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Surface Roughness of Organically Modified Ceramic (ORMOCER)-Based bulk fill composite resin vs Methacrylate-Based Bulk fill Composite Resins (An In-Vitro Study)

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Aura bulk fill.

Abstract

Aim: to achieve the surface roughness of bulk-fill composite resins based on ORMOCER and methacrylate.
Materials and method: In this research, A total 24 specimens had been utilized in this work, were split to 2 groups (n=12) based on to the form of composite resin (Group I: bulk-fill composite resin based on ORMOCER and Group II: bulk-fill composite resin based on Methacrylate). Each group was subjected to surface roughness. Statistical analysis by, Mann-Whitney test to compare two groups, was utilized, then a Wilcoxon W test is performed. At $p < 0.05$, the significant threshold was established. A standardized cylindrical mold (polytetrafluoroethylene) had been utilized to fabricate the bulk-fill resin composite species which were examined prior and following wear stimulation and photographed utilizing a 3D-surface analyzing system.
Results: The mean Ra scores of the Aura bulk fill composite samples' surfaces were greater comparing with that of the Admira fusion x-tra composite samples' surfaces, where Ra is a measure of the arithmetic mean of all profile deviations throughout the mean sampling length in µm.
Following wear simulation, group II (Aura bulk fill) obtained the higher ΔRa mean value (0.0031±.0066 µm) followed by group I (Admira fusion x-tra) (0.0016± .0032 µm). Statistics showed that there was no variance across all groups ($p > 0.05$).
Conclusion: Composites made of methacrylate and ORMOCER are both susceptible to surface roughness after aging and wear stimulation. Considering that Admira Fusion X-tra has the lower surface roughness.

1. Introduction

The composite resins restorative materials are increasingly used for dental restoration and since they were first introduced to the market, they have seen an important advancement and significant improvements. They make an excellent replacement for amalgam owing to their favorable features including low costs, better dental structural preservation, more accurate, acceptable esthetics, a good clinical behavior, and conservative technique. (1)

In order to qualify as a genuine bulk filling type, full-body bulk-fill resin composites must be constructed in a single step with no requirements to be covered or capped. These additionally recognized as bulk-fill resin composites that may be sculpted or resemble paste due to their viscosity, which enables the restoration of the components of the teeth that are missing. Those assets are also heavily loaded with inorganic fillers, which makes them very viscous and increases the surface's resistance to wear in places with strong masticatory loads. (2)

Recent bulk-fill resin composite generations indicate that they possess enhanced mechanical characteristics and a better inorganic composite resin portion, making them more appropriate for large posterior restorations compared to the earlier generations of resin composites. (3)

An organically altered ceramic known as ORMOCER was introduced more recently. It integrates the toughness of glass with the characteristics of resin by using silicon dioxide as an inorganic basis and polymerizable organic chemicals as the organic components. The purpose of this substance is to enhance not just aesthetics but additionally abrasion resistance, enabling a reduction in surface roughness and shrinkage during polymerization, and providing safeguarding against caries. Additionally, since it is free of bisphenol A-glycidyl methacrylate (BisGMA) and all other types of typical methacrylate, it has improved biocompatibility and does not raise any questions about cytotoxicity. (4)

The bulk form of an ORMOCER called Admira Fusion X-tra (Technical Product Profile, VOCO) lacks traditional monomers like Bis-GMA and triethylene glycol dimethacrylate (TEGDMA) to increase biocompatibility. Its chemical composition depends on cutting-edge silicon oxide technological advances, both for the resin matrix and fillers. (5)

To validate its usage in clinical practice, several qualities of composite resin, such as durability to wear, fracture toughness, surface roughness, polymerization shrinkage, marginal integrity, shear bond strength and color stability. (6)

As a smooth surface has a substantial effect on the retention of microorganisms, discoloration, plaque accumulation, expanding the possibility of tooth decay and periodontal disease, aesthetic appearance, and potential to staining of direct and indirect restoration, it appears to be crucial for composite accomplishment and its aesthetic consequence. (7)

Surface texture is a crucial factor that must be taken into consideration if the reconstruction is to last. Therefore, it is advised to utilize a variety of superfine and fine diamond rotary cutting tools, in addition to aluminum oxide abrasive discs including coarse into fine grained and soft rubber discs coated with diamond and silicone. (8)

As a result, the objective of the current investigation had been to assess the roughness of the surface of a methacrylate-based composite resin and an organically modified ceramic (Ormocer).

Materials and Methods.

Sample size estimation.

G*power, edition 3.1.9.2, was used to identify the sample size. Based on prior research we expected to find a medium effect size between the two materials (effect size = 0.7) when using t-test. With 80% power (using two-sided test and α of 0.5) the samples needed for the study was estimated to be about 12 samples per experimental group.

Ethical approval

The Faculty of Dentistry at Minia University's Research Ethical Committee approved this work, which has protocol number (521/2021) at meeting number (83)

Grouping of samples

Two types of light-cured bulk fill composite were used:
1. Bulk-fill composite resin based on ORMOCER (Admira fusion x-tra, Voco, Germany.
2. Bulk-fill composite resin based on Methacrylate (Aura bulk fill, SDI, Australia)
The materials used in this study were presented in the table (1)

Commercial name	Description	Chemical Composition	Shade	Manufacturer	Polymerize tion time	Lot No.
Admira fusion x-tra	Single-Shade Omni-Chromatic Nano-ORMOCER restorative material, plus x-tra.	*Matrix:* ORMOCER® *Filler:* glass ceramics, silica nanoparticle, pigment content: 84 wt%	Universal	Voco, Cuxhaven, Germany	40 s	#1750435
Aura bulk fill	Nano hybrid composite designed for filling posterior teeth in a single layer.	*Matrix:* Bis-EMA, Bis-GMA, UDMA, TEGDMA *Filler: Silica* (20 nm) and salinized barium glass content:78 wt%	Universal	SDI, Bayswater, Australia	20 s	#201345

Abbreviations: Bis-GMA, bisphenol A-glycidyl methacrylate; Bis-EMA, ethoxylated bisphenol-A-dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

Each group was subjected to surface roughness test
Table 2: Factorial design of different the test used in study: illustrated in table (2)

Groups / Tests	**Group I** ORMOCER®-based bulk-fill composite resin (Admira fusion x-tra)	**Group II** Methacrylate-based bulk-fill composite resin (Aura bulk fill)	**NO.**
Surface roughness test	12	12	24

Sample preparing

The bulk-fill resin composite samples shown in figures 3A and B were created using a typical cylindrical poly tetra-fluoroethylene mold with dimensions of 10 mm in thickness and 2 mm in diameter. Utilizing a gold-plated instrument that was mounted on a 1mm glass slide with a transparent maylar strip, the composite resin had been placed into the mold. To avoid the development of an oxygen-inhibited layer and to assure smooth and level surfaces, another transparent Mylar strip and a 1-mm thick layer of glass slide were put over the specimen. Next, gently pressing with the fingertips was utilized to eliminate any extra material from the mold.
Each specimen was light cured on their upper and lower surfaces while maylar strips was subsequently released from the mold by using increased pressure after being put on each side of the mold. fig (1).

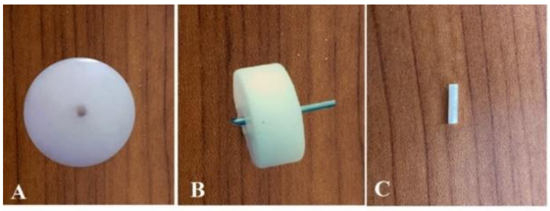

Fig (1): showing (A)and (B) A standardized cylindrical mold, (C) The specimen of composite resin

Surface roughness evaluation

Utilizing a 3D-surface analysis system, specimens were inspected and captured prior to and following wear stimulation to get an accurate reflection on the specimens' surface and for qualitative examination of the wear regions. The demand for a non-contact, quantitative measurement of surface topography is often satisfied by optical profilometry.

A USB digital microscopy with an in-built camera (Scope Capture Digital Microscope, Guangdong, China) was used to take pictures of the specimens' surface topography at a constant magnification of 120X. Each picture has a resolution of 1280 × 1024 pixels when it was captured. To identify and verify the region of roughness measurements, digital microscope pictures were resized to 350 x 400 pixels utilizing Microsoft Office Image Organizer. According to the size of the usual bacteria predicted to stick to composite surfaces in vivo, this region was selected **(Giacomelli L et al., 2010)** [(11)].

Utilizing WSxM program (Ver. 5 develop. 4.1) (Nanotec, Electronica, SL), the resized pictures were examined. **(Horcas I**

et al., 2007) [12]. All restrictions, frames, sizes, and measurable characteristics are represented in pixels inside the WSxM program. As a valid indicator of surface roughness, the average heights (arithmetic mean roughness, or "Ra") expressed in m were calculated using the WSxM program **(Mahrous et al., 2018)** [13].

A computerized image analyzing system (Image J 1.43U, National Institute of Health, USA) was then used to construct a 3D representation of the surface profile of the specimens based on the peaks and valleys seen in the studied region. The reference was the untouched surface. This technique produced a 3-D geometry of the worn surface.

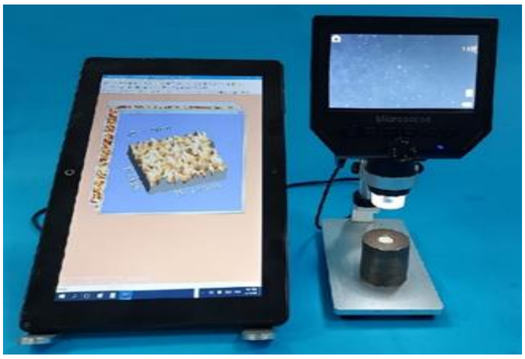

Fig (2): showing a digital microscope with a built-in camera.

Surface roughness calculation:

After specimen preparation and before wear simulations, each sample was analyzed, and the amount was given as the arithmetic average roughness (Ra1) in µm. The arithmetic mean of the 3 successive readouts on every examined sample was used to calculate the readout value. The collected samples were then exposed to wear stimuli, and following the procedure was complete, the device used for testing was turned off. Using a brush, the surfaces of the specimens were cleansed of any foreign objects or contaminants, each item underwent a fresh roughness analyzing and has been captured once more as before. taken into account as the final measurement (Ra2). Based on the equation, the difference between roughness of the surface data prior to and following wear stimulation was determined. **(Wahsh M & Saeed M 2023):**

$$\Delta Ra = Ra2 - Ra1$$

whereas Ra is the average of all deviations from the profile across the mean length of the sample in µm.

Statistical analysis:

Measurements were gathered, displayed as a mean and standard deviation, and then examined employing IBM® SPSS® *. Version 26 of statistics for Windows, The Mann-Whitney U test and Wilcoxon W test were employed for contrasting the two groups. At $p < 0.05$, the significant threshold was established.

Results

The roughness of the surface measurement results (ΔRa values in µm) for the composite materials are demonstrated in Table (3).

Groups	ΔRa (µm)		P value
	Mean	Standard deviations	
Group I (Admira fusion x-tra)	0.0016	± 0032	0.485
Group II (Aura bulk fill)	0.0031	± 0. 0066	

Table (3): representing the means and standard deviations of Ra before and after wear simulation and ΔRa values in µm for the composite materials.

Group II reported the higher ΔRa mean value following the wear simulations (Aura bulk fill) (0.0031±.0066 µm) followed by group I (Admira fusion x-tra) (0.0016± .0032 µm). The variations among the groups were statistically not substantial (p>0.05) as demonstrated in fig (3).

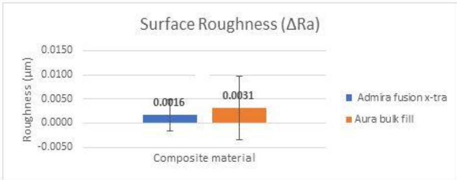

Fig (3): a bar graph displaying the ΔRa mean value and SD after wear simulation of the two groups.

The results of surface roughness images using USB Digital microscope:

Microscopically before wear stimulation, the studied groups showed smooth and uniform surfaces and same surface gloss.

Microscopically after wear stimulation, visible surface defects as Furrows, granular debris, chipping flake, pit-like structure, scratch patterns, and obvious striated marks had been revealed on the worn surfaces of the studied groups represents the occlusal marker of the antagonist teeth.

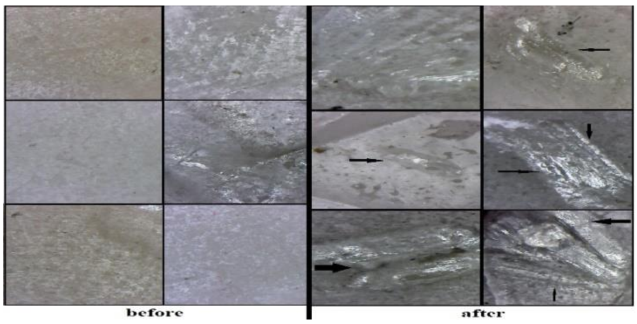

Fig (4): The surface roughness images using USB Digital microscope before and after wear simulation of the 1st group.

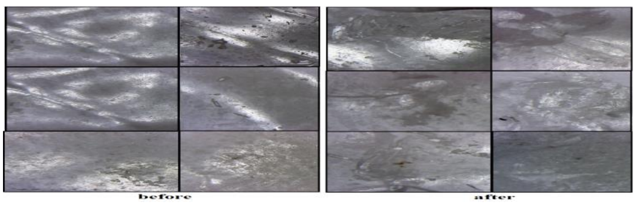

Figure (5): The surface roughness images using USB Digital microscope before and after wear simulation of the 1st group.

The outcomes of WSXM software's 3-D surface roughness pictures:

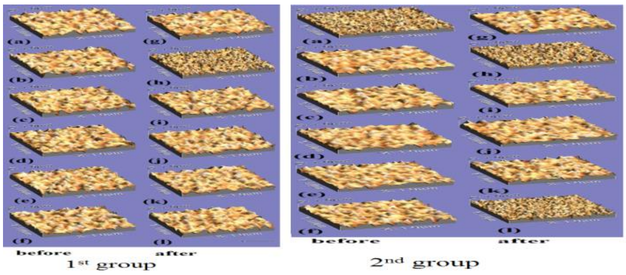

Figure (6): displays the first group's and second group's 3-D surface roughness topographic characteristics prior to and following wear simulations. (a), (b), (c), (d), (e), and (f) before wear simulation. (g), (h), (i), (j), (k), and (l) after wear simulation.

Discussion

The surface topography and roughness of the surface of the reconstruction are the most important factors that influence its aesthetics because they improve optical integration with the protective enamel tissues and surface polish, avoid stains and discoloration of the newly placed restoration, improve durability against abrasion, reduce plaque depositing, and preserve the good condition of the tissues that line the gums. Additionally, as the restoration's surface becomes smoother, less micro-leakage occurs within the tooth and the restoration, lowering the risk of subsequent decay. Research additionally demonstrate that a smooth and thoroughly polished restoration may boost the comfort of patients, and oral hygiene improves as a function of the restoration's surface smoothness. **ztürk Eet al., 2015** [(8)], **Erdemir U et al. 2012** [(10)], and **Babina K et al., 2020** [(9).] Following the anticipated 2-year period, every composite evaluated would have a roughness rise by in excess of this amount, necessitating the need for restorations to be repolished.

In the current research, both the surface roughness and the roughness profile were used to examine the topography.

The surface topography could be of greater significance compared to surface roughness in the development of Streptococcus mutans biofilms due to larger and deeper recesses could create a more conducive environment for microbial colonization and biofilm development. This is due to colonies of bacteria are harder to eradicate from a rough surface. **Park JW et al. (2012)** [(11)]

When surface roughness exceeds the threshold of roughness (Ra = 0.2 µm), biofilm formation also increases at the same time. Below the roughness thresholds, no additional reduction in bacterial adherence could be seen. **Hao Y et al., 2018**. Because the tongue's tip can detect a change in surface roughness of 0.3 micrometers, smooth surfaces increase patient comfort. **Magdy NM et al., 2017** [(13)]

The usage of a noncontact digital profilometer, which can scan a surface and produce a 3D surface map with no harming the samples, made the assessment process quick and simple. **Amasyalı M et al., 2019.** [(12)]

Surface profilometers have long been used in in vitro to evaluate the smoothness of dental restoratives. To determine the numerical indicators associated with surface roughness, the surface qualities of the samples was also assessed in the current investigation utilizing a contact stylus profilometer.

According to various research published in the literature, the surface characteristics of the composite resin change when filler particle size reduces. These findings reveal that when contrasted with the traditional microhybrid composites **Garoushi S, et al.,2011**[(13)] and **Filho HN, et al.,2003**[(14)], nano-scale components produce a smoother surface.

Smaller flaws were noted on the surfaces of composite resins during polymerization and polishing, and smoother surfaces were produced, according to **Ergücu Z, et al., 2007**[(15)]. Similarly, nano-filler composites offered decreased surface roughness and improved polish ability, according to **Ereifej NS et al., 2013**[(16).]

Any resin composite material's surface roughness and gloss are the results of the interplay of a number of inherent and external elements. kind of resin matrix, filler (kind, size, and dispersion of the particles), and the strength of the binding at the filler/resin interface are a few examples of intrinsic characteristics that are connected to the substance itself. **Lefever, D. et al 2012**. [(17)]

The nano-hybrid composite employed in this work has extremely tiny primary particles, yet these particles combine to form bigger masses. The roughness of the surface of the nano-hybrid composite might be increased by this structure. The kind and quantity of filler, as well as the organic matrix structure, are additional significant elements impacting the roughness of the surface of composite resins. **Ereifej NS et al., 2013** [(15)]

According to this outcome, which is not significantly various. Admira Fusion X-tra exhibited a rougher surface profile than Aura (3.38 µm), according to **CAK Shimokawa et al 2019**[(19)], however this difference was not statistically significant ($p \geq 0.05$) from Aura (2.38 µm).

In research of **Asadian F et al., 2022**[(20)], there was no discernible difference between a hybrid conventional composite and bulk-fill composites in terms of surface roughness.

As a result of the filler particles in the material employed ormocer being harder compared to the matrix, preferential reduction via finalizing and shining in addition to disposing of the filler phase in a beneficial surface and leading to greater surface roughness, **Tagtekin DA et al., 2004**[(21)] found that the ormocer experienced a greater degree of surface roughness compared to conventional hybrid RBC.

According to the research by **O'Neill C et al., in 2018**[(22)], a bulk-fill composite exhibited surface roughness that was 2–7 times greater than that of a traditional hybrid composite. They may have employed Admira Fusion x-tra as the bulk-fill composite, which might account for this result. Filler particles in hybrid composites typically vary in size from 40 to 300 nm. When the resin matrix wears, the filler particles become exposed due to their large size and asymmetrical arrangement, which increases surface roughness in comparison to traditional composite resins. Moreover, one of the key elements influencing the surface roughness of materials following wear is the size and distribution of filler particles in the resin matrix. **Han JM et al., 2014**. (23) and **Moraes RR., 2008.** (24)

The results of **Ho TK, et al., 2018**(25) evaluation of the composite specimens' surface roughness during chewing simulations. Their findings indicated that while the test introduced the fillers, which led to a boost in surface roughness, the surface roughness measurements did not substantially rise following the test.

As regard of adhesion of bacteria and comfort for patients, ORMOCER and resin-based composite were judged to have a clinically suitable surface roughness. These outcomes might be explained by the same sol-gel manufacturing procedure that was used to create the nano-particles in the two composites. While resin-based composite fillers have been founded on their own registered "Sub-Micro-Pearl-Technology," this procedure is a controlled reaction between various chemistries that produces uniform nanoparticles which are harvested once they expand to the desired diametric size (the nanoparticles' diameter in OBC = 20-40 nm). In this procedure, the spherical fillers are gradually coated in an organic solution using the sol-gel technique. After a few weeks, the fillers have "grown" uniformly into spheres that are precisely 0.26 mm in diameter. This characteristic produces a polished surface that is very smooth **ismail EH et al .,2022**(26).

According to the findings of the **Ebaya, M.M. et al., 2022**(27) research, no statistically substantial variations were existed between the two tested restorative materials for surface roughness in the baseline assessment.

Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Both ORMOCER- and methacrylate-based composites are prone to surface roughness after aging and wear stimulation.
2. Universal shade composites have accepted surface roughness immediately.

List of abbreviations

Organically Modified Ceramics (ORMOCER)

ethoxylated bisphenol-A-dimethacrylate (Bis-EMA)

bisphenol A-glycidyl methacrylate (BisGMA)

triethylene glycol dimethacrylate (TEGDMA)

urethane dimethacrylate (UDMA)

Declarations

Publication consent

"Not applicable"

Availability of information and resources:

This article contains all of the data that has been produced or examined during this investigation. The corresponding author may be contacted for further information.

Conflict of interest

The authors claim to have no conflicts of interest.

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Authors' contributions

Resources, data analysis, and writing original draft: Sara Gamal Mohamed; review and editing: Mohamed Mostafa Abdel-Moaty and Asmaa Abdel-Hakeem Metwally. All authors have read and agreed to the published version of the manuscript.

Disclosure statement

The authors did not disclose any possible conflicts of interest.

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