness, with the use of higher pressure of the device.

Consistent with the present study, Naser-Alavi et al. [19] showed increased surface roughness in bulk-fill micro-hybrid and nanohybrid composite resins with an approximate pressure of 63 PSI of the WP-100 device. In addition, the present study results are relatively consistent with a study by Alharbi and Farah [20], in which a 50-PSI pressure of the Aquaris device did not change the surface roughness of composite resin materials. However, the device's maximum pressure (100 PSI) resulted in changes in the surface roughness of some composite resin materials. Microhybrid composite resins with spherical particles (Estelite Sigma Ouick and SphereTEC One Ceram-x) exhibited more surface roughness than other microhybrid composite resins. It was reported that their shape could affect the material's resistance to abrasion in addition to the particle size. The relative differences between the two studies might be attributed to differences in the type and model of the devices, the selected pressure, the procedural steps, the long process of the present study to simulate the oral cavity environment, and the material's aging, and the differences in the tested materials.

The present study, giomer was used, with large S-PRG particles made of glass-ionomer. These fillers contain a large amount of fluoride and metallic ions, and water can easily penetrate them. The giomer material has more water sorption than composite resins [27]. On the other hand, S-PRG fillers might have a lower chemical bond with the resin matrix due to the heterogeneous nature of the particles. Therefore, the filler–matrix bond interface might not be as stable as conventional composite resins; more filler detachment might occur under the effect of abrasive agents [28]. As a result, when OID was applied in the present study, the giomer material was possibly more susceptible to hydrolytic changes, filler particle debonding on superficial layers, particle loss, and increased surface roughness. Tanthanuch et al. [29] also reported poorer function and more surface roughness in giomer than nanohybrid composite resins after immersion in an acidic solution.

Another finding of the present study was the similar effect of water and 0.05% CHX as the solutions used in OID on changes in the surface roughness of the samples. In a study by Furtado and Amorin [17], immersing bulk-fill composite resins in alcohol-free 0.05% CHX did not change surface characteristics. However, alcohol-containing 0.1% CHX increased the materials' surface roughness. These changes might be attributed to the concentration and alcohol content of mouthwashes. Da Silva et al. [18] reported that alcohol-containing mouthwashes and those with the lowest pH produced the highest surface roughness in composite resins.

The effect of mouthwashes depends on their chemical content and pH. Alcohol is a bipolar molecule that destroys the bonds between the resin matrix and fillers [28]. On the other hand, methacrylate monomers are hydrolyzed under low pH; therefore, all these changes make the rein material susceptible to erosion and abrasion [30]. According to the Waterpik device's manufacturer, mouthwashes can be used in diluted forms in this device. Therefore, in the present study, diluted CHX mouthwash with 0.05% concentration was used, and its pH was determined at 6.16 by a pH meter. Therefore, the results can be justified considering the low concentration, an almost neutral pH, and the alcohol-free nature of the mouthwash used.

The sample's surface topography was evaluated to support profilometry findings in the present study. The SEM images confirmed changes in the material's surface roughness as measured by profilometry to a great extent. Therefore, applying OID appeared to result in filler particle detachment, leaving cavities on the material surface. More numerous, larger, and deeper cavities were visible in the images of samples treated with the higher pressure of the device.

In the present study, OID increased the surface roughness of the giomer beyond the bacterial colonization threshold (0.2 µm) but less than the patient's clinical diagnosis threshold (0.5 µm), which was higher than those reported by Alharbi and Farah [20]. Such a discrepancy might be attributed to the S-PRG fillers with a large size, leaving large cavities due to the detachment of the particles compared to composite resin. Therefore, the giomer material is more susceptible to increased surface roughness by abrasive agents.

At the end of the study, samples in the control group were slightly smoother than the baseline, which might be explained by water sorption and the short-term swelling of the resin matrix in the absence of abrasive forces, resulting in less surface roughness in subsequent measurements by a profilometer [18].

Considering the limited results of the present study, applying the WP-100 oral irrigation device to the giomer restorative material is not entirely safe. The present study confirmed the detrimental effects of this device on the giomer material surface. The continual use of the device might compromise the material surface, increasing its surface roughness, which was more prominent at higher pressures of the instrument. Therefore, it is advisable to exercise caution in prescribing this oral hygiene adjunctive device to patients with resin restorations (especially giomer) in the cervical areas of teeth exposed to OID at a high rate. Suppose this device is used in these patients. In that case, a minimum required pressure should be applied with the periodic supervision of the dentist in charge to monitor and polish the restorations.

The results of the present *in vitro* study cannot directly be extended to the clinical conditions. The saliva, pellicle, pH cycles, and heat might affect the test conditions in the oral cavity. Therefore, it is recommended that future studies be carried out under conditions as close as possible to the oral cavity conditions. In addition, due to the lack of studies on this subject, further studies are suggested with more diverse restorative materials and mouthwashes with different formulations.

Conclusion

Applying the Waterpik oral irrigation device resulted in increased surface roughness and changes in the topography of the giomer. The severity of changes was proportional to the device's pressure, with a pressure of #10 resulting in more surface roughness than a pressure of #7. Water and 0.05% chlorhexidine digluconate as the solutions used with oral irrigation devices caused similar changes on the surface of the giomer restorative material.

Authors' Contributions

FNA	https://orcid.org/0000-0002-4879-5434	Conceptualization, Methodology, Validation, Investigation, Resources, Writing - Original Draft, Writing - Review and Editing, Visualization and Funding Acquisition.
FH	https://orcid.org/0009-0008-0813-4042	Software, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Review and Editing and Visualization.
AS	https://orcid.org/0000-0003-4504-5141	Conceptualization, Methodology, Validation, Writing - Original Draft, Visualization, Supervision, Project Administration and Funding Acquisition.
NM	https://orcid.org/0000-0001-5084-7021	Conceptualization, Validation, Formal Analysis, Investigation, Resources, Data Curation, Writing - Review and Editing, Visualization and Funding Acquisition.

All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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