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The Effect of Zirconium Dioxide Nanoparticles on the Surface Roughness of a New Resin Based Alkasite Material: An invitro study

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ABSTRACT
Objective: To evaluate the impact of the addition of different ratios (0, 5, 10%) of zirconium dioxide nanoparticles on the surface roughness of a resin based alkasite material.
Materials and Methods: An alkasite resin-based material (Cention N) (CN) and zirconium dioxide (ZrO_2) nanoparticles (NPs) were used. ZrO_2 NPs was added to the powder of Cention N at ratios of 5% and 10%. A total number of 30 specimens were prepared using split -Teflon mold then divided into 3 groups (10 specimens each) as follows; group I: CN (without the addition of ZrO_2) as control group, group II: CN with 5% ZrO_2 NPs, group III: CN with 10% ZrO_2 NPs. Each group was tested for the surface roughness using a contact profilometer. The collected data were subjected to statistical analysis.
Result: Surface roughness significantly increased with increasing ZrO_2 NPs.
Conclusion: The modified resin based alkasite material byzirconium dioxide nanoparticles increased in the surface roughness with increasing the ZrO_2 NPs.
Key words: Resin based alkasite material, Zirconium dioxide nanoparticles, Surface roughness.

I. INTRODUCTION

Dental composites are becoming the preferred choice for restorative materials, gradually replacing mercury containing dental amalgam restorations. This shift is primarily driven by the inherent aesthetic appeal of dental composites and the longstanding concerns about the toxicity associated with mercury containing alternatives.[(1)]However, composite resin has many disadvantages, for example, polymerization contraction, marginal leakage, and secondary caries. Good clinical results can be achieved with improved composite restoratives, but it takes many steps for isolation and incremental technique. these procedures are time consuming for the dentist and expensive for the patient.[(2)]

Consequently, dental research was performed to find solutions to these problems. A new restorative material was developed which is a fluoride-releasing product, cost-effective, offers both strength and good esthetics, and easy to use without the complicated equipment. This new restorative material has an alkaline filler, which is able to neutralize acidity by releasing hydroxyl ions, so it is called an “alkasite”. It also has the ability to minimize the contraction force as it contains a special patented filler (isofiller) which acts as a shrinkage stress reliever.[(3)]

Alkasites, commercially available as Cention N (CN) (Ivoclarvivadent, Schaan, Liechtenstein), are esthetic filling materials which have high flexural strength and can be used as a bulk filling material because of their dual curing option. They are essentially a subgroup of the composite resin. These alkasite materials have a great anticariogenic activity because of their ability to release fluoride, calcium, and hydroxyl ions which aid in neutralizing the excess acidity in the mouth, thus preventing demineralization.[(4)]

The integration of nanotechnology in dentistry has significantly advanced dental restorative composites, particularly through the reinforcement of these materials with metal oxide nanoparticles such as silica (SiO_2) and zirconia (ZrO_2). Zirconium dioxide (ZrO_2) is one of the most important nanoparticles which entered the world of dentistry, as well as other fields of industrial applications, due to their excellent properties. They have high strength, fracture toughness, excellent biocompatibility, high corrosion resistance, and suitable dimensional stability. Also they have good aesthetic characteristics, but if they are added in large amounts to restorative materials they affect the aesthetic.[(5)]So, the purpose of this study was to evaluate the impact of modification of resin alkasite restorative material with zirconium dioxide nanoparticles on its surface roughness, microhardness, compressive strength, and shear bond strength to dentin.The null hypothesis was that the addition of ZrO_2 will not have an effect on the properties of resin alkasiterestoratve materials.

II. MATERIALS AND METHODS

I. Material

Table 1. Materials used in the study, their composition and manufacturer.

Category	Product Name	Manufacturer	Batch no.	Composition
Resin based alkasite material	Cention N	IvoclarVivadent Schaan Liechtenstein	/Fl-9494	**Powder**: Barium aluminium silicate glass, Ytterbium trifluoride, Isofiller (Tetric N-Ceram technology), Calcium barium aluminium fluorosilicate glass, Calcium fluoro silicate glass, A copper salt& thiocarbamide-self cure, Initiator or Ivocerin and, acyl phosphine oxide photoinitiator, Pigments. **Liquid**:UDMA-DCP Aromatic aliphatic-UDMA PEG-400 DMA
Metal oxide nano particle	Zirconium dioxide nano particle	Nano Gate, Cairo, ARE	002	Zirconium dioxide powder with particle size measuring <50 nm by (TEM).

III. METHODS.

1. Sample size calculation

Sample size calculation was based on difference between different restoration material on surface roughness, compressive strength and microradness, depneding on the highest calculated sample size retrived from previous research(1) Using G power program version 3.1.9.4 to calculate sample size based on effect size of 2.35, using 2-tailed test, α error=0.05 and power=90.0%, the total calculated sample size will be 5 in each group at least.

2.Study design and grouping

A total of 30 specimens were used in the study. The specimens were divided into 3 groups (10 specimens each) as follows; Group A: control group in which specimens were prepared from the resin based alkasite material without any modifications, Group B: specimens were prepared from the resin based alkasite modified with 5% (w/w) ZrO_2-NP and Group C: specimens were prepared from the resin based alkasite material modified with 10% (w/w) ZrO_2-NP.

3. Preparation of specimens

Specimens' powders were prepared by blending 5% and 10% (w/w) zirconium dioxide nanoparticles powder with the resin based alkasite powder by an amalgamator using Eppendorf tubes for 10 min. The unblended powder was used as the control for the test. A total of 30 specimens were used in the study, 10 for each group.

4. Surface roughness testing

Thirty-disc shaped specimens (ten from each group) were fabricated using a split Teflon mold (7mm diameter x 3mm height). The powder and liquid were mixed according to manufacturing recommendation, then used to fill the mold. It was covered with a 10 mm wide Mylar strip which was pressed between two glass slabs to extrude the excess material with constant pressure. The specimens were light cured for 20 seconds at the top and bottom surfaces with a light curing unit (DEMI, Kerr®, USA) at a light intensity of 800 mW/cm2. A surface profilometer (Surftest sj-210 portable surface roughness tester, Mitutoyo crop, Kawasaki, Japan) was used to measure the surface roughness of the samples in accordance with ISO 4287-1997. The stylus traversing distance was 5 mm, cutoff value was 25 mm, the tracing diamond tip radius was 5 µm, and the measuring strength and velocity were 4 mN (0.4 g) and 0.5 mm s^{-1}. The Profilometer was calibrated before starting the test. The surface roughness was measured 3 times for each specimen,The Ra value was obtained by calculating the mean of roughness values.[6, 7]

3. statistical analysis

Statistical analysis was performed using a softwareprogram (SPSS 18; Chicago, IL, USA).

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The data were presented as means and standard deviations (SD). For comparison between groups, one way analysis of variance (ANOVA) test was used, then Bonferroni post hoc test was used for pairwise comparison. The level of significance was set at $P \leq 0.05$.

IV. RESULTS

The means and standard deviations for surface roughness, surface microhardness, compressive strength and shear bond strength are presented in Table 2.

1. Surface Roughness (Ra)

The results of the One-way ANOVA tests showed that specimens in the 10% (w/w) ZrO_2-NP-modified alkasite group and 5% (w/w) ZrO_2-NP-modified group showed significantly higher roughness values (0.436±0.023 and 0.407±0.041 µm respectively), compared to the control group (0.251 ±0.046 µm) ($p < 0.0001$). However, there were no significant differences between the two former groups.

Table 2: Means and standard deviations (SD) of Surface Roughness (Ra)of Cention N with zirconia NPs incorporation and post hoc's analysis.

Group	Surface roughness (µm)	
	Mean	SD
Cention N (control)	$.251^{b}$	.046
Cention N 5% (w/w) ZrO_2	$.407^{a}$	.041
Cention N 10% (w/w) ZrO_2	$.436^{a}$	.023
P value	< .0001	

Mean values for each property represented with the same superscript letter (column) are not significantly different ($P \geq 0.05$), While the mean values with different letters are significantly different ($P < 0.05$).

V. DISCUSSION

Preserving and enhancing the physicomechanical characteristics of restorative materials is essential for the longevity and durability of the restoration. Consequently, research in this field could provide valuable insights for their usage and potential alterations of the material.(8)In this study, Surface Roughnessproperty of a resin based alkasite material modified with different concentration of ZrO_2/NPs was studied. Proper percentages of zirconium oxide nano-fillers (percentages of 5% - 10% by weight) were selected. That is because these percentages lead to improvement of properties of restorative materials in other studies.(6, 8-11)

Surface roughness was evaluated in this study because it plays an essential role in preventing plaque deposition, secondary caries, discoloration, wear as well as maintaining the aesthetic value of a restoration.(12)When the surface roughness exceeds 0.2µm, it provides a suitable environment for bacteria to accumulate on the material's surface.(13)Also, the roughness of the restoration can be identified by tongue if the value exceeds 0.5 µm. In the present study, the surface roughness values of both control and experimental groups were within the threshold limit of 0. 4 µm.(14)

In the present study a contact profilometer was used to measure surface roughness. The prevalent use of stylus-based roughness testers can be attributed to their well-established measurement and analysis techniques, the ability to directly measure the actual surface, and their compatibility with previously accumulated measurement data.(15) The null hypothesis was that the addition of ZrO_2will not have an effect on the properties of resin alkasiterestoratve materials. In this study, there was a significant increase in surface roughness of the groups of resin based alkasite modified with 5 % &10 % (w/w) ZrO_2 NPs compared to the control group. This could be explained by the less filler loading of the control group compared to the experimental groups. So, with increasing the concentration of ZrO_2 NPs, the surface roughness increased.(14)This may be attributed to the aggregation of ZrO_2 NPs on the surface which can lead to lack of homogeneity and interfacial bonding between the particles and polymer matrix, thus increasing the surface roughness.(6)These results are in accordance with those of Maalyet al. who incorporated 3, 5 and 7% (w/w) of TiO_2 NPs to resin based alkasite material and found that there was an increase in surface roughness of the material.(16) On the other hand, these results are in disagreement with those of Aref et al. whofound that the incorporation of TiO_2 NPs with concentrations of 3 and 5% (w/w) to resin based alkasite materials insignificantly increased their surface roughness.(9)

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VI. CONCLUSIONS

The addition of zirconium oxide nanoparticles to cention N leads to significant increasing of surface roughness.

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