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EFFECT OF SIMULATED TOOTHBRUSHING ON SURFACE ROUGHNESS OF DIFFERENT RESIN COMPOSITE MATERIALS: IN VITRO STUDY

Hazem H. Farouk[1*], Radwa I. El-Toukhy[2], Nadia Zaghlol[3]

ABSTRACT

Objective: To evaluate the variations in surface roughness of three nano-scale resin composites (injectable universal nano-fill, universal nano-fill, universal nano-hybrid) prior to and following a simulation of toothbrushing. **Materials and methods:** 30-disc shaped (10 × 2 mm) samples were fabricated from three different resin composites and grouped into three groups based on the kind of resin composite (n=10): 2 nanofilled composites (G-aenial universal injectable and Filtek Z350 XT) and one nanohybrid composite (Tetric N-ceram). Each specimen was subjected to a toothbrushing simulator for 30 and 60-minute which represented 6 months and 1 year of daily clinical tooth brushing respectively. Surface roughness (Ra) was assessed prior (baseline) and following 30, 60-minute of simulated toothbrushing by profilometer device. Analysis of data was done utilizing the Two-way ANOVA test and post-hoc test for pairwise comparison. **Results:** After toothbrushing the surface roughness increased significantly in all tested materials. The Ra was statistically higher in the nanohybrid composite than in the two nanofilled composites. However, the two nanofilled composites recorded non-significant differences. The injectable universal nano-fill group showed the lowest mean value of surface roughness, while the highest value was recorded for the nano-hybrid group prior to and following the tooth brushing. **Conclusions:** Surface roughness after simulated toothbrushing was material and time-dependent**.** Nanofilled resin composites may be more suitable for dental aesthetic restorations that require long-term maintenance of smoothness.

KEYWORDS: Surface roughness, Simulated toothbrushing, Nanofilled composite, Nanohybrid composite.

INTRODUCTION

The usage and popularity of dental composites have increased due to breakthroughs in restorative materials. Due to significant advancements in the area of cosmetic dentistry with regard of physical, mechanical, and aesthetic properties, composite materials have been used for years as predominated restorations [(1)]. There are several types of composite materials that may be used in clinical settings. These materials contain a broad variety of inorganic and organic elements that could have an impact on the materials' handling characteristics and usage in clinics. It has been demonstrated that composite materials efficiency may be significantly increased by adding well-dispersed inorganic particles into the resin matrix [(2)].

1. Masters Candidate, Conservative Dentistry Department, Faculty of Dentistry, Mansoura University, Egypt.
2. Assistant Professor of Conservative Dentistry Department, Faculty of Dentistry, Mansoura University, Egypt.
3. Professor of Conservative Dentistry Department, Faculty of Dentistry, Mansoura University, Egypt.

• ***Corresponding author*:** hazemmoaty@gmail.com

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The three main components of tooth-colored resin composites, which are heterogeneous substances, are the resin matrix, filler particles, and silane-coupling agent [3]. Composite restorations now provide a significantly higher level of functionality because of the development of nanotechnology. Improved aesthetics and mechanical efficiency are able to be attained with nanotechnology due to the smaller size of fillers and, subsequently, the greater filler load [4].

Typically, filler criteria like kind, dispersion, and particle size have been used to categorize composite materials. With an attempt to increase early polishability, smoothness, and gloss preservation, the filler size has progressively lowered, moving from hybrid, microhybrid, and microfilled composites to nanofilled composite materials. Currently, the marketplace mostly consists of two kinds of nano-sized composites: nanofilled and nanohybrid composites[5]. Nanohybrid composite materials depend on blending nanoscale and micrometer-sized fillers, whereas nanofilled ones comprise of nanosized fillers and/or nanofiller clusters. Because of their combined qualities of mechanical and esthetics properties, such substances are suggested to be utilized restoration of the anterior and posterior teeth [6].

Based on the viscosity of the composite materials it can be categorized into three groups: universal, packable, and flowable. Universal composite materials are moderate viscosity while packable composites are stiffer. Flowable composite materials are characterized by low viscosity because of the existence of modifying agents like surfactants and they have a reduced filler content [7]. The injectable method of composite restoration has several benefits, including being predictable, repeatable, easy to use, minimally invasive, and patient-affordable [8].

The surface qualities of dental restorations are very significant for their clinical effectiveness, and the surface roughness is thought to be an important surface attribute. Abrasion resistance, discoloration, and recurrent caries are all exacerbated by surface roughness, which also reduces aesthetic appeal [9]. The filler ingredient, kind, size, and shape are among the many crucial elements that influence the surface roughness of every restoration [10].

Tooth brushing is an efficient way to maintain an environment conducive to excellent oral health. However, it causes the mechanical characteristics to deteriorate and the surface roughness to rise, which in turn causes plaque to gather up restorations [11]. Moreover, surface texture, gloss, and color alterations due to the surface roughness might affect restorations' longevity and clinical efficacy [12]. Furthermore, the average time taken to brush by a person daily is 120 seconds. Based on this estimation, the maximum contact time for one tooth surface per day is 5 seconds. Thus, the 30 and 60-minute brushing time is equivalent to 6 months and 1 year of daily clinical tooth brushing respectively [13].

The current research's objective was to evaluate the variations in surface roughness of three nano-scale resin composites (injectable universal nano-fill, universal nano-fill, universal nano-hybrid) before and after laboratory tooth brushing simulation. The null hypothesis was that there is no significant difference in the evaluated nano-fill resin composites and nano-hybrid resin composites in surface roughness prior to and following tooth brushing simulation.

MATERIAL AND METHODS

Materials

Three types of composite restorations were utilized in the current research as listed in **(Table 1)**.

TABLE (1) Materials used in this study:

Brand name and material specification	Composition	Manufacturer and (Lot number)
G-aenial universal injectable (Nanofilled resin composite)	– Matrix: TEGDMA, UDMA, Bis-MEPP, photoinitiator and pigments. – Filler: ultrafine Barium glass and silica particles (150 nm), 69 wt.%, 50 vol.%.	GC Corp. (2108191)
Filtek Z350 XT (Nanofilled resin composite)	– Matrix: Bis-GMA, TEGDMA, UDMA, Bis-EMA, photoinitiator and pigments. – Filler: Silica, zirconia, nanoparticles (20 μm), and nanoagglomerated (0.4 - 0.6 μm), 78.5 wt.%, 55.9 vol.%.	3M ESPE. (NC40172)
Tetric N-ceram (Nano-hybrid composite)	– Matrix: Dimethacrylates (19-20% weight), photoinitiator, and pigments. – Filler: Brium glass, ytterbium trifluoride, mixed oxides and copolymers (0.4 – 0.7 μm), 80-81 wt.%, 55-57 vol.%.	Ivoclar Vivadent. (Z01SY3)

TEGDMA: triethyleneglycol dimethacrylate. UDMA: urethane dimethacrylate. Bis-MPEPP: Bisphenol A polyethoxy Methacrylate. Bis-GMA: bisphenol-A-diglycidyl-methacrylate. Bis-EMA: bisphenol A diglycidyl methacrylate ethoxylated.

Method

Sample size:

The research was using 30 specimens with sample size of 10 in each group. Considering the prior study by Lemos C et al [12], a sample size of 10 within every group and a significance alpha level of 0.05 (two-tailed) at a 95% confidence interval, there was 80% power to identify a variation among averages of 18.84. The findings will be regarded as “statistically significant” if the p-value is below 0.05 (two-tailed) in 80% (the power) of such studies. The variation in averages in the rest of the 20% of the studies will be labeled as “not statistically significant.” StatMate 2.00 from GraphPad produced the report.

Sample preparation:

From every material ten-disc shaped specimens (n = 30) were made by using a specially constructed split cylindrical Teflon mold of 10 mm diameter × 2 mm depth. A microscopic glass slide and a celluloid strip were positioned beneath the mold, and then a gold-plated instrument was used to apply the resin composite until the entire mold space was filled. Celluloid strip was applied on the top of the mold to avoid formation of oxygen inhibited layer. A second microscopic glass slide was placed on top of the resin composite surface, and a steady load of 500 grams was then imposed on the top of the glass slide for 30-seconds, to remove the extra resin composite and minimize surface voids [14].

The second microscopic glass slide and the weight removed then the resin composites were polymerized for 20 seconds based on the materials manufacture instructions with a LED light curing unit (Premium plus, UK ltd, Co2 curing light, China, wavelength 390~430nm/440~480nm, light intensity 1200 mW/cm^2) through the celluloid strip on the top surface of the samples. The curing light tip was put in direct contact with the celluloid strip and perpendicular to each specimen’s surface. The light intensity was determined at 800mW/cm2 using a dental radiometer (Premium plus UK ltd, c10 curing light meter, China). After removing the celluloid strip, an additional 20 seconds of light curing was applied to both sides of every sample. Then, a resin composite specimen in the shape of a disc was obtained once the mold was removed. Each specimen was finished and polished with blue Sof-Lex finishing and polishing discs (3M ESPE Dental Products, St. Paul, MN, USA) according to manufacturing instruction. Baseline measurements for surface roughness were assessed before brushing simulation process.

Sample grouping:

The total number of 30 samples were divided into three equal groups (n=10) based on the kind of resin composite restoration (G-aenial universal injectable, Filtek Z350 XT and Tetric N-ceram). Every group was examined for surface roughness (before and after 30, 60-minute of simulated toothbrushing).

Surface Roughness measuring

The surface roughness (Ra) of all specimens was measured with profilometer (Surftest SJ210, Mitutoyo Corp., Kawasaki, Japan). By Employment of a diamond stylus with a 5-micrometer tip radius and tip angle of 90 degree. On the sample surface, the probe was positioned in the center. The scan rate was 0.5 mm/s, with a tracing length of 0.8 mm. The measurements were captured at a resolution of 0.01 µm. A long line from the sample was configured to be read by the apparatus. In a regulated temperature and dry environment, scanning was carried out using the contact mode. Five scans of every sample were performed, and the (Ra) average in (µm) was then computed.

Simulated Toothbrushing

A specially manufactured brushing simulation equipment was created at Mansoura University's Faculty of Engineering's Department of Mechanics and Power. A battery-operated brushing (Oral-B Pro-Health Clinical Battery Toothbrush, Braun, Frankfurt, Germany) was one of the primary part of the equipment, that is secured to a plate, with the brush tip makes contact with a metal ring holding the sample disc **(Figure 1)**. With a specifically made sample holder, each sample was secured using double-face tape. From the force and time adjustment buttons, the applied force was adjusted at 2.5N according to the (2014) version of ISO (2813) basic specification [15] and the time was adjusted at two intervals 30 and 60 minutes. The toothbrush head was immersed in a toothpaste (Colgate Total, Colgate-Palmolive, Guildford, UK) which was combined with water to create a slurry (2:1, water: toothpaste) [12].

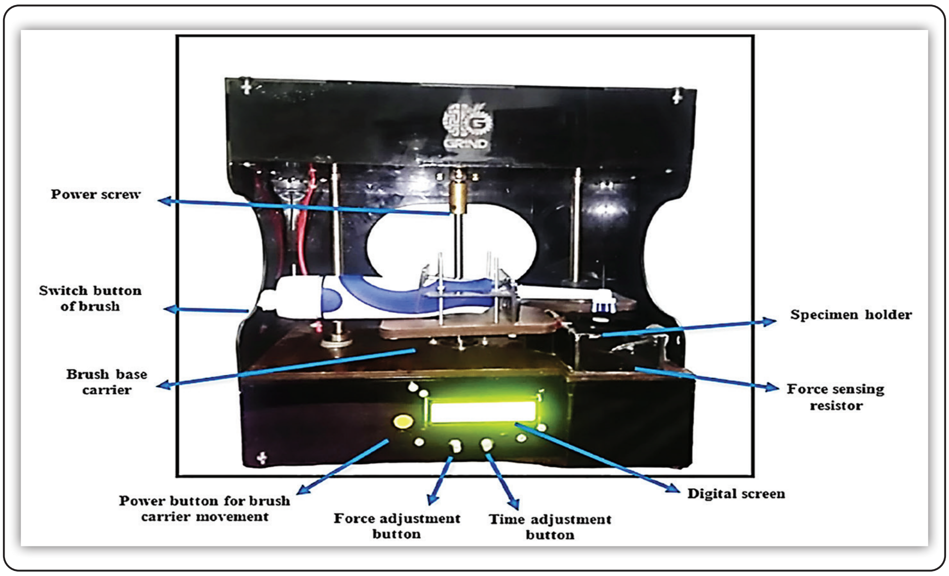

FIG (1) Photograph showing custom made brushing simulation device

The toothbrush was moved by pressing the trigger in charge of its motion. Consequently, the toothbrush holder began to gradually descend in a linear manner till the brush head touched the fixed specimen surface. After that, the electronic timer of the equipment began to calculate once the brushing cycle speed reached 250 cycles per minute. Every sample was subjected to brushing for 30 and 60-minute which was equivalent to 7500 and 15000 cycles. Finally, every specimen was thoroughly cleansed with tap water and 10-minute ultrasonically with distilled water for ten minutes to get the abrasive particles of the toothpaste off and then maintained in distilled water at 37 degree Celsius. With every specimen, a new toothbrush and newly created toothpaste slurry were utilized.

Statistics evaluation:

IBM SPSS Corp., released in 2013, was used to analyse the data given into the computer. Windows-compatible IBM SPSS Statistics, Version 22.0. Armonk, NY: IBM Corp. The cutoff for significance was chosen at $P \leq 0.05$. Two Way ANOVA test was utilized to assess the combined effect of 2 independent factors on dependent continuous outcome with the Post Hoc Tukey test for pairwise comparison.

RESULTS

According to the Two-way ANOVA test, our result displayed that the changing in the materials had a statistically significant effect on the change of surface roughness. Changing time of assessment (before brushing, after 30 min of brushing, after 60 min of brushing) had a statistically significant effect on change on surface roughness. The combination of both variables (materials and time) had a statistically significant effect on the change of surface roughness. According to adjusted R squared that equals 0.563, so 56.3% of the change in surface roughness was affected by changes in the materials and time of assessment.

Material as a variant:

Post-hoc test showed that before and after 30, 60-minute of simulated toothbrushing brushing: the injectable universal nano-fill group showed the lowest mean value of surface roughness, while the highest value was recorded for the universal nano-hybrid group.

The injectable universal nano-fill and the universal nano-fill groups recorded non-significant difference. However, the Ra was statistically higher in the nanohybrid composite than in the two nanofilled composites.

Time as a variant:

All the three materials showed the least value of surface roughness at baseline, and the highest value after 60-min of brushing, and there was a significant difference in the roughness values of each material itself at baseline, after 30-min, and after 60- min as shown in **(Figure 2)** and **(Table 2)**, based on the post-hoc test results.

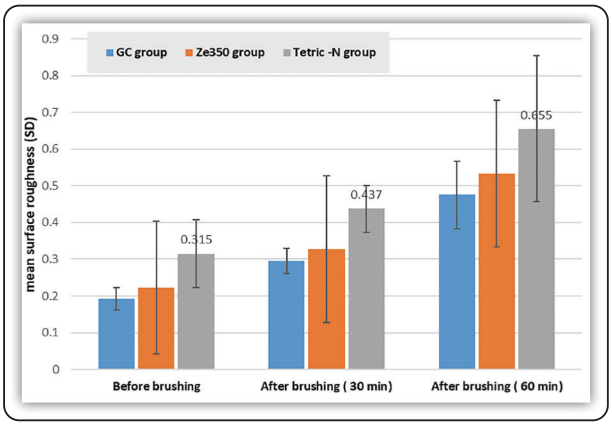

FIG (2) A bar graph displaying the data for the mean and standard deviation of the three materials' surface roughness as influenced by various follow up periods

TABLE (2) Post Hoc Tukey test of surface roughness between studied groups.

Surface roughness	Injectable nano-fill (N=10)	Universal nano-fill (N=10)	Universal nano-hybrid (N-=10)
Before brushing	$0.192\pm0.03^{A}_{a}$	$0.223\pm0.034^{A}_{a}$	$0.315\pm0.093^{B}_{a}$
After brushing (30 min)	$0.295\pm0.074^{A}_{b}$	$0.328\pm0.055^{A}_{b}$	$0.437\pm0.063^{B}_{b}$
After brushing (60 min)	$0.475\pm0.18^{A}_{c}$	$0.533\pm0.20^{A}_{c}$	$0.655\pm0.199^{B}_{c}$

Different Capital superscripted letters in the identical row indicate significant variation among materials (P<0.05).
Different small superscripted letters in the identical column indicate significant variation at every brushing time (P<0.05)

DISCUSSION

Resin composites are an essential dental restoration among dentists due to the rising need for cosmetic dentistry [(16)]. However, because of the physicochemical interactions occurring inside the restoration, the resin composites are subject to internal elements as well as external causes which including abrasive materials, for example, from the brushing process influencing the composite characteristics such as surface roughness [(12)]. Surface roughness (Ra) of restorations is related to individual unpleasantness, discoloration, wear, and plaque buildup. Additionally, it may have a detrimental impact on the aesthetic and functional results of the occlusion [(17)].

Employing the profilometer equipment, the (Ra) was evaluated numerically. The profilometer with a stylus that was employed in this investigation offers scale-size values for the Ra. Moreover, it enables the scanning of a larger surface area and delivers reliable Ra values, allowing for sufficient comparability of the researched resin composites[(18)].

Furthermore, the abrasive action caused by mimicked toothbrushing is a significant in vitro wear component and may mimic a clinical situation, it is regarded as a model that has previously been established in research [(19)]. Based on Sexson J [(20)], an individual does around 15 cycles of daily tooth brushing throughout every session. By doing so, around 10,000–14,600 cycles are finished by the completion of a year when oral hygiene care is focused on brushing teeth twice daily.

Our findings revealed that all tested composites showed significant increase in Ra after simulated tooth brushing and the brushing time was significant increase the Ra. The greatest Ra values were found following 15000 cycles. Such findings agreed with prior investigations which demonstrated a rise in Ra following simulated tooth brushing [(12,15,21)]. This may be due to the process of tooth brushing producing micro and macro imperfections on the resin composite surface which lead to increased irregular patterns and surface roughness. That led to a progressively increased in the Ra which was linked to the rising number of cycles for simulated tooth brushing [(22)].

In addition, the wear of the organic component of the resin may be used to clarify how the composite resins abrade, it results in gaps being created that differ based on the particle's size, thus raising the Ra following a simulation of tooth brushing [(19)].

Moreover, brushing could result in a rough surface on nanohybrid composite since bigger and more irregular filler tends to be highly protrusive following the polymerization. In addition, the nanofilled composite containing nanomer and/or nanocluster fillers could generate minimal flaws and scratches when brushed [23]. Nanoscaled silica/zirconia fillers and nanoclusters are present in the nanofilled composite restoration that was employed in this investigation. Such the agglomeration of the nanoparticles (nanoclusters) may lose their agglomeration because of the resin matrix has not enough retention when brushed [24].

Within the current research, the universal nano-hybrid group showed the significantly greatest value of Ra than the two tested nanofilled composites before and after simulated tooth brushing. This may be due to the Ra and composite wear has been associated with filler particle size. Composite resin with larger filler particles (nanohybrid) will be more roughness than those of finer filler particles (nanofilled)[25]. Based on our results, the null hypothesis was rejected.

Our results agreed with Yu P et al [26] who found that the nanofilled composite exhibited a significantly lower Ra value compared to the nanohybrid composite. Their explanation was that the shapes and distribution of filler particles impact the Ra and the specific filler pattern of nanoclusters in nanofilled composite result in smoother surface. It has been observed that the Ra relies on a number of variables and is affected by the kind, dimension, form, and arrangement of filler particles, as well as the resin matrix [27].

Additionally, the nanofilled composite consists of nanoparticles and nanoclusters decreasing the gaping area among the fillers and raising the filler loading. This improved the mechanical qualities and increased wear resistance, as during abrasion such nanoclusters wear at the rate like the adjoining resin matrix. The outcome is a long-lasting polished surface that is shiny and smooth [21].

Regarding nanohybrid composite, it contains filler particles larger than those of the nanofilled one. It may be expected that during brushing abrasion, the resin matrix wears down more quickly than the filler particles do, leading to greater irregularities in the surface texturing than nanofilled composite [26].

Again, our results showed that the injectable universal nano-fill group showed the lowest mean value of Ra before and after brushing. These findings agreed with Prakash V et al [28] who found that G-Aenial flo had the lowest mean value of Ra before and after brushing. They explained that may be due to the G-Aenial Flo is a true nanofiller composite which enhanced Ra lowering results in greater polish and luster than the nanocluster-filled (Filtek Z350 XT) resin composites. While the nanohybrid resin composite had higher Ra because the filler particles were bigger.

On the other hand, our findings were in contrast with Monteiro B et al [21] who found that there was no significant variation in Ra between nanohybrid and nanofilled composite resins after simulated brushing. This disparity in outcomes is likely due to differences in materials and methods as the type of nanohybrid composite and the number of brushings conducted in each research.

The limitation of our research is that the degradation of restorations in the oral environment is influenced by mechanical and chemical mechanisms which is a complex process. The vitro research might not fully capture all the circumstances and interactions affecting dental restorations within the mouth, because of the impact of additional liquids, enzymes, and proteins found in saliva. Thus, further randomized clinical research is necessary to evaluate these investigated factors [29].

CONCLUSIONS

Under the constraints of this research, we may conclude that:

- Surface roughness after simulated toothbrushing was material and time-dependent.
- The toothbrushing process had a negative effect on the surface roughness of all tested resin composites.
- Nanofilled resin composites may be more suitable for dental aesthetic restorations that require long-term maintenance of smoothness.

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