



## Comparative Evaluation to Surface Roughness of Modified Heat Cured Acrylic Resin by Zinc Oxide Nanoparticles and CAD/CAM Denture Base Materials - In Vitro Study

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### Abstract

One of the most promising CAD/CAM approaches is milling denture base materials from highly condensed pre-polymerized resin discs. In an effort to overcome the disadvantages of acrylic resin denture base materials, nano-filler materials have been added as well as denture base chemistry adjusted to strengthen the denture base. This eliminates disadvantages associated with polymerization shrinkage compared to conventional heat-cured acrylic resin. Aim of this study: evaluate the surface roughness of PMMA acrylic resin after strengthening the denture- base by addition of zinc oxide nano-filler material to acrylic resin PMMA with concentration (1%) and compare with milled CAD/CAM and non-modified heat-cured PMMA denture base materials. Materials and methods: thirty specimens of acrylic resin PMMA were prepared and divided into three groups 10 specimens for each groups as follows; Control Group (Group1) without ZnO nanoparticles ; Group (2) with (1%) by weight of ZnO nanoparticles ; Group (3) milled CAD/CAM. Each specimen is of dimension ( 10 x 10 x 3 ) in mm and was fabricated using conventional processing method and milling the CAD/CAM blocks .Results: showed the lowest mean value was recorded by milled CAD/CAM (0.230 Ra) Then the non-significant reduction with mean value (0.312 Ra) by PMMA+ ZnO 1% and highest mean value of surface roughness was recorded by pure PMMA without additive (0.327 Ra).Conclusions: There were significant differences between control group PMMA and milled (CAD/CAM) with slight reduction of surface roughness of PMMA with (1%) ZnO nanoparticles.

## Introduction:

The majority of individuals worry about losing their teeth. There are successful treatment options to restore lost teeth, regardless of the underlying reason. The continuation of everyday life depends on their replacement with prostheses like dentures, which are made of acrylic resin. <sup>(1)</sup>.

### First introduced:

In 1937, polymethyl methacrylate is today the material of choice for fabrication of removable partial and complete denture bases. Due to its ease of use, good fit, dimensional stability, and aesthetics, it is still used in implant-supported dentures these days <sup>(2)</sup>. Acrylic resin does have some significant drawbacks, though, including low strength, particularly under fatigue failure inside the mouth, residual monomer allergy, low abrasion resistance, and brittleness on impact. These drawbacks frequently cause fractures in dentures <sup>(3)</sup>. Several continuous efforts have been taken to increase denture base strength in order to reduce the risk of denture fractures. These efforts include reinforcing denture bases with filling materials, altering the denture base polymer chemistry by co-polymerization and cross-linking of resins, and developing new materials with improved properties <sup>(4)</sup>.

PMMA has recently been reinforced with various nanoparticles to overcome these disadvantages.

These nanoparticles serve as the reinforcing material. Various fillers, metal oxides, and carbon graphite fibers have been incorporated into the composition to solve these problems and improve the mechanical properties of denture acrylic resin <sup>(5)</sup>.

## Materials and Methods

During the mold preparation, a conventional flasking procedure was operated for complete dentures. Separating medium (Alginic isolator, Zhermack®) were employed and let to dry for the layer of plastic before putting the lower part of metal flasks filled with die stone (Elite® stone, Zhermack®) and combined in vibration according to the directions of the

manufacturer to remove the trapped air, then left to set. Acrylic sheets were used to make the plastic model pattern, which designed by using computer software (AutoCAD), and then cut by a computer-controlled laser cutting machine. The length, width, and thickness of the plastic models pattern utilized in mold fabrication were precisely designated according to the specifications needed for test <sup>(7)</sup>. Square shape (10 x 10 x 3 mm) specimens were prepared according to Berger *et al.* 2006 <sup>(6)</sup>. As showed in Fig. (1). 30 specimens were prepared, were measured by used an electronic digital caliper.

According to the manufacturer's instructions, the powder-to-liquid mixing ratio for heat polymerized acrylic resin (SR Triplex® Hot, Ivoclar Vivadent) was 2:1 by weight. According to the manufacturer's recommendations, a thermostatically controlled water bath was utilized for a curing cycle (heat up to 100°C for 90 minutes and allow boil for 45 minutes). The flasks were then removed and allowed to cool slowly on the bench before being opened <sup>(8)</sup>.

The modified PMMA specimens were first prepared by mixing the weight of (1%) zinc oxide nano powder with "heat-cured PMMA" fluid monomer, by sensitive balance high accuracy ( $\pm 0.000g$ , Kern Type PCB 350-3) which was sonicated and dispersed in the liquid monomer for 3 minutes using an ultrasonic bath type of 20W and 60 kHz, and then the Heat-cured PMMA polymer powder was added and manually mixed to avoid particle agglomeration. <sup>(9)</sup>

The milled CAD/CAM specimens; a 3D specimens design with dimensions were virtually designed using computer software (SketchUp Pro "2020") were saved to as standard tessellation language (STL) file form. Then, STL files were imported to CAD software (Exocad Dental DB) which eventually connected to the milling machine to be used for fabricating the milled samples from (Ivotion Base CAD) pre-polymerized PMMA blocks (SPEC 98.5x30 shade Pink Monolayer) as shown in Fig. (4), with CAD/CAM milling

machine (MAXX DS 200-5Z, Korea) as shown in Fig. (5) with milling PMMA burs (2.5, 1, 0.5 mm) respectively; the number of the axis was five-axis with dry milling subtractive technique.<sup>(10)</sup>

All specimens were finished using tungsten carbide acrylic burs and abrasive silicon carbide disc (Grit 120, 600) respectively on both sides.<sup>(11)</sup>

Samples of all groups were stored in distilled water at 37°C for two days using an incubator.

The specimens were grouped as following:

1. 1<sup>st</sup> group (group A): control group 10 samples (pure).
2. 2<sup>nd</sup> group (group B): addition 2% ZnO nanoparticles 10 samples.
3. 3<sup>rd</sup> group (group C): milled CAD/CAM 10 samples.

Using the profilometer (Taylor Hobson Ltd, UK), as shown in Fig. (2), the surface roughness of the specimen was tested, and minute surface variations were detected by moving the diamond stylus diagonally across it as the specimen was moved. The surface roughness was calculated as the mathematical average using the measured profile height of surface irregularities. Surface variations were measured as the vertical displacement of the stylus. With a scan length range of 0.8mm, the stylus tip radius was 2.5mm<sup>(12)</sup>.

## Results:

Statistical analyzes were performed using SPSS software version 26 using descriptive statistics, normality tests, and inference statistics (ANOVA and Duncan's test).

Descriptive statistics including mean and standard deviation are presented in Table (1). The lowest value of surface roughness between tested groups was shown in group (C) milled CAD/CAM, while the highest value was shown in control group (A), (ANOVA) test displayed that there were statistically significant differences between groups at p-value <0.05 as seen in Table (2). Duncan's multiple comparison test for surface roughness as seen in Fig.

(3) revealed significant decrease in the mean of surface roughness in milled CAD/CAM group and non-significant reduction of surface roughness in (1%) ZnO nanoparticle as compared to control. A comparison between experimental groups (1% ZnO, milled CAD/CAM), there were significant differences between them.

## Discussion:

Denture surface roughness may contribute to microbial colonization and staining<sup>(13)</sup>. In this way, surface roughness increases the surface area, allowing pigments to accumulate and microbial adherence to increase, ultimately degrading the aesthetics and appearance of dentures<sup>(14)</sup>

CAD/CAM milled samples demonstrated statistically significant low mean surface roughness values in this study, followed by modified heat-polymerized samples with (1%) zinc oxide nanoparticles, and conventional heat-polymerized samples showed higher surface roughness values, as shown in Fig.(3). As compared to the control group, the CAD/CAM group had a lower mean surface roughness value with a significant difference. **Duncan multiple comparison test** reveal that reinforced heat-cured PMMA with (1%) zinc oxide NPs group showed a non-significant decrease in surface roughness as compared to control groups. Nevertheless, when comparing the results between experimental groups, Milling CAD/CAM group has a significantly low mean value of surface roughness (Ra) than (1%) Zinc oxide NPs

The results of surface roughness of the CAD/CAM group in the study are in agreement with those Al-Dwairi et al .(2019)<sup>11</sup> Murat et al .;(2019)<sup>13</sup>; Steinmassl et al .(2018)<sup>15</sup> and Elfaidy et al .(2018)<sup>4</sup>, According to these studies, CAD/CAM acrylic resin had a statistically significant reduction in surface roughness when compared to heat-polymerized acrylic resin

In CAD/CAM, it is possible to explain the lower mean value by the standardized polymerization conditions; CAD/CAM PMMA material milled at high temperatures and pressures results in better conversion, and residual

monomers are lower than in conventional heat-cured acrylic resin material. Therefore, there is hardly any residual monomer or even enough for co-polymerization of free radicals. Therefore, CAD/CAM denture base materials exhibit low surface energy wettability and are resistant to various / surface chemical treatments. As a result of highly condensed resin, free monomers and porosity decrease, allowing a desirable balance between minimal fabrication distortion and consistently better adaptation with the slightest gaps notified by<sup>(16)</sup>.

In contrast, Srinivasan *et al.* (2018)<sup>17</sup> find milled CAD/CAM acrylic resins to fabricate dentures of significantly increased surface roughness compared to conventional non-modified denture base materials. On the other hand Alp *et al.* (2019)<sup>18</sup> reported no

significant difference in surface roughness values between conventional heat-cured PMMA and milled CAD/CAM denture base resin

This controversial result is probably due to different approaches to sample preparation. The sizes of the burs depend on the quality of the milling tools, the milling process, and even the brand company of milling denture base resin differ<sup>(15)</sup>.

The surface roughness was reduced after filler addition and also demonstrated statistically non-significant differences

when compared to the control non-modified PMMA group. This agrees with the results acquired by Cierech *et al.* (2016)<sup>19</sup> who also concluded that there was a reduction in roughness but non-significant differences between PMMA and PMMA with nano ZnO composite. Meanwhile, the study by Hamad *et al.* (2016)<sup>20</sup> concluded that the addition of zinc oxide was found to significantly %2.5 reduce the surface roughness of the composite compared with pure PMMA. As a result of filler taking up empty (vacant) space between polymer molecules, the surface roughness value decreased significantly

## Conclusion:

CAD/CAM dentures exhibit more favorable surface roughness, trying to make them more acceptable as acrylic resin denture base material for edentulous patients. In addition, the use of ZnO nanoparticles as dental fillers at 1% by weight non-significantly reduction the surface roughness of denture base material (PMMA).

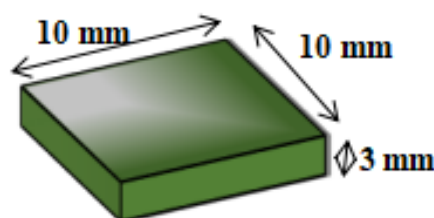
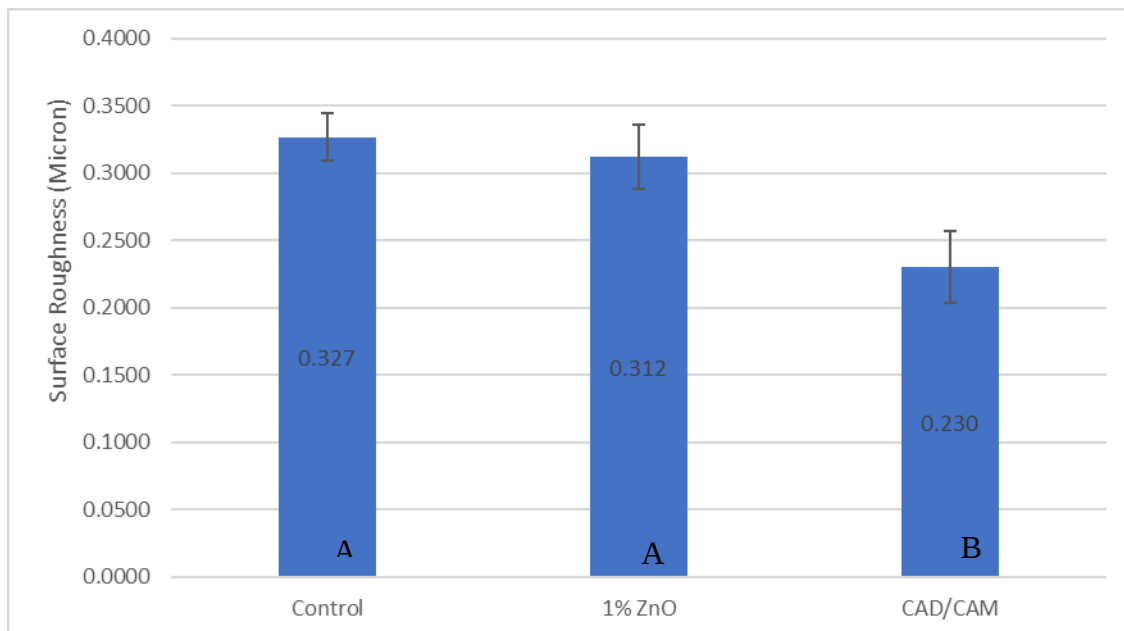


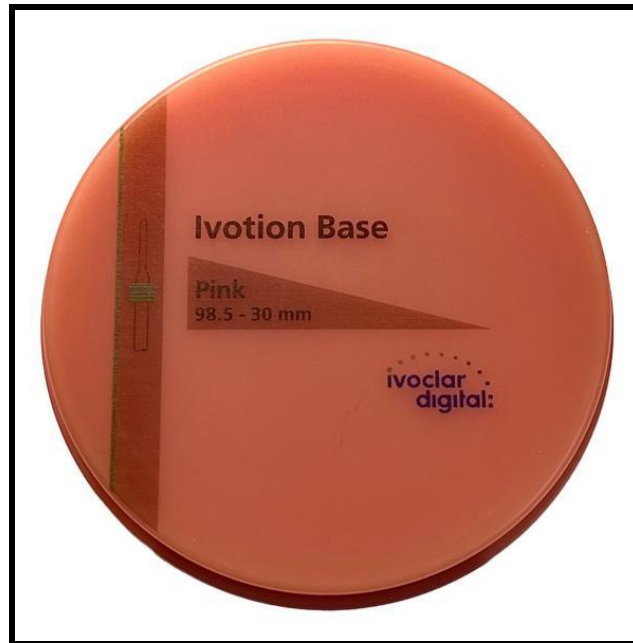
Fig. (1): Dimensions of surface roughness test specimen



**Fig. (2):** Profilometer for surface roughness measurment.



**Figure (3):** Duncan multiple comparison test, Mean, standard deviation for surface roughness of control and experimental groups of (1%) ZnO nanoparticles and CAD/CAM group.



**Fig.(4): Milled CAD/CAM Ivotion Base**



**Fig. (5): Milling CAD/CAM machine.**

**Table (1):** Mean, standard deviation and standard error for surface roughness test of control and experimental groups of ( 1%) Zinc oxide, CAD/CAM .

| Group         | NO. | Mean<br>(Micron) | S.E   | S. D  |
|---------------|-----|------------------|-------|-------|
| Control       | 10  | 0.327            | 0.005 | 0.031 |
| 1% <u>ZnO</u> | 10  | 0.312            | 0.007 | 0.023 |
| CAD/CAM       | 10  | 0.230            | 0.008 | 0.026 |

\*S.E: standard error; S.D: standard deviation ; NO: number of specimens.

**Table (2):** One-way analysis of variance for surface roughness of control and experimental groups of (1%)ZnO nanoparticles and CAD/CAM group.

| SOV            | SS    | DF | MS    | F-value | P-value |
|----------------|-------|----|-------|---------|---------|
| Between Groups | 0.055 | 2  | 0.027 | 51.225  | 0.000*  |
| Within Groups  | 0.014 | 27 | 0.001 |         |         |
| Total          | 0.069 | 29 |       |         |         |

SOV: the source of variance; SS: Sum of Squares; df: the degree of freedom; MS: mean square. \* : Statistically significant at  $p \leq 0.05$ .

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