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INFLUENCE OF ULTRASOUND AND MANUAL TOOTHBRUSHING ON ABRASION RESISTANCE OF THREE DISSIMILAR GLASS-IONOMER-BASED RESTORATIVE MATERIALS

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ABSTRACT

Objectives: The surfaces of restoration materials can be abrasively worn down by tooth brushing. The objective was to assess the abrasive impact of two distinct toothbrushing approaches (ultrasound and manual) on the abrasion resistance of three different glass-ionomer-based restorative materials. **Materials and Methods:** A total of 78 glass-ionomer- based restorative materials of disk-shaped samples were used in this study. The samples were divided into three equal main groups (n= 26) according to the type of restorative material; Group A; Giomer, Group B; light-cured Resin-modified GIC (RMGIC), Group C; conventional GIC. Then each main group was further subdivided equal two subgroups (n=13) based on the method of brushing (Manual and ultrasound). A cylindrical split Teflon mold with dimensions of (7 mm diameter and 2 mm thickness) was used to make disks of the different restorative materials in all groups. The brushing simulation was carried out by a device with moving arms holding manual and ultrasound toothbrushes. Measurements of abrasion resistance (surface Loss) using scanning electron microscopy (SEM). **Results:** The results revealed that all Giomer restorative material had the higher significant abrasion resistance followed by RMGIC and then GIC. **Conclusion:** Surface abrasion varies depending on the material as well as the brushing approach.

KEYWORDS: Abrasion Resistance, Manual, Toothbrushing, Ultrasound, Glass Ionomer, Restorative Materials.

INTRODUCTION

Highly organized, varied microbial populations adhered to the surface of hard tooth tissues make up dental plaque (dental biofilm) [(1)]. The development of biofilms is a gradual process that happens in a series of stages: an acquired pellicle forms, followed by adhering bacteria proliferating after the early colonization, secondary colonization/co-aggregation, and maturation of the biofilm [(2, 3)].

Brushes and toothpaste are typically used for oral care to mechanically remove the dental biofilm. Brushing your teeth is a healthy oral hygiene practice that may help to avoid dental cavities and promote gingival health[(4)]. In general, the effectiveness of brushing depends on the type of toothbrush used, whether it is worn, how it is used when it is used, and whether mouthwash is used [(5)].

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The complete and long-term removal of dental biofilms from the oral cavity cannot be ensured, however, at this time [6]. But ultrasonic toothbrushes appear to be quite effective in getting rid of dental plaque and can significantly improve oral health [3]. Along with the direct scratching action, the bristle motion of the toothbrush creates turbulent fluid flow, which directly results in hydrodynamic phenomena including wall shear pressures that operate parallel to the tooth surface. Ultrasound toothbrushes may help in providing adequate dental care due to their usage of frequencies greater than 20 kHz in comparison to manual brushes. [3, 4].

Direct restorative applications that may be used in one session are increasingly chosen for the maintenance and defense of the integrity of dental hard tissues[7]. In comparison to resin-based restorative materials, GIC materials have inferior physical and mechanical qualities, such as a lesser resistance to fracture, hardness, and resistance to wear[8]. Compared to GICs, RMGIC has better mechanical and aesthetic qualities, and it releases fewer fluoride ions[9].

A direct dental restoration's endurance and the material's physical characteristics, like hardness, wear resistance, or surface roughness, determine how long it will last[10]. Because it can promote surface bacterial colonization, the surface roughness of restorative materials is a crucial feature [9]. Long-term abrasive exposure can weaken the mechanical resistance of restorative materials, rendering them more susceptible to abrasive wear like that caused by toothbrushing[11]. Surface roughness changes occur when inorganic materials, like GIC, are exposed to abrasive wear, however, RMGICs are less susceptible to this phenomenon[9]. The purpose of this in vitro study was to evaluate the abrasive effects of two different toothbrushing approaches on the abrasion resistance of three various glass-ionomer-based restorative materials.

MATERIALS AND METHODS

From the results of a previously published study by Saruttichart et al. (2017) [12], a power sample size calculation of 13 samples per group was required to detect a significant difference between groups for a 95% confidence interval and power of (50%). A total of 78 glass-ionomer-based restorative materials of disk-shaped samples were used in this study. The samples were divided into three equal main groups (n= 26) according to the type of restorative material; Group A; Giomer (Beautiful II, Shofu, Kyoto, Japan), Group B; light-cured RMGIC (Riva LC Capsule, Riva (SDI), Australia), Group C, conventional GIC (Medfill, Promedica, Germany). Then each main group was further subdivided equal two subgroups based on the method of brushing (Manual and ultrasound).

Sample preparation:

For the creation of the glass-ionomer-based repair discs in all groups, a split Teflon cylindrical mold with dimensions of (7 mm diameter and 2 mm thickness) was employed (Fig. 1). A polyester strip (Stripmat, Polydentia, Mezzovico, Switzerland) with a thickness of 0.05 mm was laid on a glass slab before the GIC material was put into the mold. The mold was then set, and the glass-ionomer-based material was packed. Each glass-based restorative substance was slightly overfilled into the Teflon mold. A second polyester strip was applied on top of the mold, and a second glass slab was clamped with consistent pressure of the glass slab to provide a uniform surface polish and remove extra cement[13,14].

The conventional GIC material was allowed to self-cure for 2 minutes and 20 seconds. While the Giomer and RMGIC were cured according to the manufacturer's instructions with a light-emitted diode (LED) light-curing unit (Blue phase C 5, Ivoclar Vivadent) for 20 seconds from both sides to ensure adequate polymerization. The light polymerization was performed with the tip

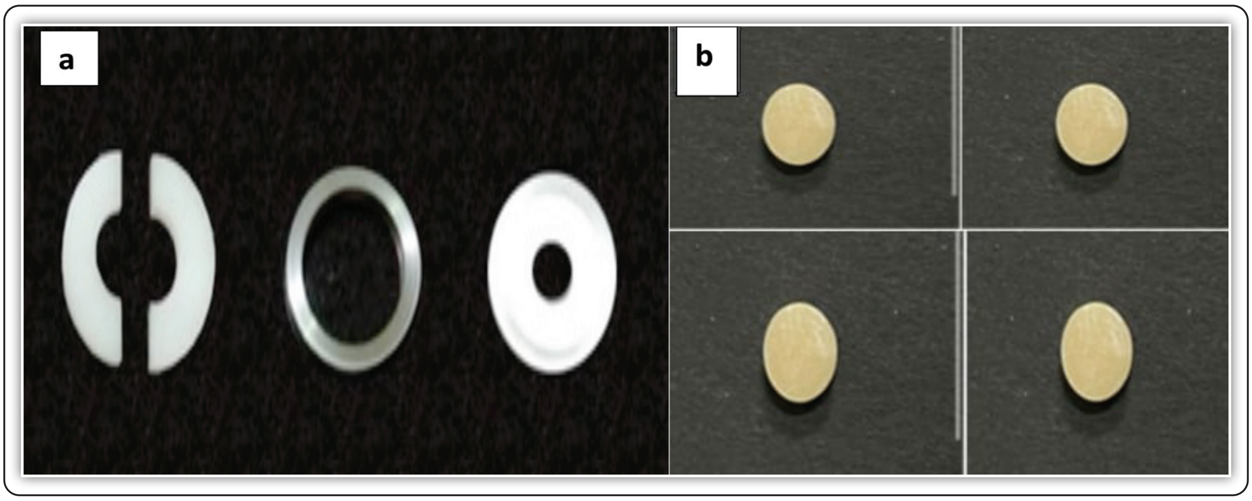

FIG (1) A photograph showing (a) cylindrical split Teflon mold (7 mm diameter and 2 mm thickness), (b) GIC disk samples.

positioned at a distance of 1 mm from each Giomer and RMGIC disk with the aid of a microscopic glass slab. Then, the conventional GIC and RMGIC materials were immediately coated with a nanofilled resin coating (EQUIA Coat, GC Europe, Leuven, Belgium) and light-cured for 20 seconds using a LED light-curing unit [13, 14]. (**Fig. 1**)

After a complete set, all samples were kept in an incubator (PA.3A, Advanced Technology, Egypt) at 100% relative humidity in distilled water at 37˚C. The samples were then polished on their surface using four sets of abrasive polishing discs (Sof-Lex extra thin, 3 M ESPE). A low-speed Endomotor handpiece (TCM ENDO III, SybronEndo, Nouvag AG, Switzerland) operating at 13,000 revolutions per minute under dry circumstances was utilized to polish in four different directions for a total of 60 seconds. With a steady pressure of around 2 Newton, one operator applied seven polishing strokes for 15 seconds in each direction. The samples were rinsed with water and given an air blow between each polishing cycle. Only one sample was polished with each abrasive wheel. The polished samples were cleaned using an ultrasonic cleaner for five minutes in distilled water (BioSonic UC125, Coltene Whaledent, Altstatten, Switzerland) and then allowed to air dry [13, 14].

Brushing simulation procedures:

Before the brushing simulation (abrasion) processes, one-sided adhesive tape was applied to half of each sample's surface. A machine with movable arms carrying manual and ultrasonic toothbrushes performed the brushing simulation. In this study, a manual toothbrush and a commercial ultrasonic toothbrush were both employed, with the following specifications: rotation sense changes every 30 seconds, and a load of the toothbrush standardized at 250 grams. The sample surfaces were parallel to the toothbrushes' alignment. A groove was drawn as a guide on the samples at the limit using adhesive tape to retain the reference surfaces for lesion-depth estimation and allow the correct superimposition of the baseline and posttreatment profiles. To apply the toothpaste, 500 microliters of distilled water were diluted with pre-weighted 0.2 grams of toothpaste (Colgate-Palmolive, Chonburi, USA), before being dispensed with a syringe straight to the surface of the sample. People were expected to wash their teeth twice daily for an average of two minutes in this research (10 seconds for each sample). The mechanism used to evaluate the toothbrush's abrasion was based on a 1.25-hertz frequency for 20,000 cycles, which was equal to 8000 seconds of abrasion and 2 years of brushing [13, 14, 15].

Evaluation of surface loss measurements:

After surface toothbrushing simulation (abrasion), the tape was removed from each sample. The samples were selected for scanning electron microscope (SEM) made in USA model Prisma E (Thermofisher company) to assess the surface topography. SEM examination of each sample was operated at an accelerating voltage of 30 kV. The examination of all groups was done at x500, x2000, and x3000 magnification. Then, an area 2 mm long (x) and 2 mm wide (y) was scanned with SEM at the center of the abraded substrates. By subtracting the mean height of the test region from the mean height of the unabraded area, Image J software version 1.53 (National Institutes of Health, USA) was used to determine surface roughness parameters (Ra and Rq in mm) from SEM pictures [15]. (**Fig. 2**)

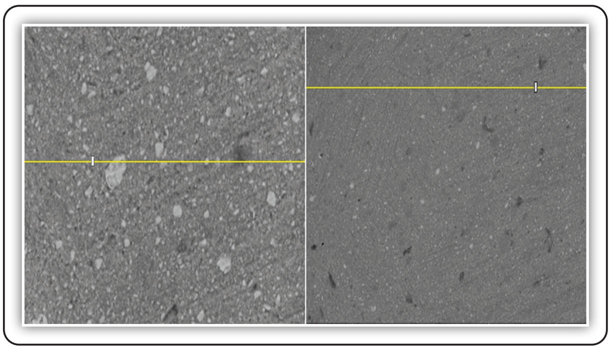

FIG (2) A photograph showing the SEM measurement method.

Statistical analysis

The Shapiro-Wilk test was used to verify the normality of distribution. The collected data were tabulated and analyzed statistically using SPSS® statistics Version 20. The One-way ANOVA test was used for quantitative data with normal distribution to compare more than two groups. An independent t-test was used to compare two group means. The results were set as significant at $p<0.05$.

RESULTS

The independent t-test results showed that the difference between the sample means of manual tooth brushing and ultrasonic tooth brushing for the three tested restorative materials is statistically significant. The results revealed that ultrasonic tooth brushing resulted in a significant increase in surface loss of all tested materials in comparison with manual tooth brushing.

The One-way ANOVA results revealed that there was a statistically significant difference in the abrasion resistance of the three tested restorative materials after manual or ultrasonic brushing. The results revealed that Giomer had the higher significance abrasion resistance (lower surface loss) followed by RMGIC and then the conventional GIC.

TABLE (1) Comparison of area loss of different restorative materials with manual versus ultrasonic tooth brushing:

Variable	Manual toothbrush	Ultrasonic toothbrush	t-value	p-value
	Mean± SD	Mean± SD		
Giomer	0.49 ± 0.027^{Ca}	0.66 ± 0.024^{Cb}	16.49	<0.001*
RMGIC	0.72 ± 0.026^{Ba}	0.92 ± 0.025^{Bb}	20.41	<0.001*
GIC	0.92 ± 0.033^{Aa}	1.21 ± 0.020^{Ab}	26.79	<0.001*
p-value	0.0000*	0.0000*		

**; significant at p≤0.05.*

Different uppercase letters in the same column mean are statistically significant.

Different lowercase letters in the same raw mean are statistically significant.

The independent t-test results showed that the difference between the sample means of manual tooth brushing and ultrasonic tooth brushing for the three tested restorative materials is statistically significant. The results revealed that ultrasonic tooth brushing resulted in a significant increase in surface roughness of all tested materials in comparison with manual tooth brushing.

The One-way ANOVA results revealed that there was a statistically significant difference in the surface roughness of the three tested restorative materials after manual or ultrasonic brushing.

The results revealed that conventional GIC recorded the higher significance surface roughness followed by RMGIC and then Giomer.

TABLE (2) Comparison of surface roughness of different restorative materials with manual versus ultrasonic tooth brushing:

Variable	Manual toothbrush	Ultrasonic toothbrush	t-value	p-value
	Mean± SD	Mean± SD		
Giomer	0.069±0.002[Ca]	0.094±0.008[Cb]	9.94	<0.001*
RMGIC	0.089±0.003[Ba]	0.123±0.004[Bb]	23.41	<0.001*
GIC	0.125±0.004[Aa]	0.159±0.004[Ab]	20.66	<0.001*
p-value	0.0000*	0.0000*		

**; significant at p≤0.05.*

Different uppercase letters in the same column mean statistically significant.

Different lowercase letters in the same raw mean are statistically significant.

DISCUSSION

Teeth brushing is a very basic and popular way of preventing common oral diseases[13,16]. Unfortunately, the most frequent reason that lowers the quality of restorative materials is oral hygiene practices [17]. The purpose of this study was to assess the abrasion resistance and surface roughness of various types of glass-ionomer-based tooth-colored restorative materials after simulating brushing with manual and ultrasonic toothbrushes.

This present study examined the surface characteristics of restorative materials by imitating toothbrushing with the use of devices that looked like toothbrushing machines with moving arms holding manual toothbrushes[18,19,20]. Standardization of the force applied and toothpaste used was therefore considered in the design of the present study to limit the variables that influence the complex mechanisms of abrasion [18].

In this study, toothpaste that had been diluted was utilized to standardize the abrasive impact of the various examined tooth brushing techniques[16]. Furthermore, in this study, brushing for 20,000 strokes replicated two years of twice-daily brushing for the recommended two minutes. The American Dental Association's general recommendations for reducing the prevalence of caries and periodontitis in 2017 advocate for using fluoride toothpaste and brushing twice daily for an optimum 2 minutes [13].

Both RMGIC and the conventional GIC in this study were coated with light polymerized low-viscosity resin adhesives to increase their surface wear resistance and to simulate the clinical conditions. This is because Lohbauer et al. (2011)[21] stated that to increase wear resistance, all glass ionomer materials must be coated, either with G-coat plus or light polymerized low viscosity unfilled resin adhesives. In this study, a three-body wear test was used to assess how well glass ionomer-based restorative materials held up after brushing. The test used three different objects: a toothbrush, toothpaste, and restorative material surfaces [15].

In this present study, SEM was used to determine the difference in the effect between manual and ultrasound brushing on the abrasion resistance of tested restorative materials to get the full picture and do a thorough study. This is because it was found that SEM is required to gain the whole picture and conduct a comprehensive analysis, however, profilometers may provide you with information in only two dimensions [22].

In terms of the abrasion resistance measurement, the findings of this investigation proved that all of the materials underwent good surface stability. This could be attributed to the increasing wear resistance of RMGIC and conventional GIC materials due to coating, light polymerized low viscosity resin adhesives [21]. These results agreed with the results of the study by Komandla et al. (2021)[23] who reported that post-brushing treatment increased readings of surface roughness of glass ionomer restorative materials, however, they were below the threshold limits of 0.2 μm.

Moreover, the significant difference in the abrasion resistance of the tested restorative materials in this present study with either manual or ultrasound toothbrushing could be attributed to the fact that the materials employed in this investigation have different particle-size of fillers as Giomer, RMGIC, and conventional GIC have mean particle sizes of 0.8 mm, 5.9 mm, and 10 mm, respectively. (13) The volume and size of glass in organic particles have been shown to affect the wear of materials by Komandla et al. (2021) (23) as well. In addition, Singh et al (2021) (17) stated that the volume and distribution of the filler grains as well as the resins' superior polymerization are both likely to play a significant role in the restorative resin-based material's resistance to toothbrushing.

Moreover, the results of abrasion resistance in this present study revealed that the Giomer restorative material has higher abrasion resistance when compared with RMGIC and the conventional GIC after manual and ultrasound brushing. This is because instead of the robust bond-like silane coupling agents that were employed in the production of Giomere materials, the matrix of RMGIC and ordinary GIC was made up of molecules that were weakly coupled cation cross-linked polyacid molecules (13, 16, 23). Komandla et al. (2021) (23) stated that because of several reasons, there were reported to be significant differences in wear among the materials, one of these factors is the composition and characteristics of the matrix. Moreover, The findings of Tărăboanță et al. (2022) (9) may provide insight into Giomere and RMGIC's resilience to chemical and physical aggressiveness, therefore, after exposure to the abrasive effect of toothbrushing the resin-based glass ionomers showed lower change than GIC.

According to the findings of the current study, the mode of brushing simulation had a detrimental impact on the studied restorative materials' ability to resist abrasion, with ultrasonic brushing having the most negative abrasion effect. This result may be explained by the low-amplitude, high-frequency vibrations that ultrasonic toothbrushes create (20,000 Hz or less is the minimum) (24). Loitongbam et al. (2020)(25) stated that Evidence supports the fact that the abrasiveness of toothpaste may be caused by a combination of its abrasive action and the mechanical action of toothbrush bristles. Moreover, Dionysopoulos et al. (2017)(15) reported that factors that affect the amount of wear on the material surface include the size, shape, and type of abrasive, the pressure applied, and the properties of the wear surface.

The new design of the novel ultrasound toothbrush used in this study featured multi-tufted filaments, flat-trimmed, polished end bristles arranged crisscross-style on two flexing sides. (25) Moreover in agreement with our results Kumar et al. (2015) (26), found that flat trim end bristle designs produce less surface abrasion than alternative designs. Use of the hard bristle toothbrush with toothpaste may also be to blame for the incidence of reduced scratches or roughness by manual toothbrushes. Studies have shown that using a soft bristle brush with toothpaste is more abrasive than using a hard bristle brush. (27)

The findings of this study, however, differ from those of Demirel and Baş (2021) (28) and Komalsingsakul et al. (2021) (13) who found no difference in the amount of roughness between powered and manual brushing. The same hardness of toothbrush bristles is blamed for the lack of a statistically significant difference. But Singh et al. investigation's (2021) (17) showed that toothbrushing enhanced the roughness of the surfaces of the restorative materials.

CONCLUSION

Surface abrasion varies depending on the material as well as the brushing approach. The results revealed that all Giomer restorative materials had a higher significant abrasion resistance followed by RMGIC and then GIC.

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