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Impact of surface treatment and addition of CuO NPs of surface roughness of acrylic denture base bonded to soft liner

Saja Abd Almunaf Fadhil[1], Hawraa Khalid Aziz[2]

[1]Department of Prosthetic Dental Technology, College of Health and Medical Technology, Middle Technical University, Iraq, E-mail: sjybdalmnaffadl@gmail.com.

[2]Assistant Professor at Department of Prosthetic Dental Technology, College of Health and Medical Technology, Middle Technical University, Baghdad, Iraq. E-mail : Hawraakhalidazizaziz@yahoo.com.

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Abstract

Background: The import of the rough surface makes the application of several elements to enhance this feature vital for the adhesion of soft liners. **Aim:** The study's goal was to to ascertain the impact of copper oxide nanoparticles added in two ratios to heated-cured acrylic resin and fiber laser surface treatment on surface roughness. **Materials and methods:**60 acrylic specimens in the shape of discs were manufactured and divided into three groups: one received no addition; the other two received the addition of 0.3% CuO NPs; and a third group that received the addition of 0.5% CuO NPs. Each group was divided into two categories: those that were laser treatment and those who did not. The surface roughness test was then examined using a roughness tester called a profilometer. **Results**: The average roughness values were high for the control groups and low for the CuO NPs 0.5% groups. The mean values in the laser-treated groups had greater roughness than the control groups, according to the laser application.**Conclusion**:. As the fraction of CuO NPs increased, the surface roughness reduced. The laser treatment also reduced surface roughness.

Keywords: Fiber laser, CuO NPs, acrylic, silicone liner, surface roughness.

Introduction:

Surface irregularities that are closely spaced and whose height, width, and direction determine the dominant surface pattern are referred to as surface roughness (1). The roughness of the denture substratum is indicated by the parameter Ra, which is defined as "the mean arithmetic average of the absolute values of the roughness profile." (2) The majority of oral microorganisms, particularly those that cause caries, periodontal disease, and denture stomatitis, can only survive in the mouth if they stick to a non-shedding oral surface and begin to form colonies. For this reason, the surface roughness of the denture base material is a crucial characteristic because it affects the health of the oral tissue that comes into direct contact with the denture. (3) Increased surface roughness of acrylic resin promotes staining and aids in bacterial plaque retention, which negatively impacts the appearance and cleanliness of dentures (4). Since nanoparticles have a significantly higher surface area than traditional materials and are currently thought of as antimicrobial agents, their application as novel agents for inhibiting microbial growth has therefore arisen as a result of the development of antibiotic resistance (5)

One of the families of copper compounds that demonstrates practical physical characteristics including high-temperature superconductivity, electron correlation effects, and spin dynamics is copper oxide.

It has comparatively stable chemical and physical properties, is inexpensive, and mixes easily with polymers and polar liquids. It is noteworthy that prior research demonstrated that CuO NPs have a significant antibacterial impact (6,7)

On the other hand, whether chemical or mechanical, the acrylic resin surface treatment modifies the treated surface's topography or chemistry, which is important to increase adhesion (8)

Fiber lasers, the most recent creations currently available laser technology, are one method of surface treatment. Due to their compatibility with commercial and biological both apps ability to deliver powerful in a little amount and time, they also have a place in dentistry [9]. Fiber lasers have the potential for monolithic packing, source brilliance, oscillating mode stability, efficiency, and low maintenance costs. show some significant improvements over earlier technologies [10,11]. When compared to other lasers, laser fibers swiftly and effectively while affecting surfaces resulting in reduced thermal and mechanical damage [10]. In dentistry, ultrafast fiber lasers are mostly utilized to alter the surface of implants [10–12]. As laser parameters can affect and change the surface microstructure, using lasers as a surface treatment alternative to improve the binding between different materials is possible[13]

The goal of this study was to evaluate the impact of copper oxide nanoparticle impregnation on the degree of roughness of heat-cured acrylic and to determine whether or not the acrylic material's surface can become more rough after being changed with a fiber laser.

Material and method

Specimens' grouping:

In this investigation, a total of 60 specimens made of heat-cured acrylic (Vertex, Netherlands) were created. According to the Nano addition that will be carried out, the specimens were separated into three groups: Depending on how the specimens were treated with the laser, they were split into two subgroups: each subgroup was designated as follows: 10 specimens were fabricated without any treatment; the other 10 specimens were made with surface laser treatment. The total number of specimens was 20 control without addition, 20 second group with 0.3%CuO NPs addition, and the final 20 specimens with 0.5%CuO NPs addition.

- Fabrication of heat-cured specimens:

A. Specimen's design:

Figure 1 illustrates the specifications for the surface roughness test specimens, which were disc-shaped plastic patterns with a 10 mm diameter and a 2 mm thickness.

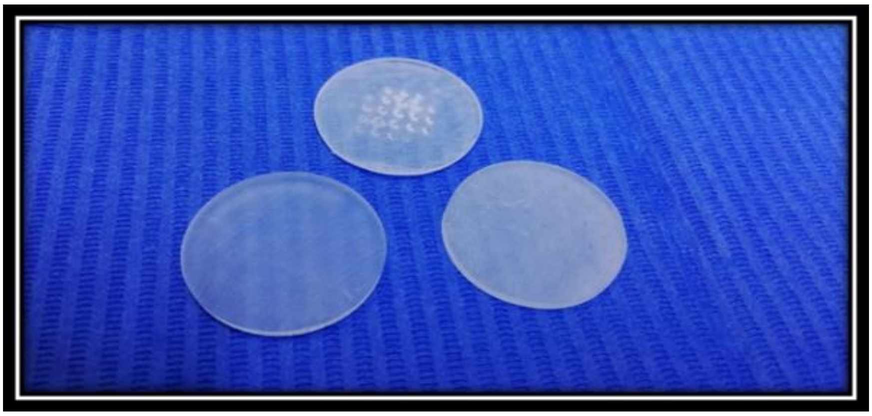

Figure 1: plastic disk for roughness specimens **.**

B. Mould prepared

Specific proportions for a plastic model were created (10 mm in diameter and 2 mm in thickness). The plastic design was filled with a resilient but flexible silicone substance (added vulcanizing vinylpolysiloxane duplicate information) to make a silicone mould. Dental stone W/P ratio: 25 ml per 100 g is poured into the lower portion of the dental flask after the silicone mold has been inserted, freshly blended in accordance with the guidelines provided by the manufacturer. The surplus Stone fragments were eliminated and leveled. [16]. Once the stone's second coating had completely solidified, After opening the flask, the plastic mold was taken out, and a hole was left in the silicone. The quantity of heat-cure acrylic powder and liquid was then selected, mixed, and sealed in a dry, clean glass jar according to the manufacturer's instructions for mixing P/L ratio. To add the groups of Cuo NPs, the acrylic powder was placed on a clean, dry glass surface, and the nanomaterial was removed from it. It was then weighted on a delicate electronic scale to calculate the necessary quantity at concentrations of 0.3 and 0.5, and added to monomer for blending in a prop sonication apparatus so that vibration can split them into individual nanoparticles.. A probe sonication device was then used to combine this mixture [17,18]. The acrylic was then extracted from the flask, all flashes were trimmed, and the precise measurements of each specimen were verified by a caliper device (Renfert, Germany) at various points. This was done after the acrylic reached the stage of dough, packed, and pressed with a hydraulic press , and curing in a water path heat cured in a water bath in accordance with the manufacturer's directions. After that, the sample's finishing and polishing were completed (figure 2).

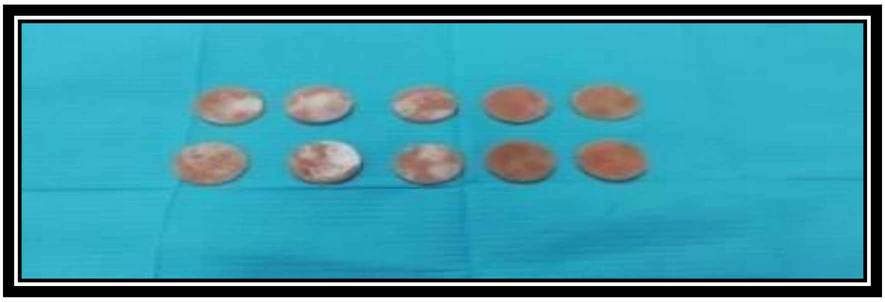

Figure 2 : Specimens of roughness.

-Laser treatment of heat cured acrylic specimens:

In the present study, a fiber laser from Wuxi, China's Raycus Fiber laser Technologies CO.LTD, operating at a wave length of 1064 nm, with an average output power of 40 W, a repetition rate of 20 kHz, a pulse length of 81 ns, and a speed of 110 mm/sec, was used to prepare the surfaces of acrylic samples (Figure 3). The samples were set on a laser machine surface that was connected to a computer, and a laser beam with an output diameter of 6.6 mm centered around a 20-meter spot area. The lens employed in this technique has the ability to choose its own focus point and change its distance either manually or automatically. The material was shielded from back reflection by the Collimator with anti-back reflection shield connected to the external laser. During the procedure, the cooling process was carried out using the air inside the fiber laser system (19).

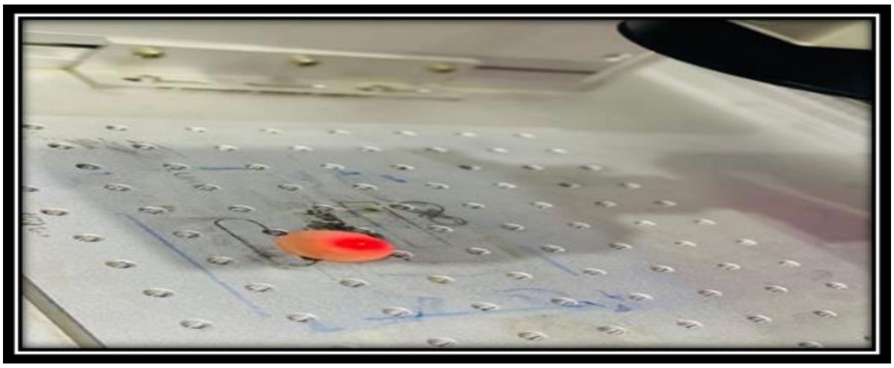

Figure 3: Fiber laser surface treatment of acrylic roughness specimen.

Surface Roughness test:

A portable digital roughness tester (Profilometer: Portable surface roughness cages, Mahrfederal Inc., Germany) with (0.001 m) precision was used to conduct the surface roughness test. The surface analyzer on this gadget has a conical diamond stylus for tracking surface imperfections (Figure 4). Three measurements were taken on the same surface of the specimen, one in the center and the other two on the sides on the right and left. The readings appeared on the digital display and were measured in Ra parameter, which is the arithmetic mean of surface roughness (ASME B46.1, 2009). The roughness testing value was calculated using the average of the three values (20).

Figure 4: Portable digital roughness tester (Profilometer).

Result:

Descriptive statistics of roughness test of addition of CuONPs and laser surface treatment showed in table (1), and figure (5). Depending to the laser treatment results were showed the maximum mean values found in laser groups. According to CuONPs addition the maximum value for control group without CuONPs addition while the minimum value was found through the 0.5 % CuONPs groups.

Table 1: Descriptive statistics of surface abrasion (μm) evaluate each group.

Studied groups		N	Mean	Std. Deviation	Std. Error	Minimum value	Maximum value
Control	**Without laser**	**10**	**1.682**	**0.651**	**0.206**	**0.6035**	**2.3250**
	With laser treatment	**10**	**2.915**	**0.473**	**0.149**	**2.1403**	**3.9660**
0.3% CuONPs	**Without laser**	**10**	**1.489**	**0.314**	**0.099**	**1.0195**	**1.9405**
	With laser treatment	**10**	**2.873**	**0.629**	**0.199**	**2.0390**	**3.8380**
0.5% CuONPs	**Without laser**	**10**	**0.911**	**0.359**	**0.114**	**0.4035**	**1.4235**
	With laser treatment	**10**	**1.312**	**0.245**	**0.077**	**1.0110**	**1.7935**

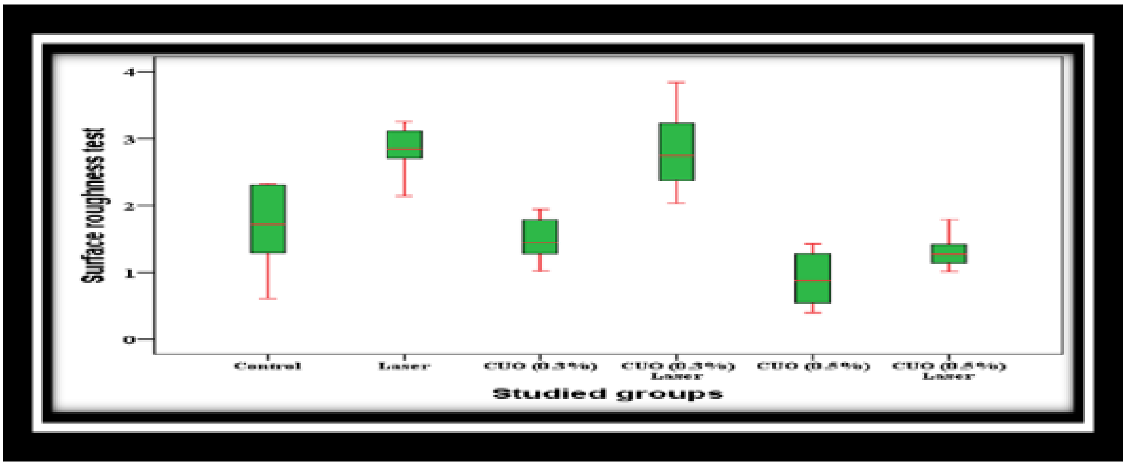

Figure 5: Box plot of surface roughness test of all groups.

For comparison between all groups depending on addition CuONPs and laser surface treatment the ANOVA test was revealed a highly significant differences among all the study groups, table (2).

Table 2: ANOVA test of surface roughness for all groups.

	Sum of Squares	**Df**	**Mean Square**	**F**	**P-value**	**Sig.**
Between Groups	35.118	5	7.024	31.672	0.000	H.S.
Between Groups	11.975	54	0.222			
Total	47.093	59				

For multiple comparisons of all groups the LSD-test between all groups was used. According to addition to CuONPs the result of the comparison between control group and 0.3% CuONPs showed there was non-significant difference while there was highly significant difference between 0.3% and 0.5% CuONPs. On the other hand, Table (3) illustrates the extremely significant differences found in the comparisons between the groups receiving laser treatment and the groups not receiving it.

Table 3: LSD test for multiple comparisons of all group of surface roughness test.

Studied groups		p-value	Sig .
Control	Laser	0.000	Highly sign.
	0.3%CuONPs	0.367	Non sign.
	0.3% CuONPs Laser	0.000	Highly sign.
	0.5%CuONPs	0.001	Highly sign.
	0.5% CuO NPs Laser	0.085	Non sign.
Laser	0.3%CuONPs	0.000	Highly Sign.
	0.3% CuO NPs Laser	0.842	Non sign.
	0.5%CuONPs	0.000	Highly sign.
	0.5%CuONPs Laser	0.000	Highly sign.
0.3%CuONPs	0.3% CuO NPs Laser	0.000	Highly sign.
	0.5%CuONPs	0.008	Highly sign.
	0.5% CuO NPs Laser	0.403	Non sign.
0.3%CuONPs Laser	0.5%CuO NPs	0.000	Highly sign.
	0.5% CuONPs Laser	0.000	Highly sign.
0.5%CuO NPs	0.5% CuO NPs Laser	0.062	Non sign.

Discussion:

The result of surface roughness showed high surface roughness in laser group than the groups without laser treatment. This result agreed with **Asli etal.,2021** who concluded all surface treated groups showed significantly higher surface roughness than the negative control group. The surface roughness was noticeably increased by each surface treatment in laser group **(21)**.

Noor et al., 2010who showed Investigated were the relationships between the surface roughness and the laser cutting parameters. It was discovered that the tip distance, power required, and cutting speed have the biggest impacts on surface roughness. **(22)**.

Gilani et al., 2021 who A commercial pulsed infrared laser was utilized to irradiate the stabilized web in order to carbonize it. With the aid of x-ray diffraction analysis, energy dispersive w-ray, and a scanning electron microscope, the resulting acrylic glass carbon composite (AGCC) was characterized to ascertain the increase in crystallinity as well as the percentage of carbon and surface roughness of the carbon glass composites. (23).

Tugut etal., 2012 who showed The denture base material's surface roughness was significantly altered by the laser irradiation, and this enhanced the adherence of the denture base to the soft lining material. Additionally, varied YAG laser pulse, er lengths energy levels were discovered to successfully boost the bond's strength. (24).

Akin,2011 who altering the bond strengths in poly methyl methacrylate/silicone specimens were dramatically boosted after the poly methyl methacrylate surface was treated with an Er: YAG laser. (25).

On the other hand, the addition of CuONPs showed decrease in surface roughness agreed with **Ergun etal.,2018** who observed there was With the addition of modified nano-ZrO2 at various percentages, indentation hardness and surface roughness increase but not significantly. (26). The results agreed with study **Kurniawan etal., 2020** who showed that the lowest mean value of surface roughness was in a group with the addition of 3% HAP and concluded that there was an effect of HAP on the roughness of heat-cured acrylic resin (27).

This study was disagreed with another study by **Mohammed, and Eldawash, 2022** who revealed there was no significant differences in PMMA color changes, superficial roughness, and hardness were observed in the groups covering various sizes of AuNPs (28).

Also this study was disagreed with **Hameed et al., 2022 who** discovered (29). PMMA's flexural strength and surface roughness were both greatly improved by the addition of nano-sized sisal fiber powder during reinforcing, while surface hardness was not significantly affected.

This study was disagreed with **Chowdhury etal.,2021** who showed the CuONPs Nano particles increase in surface roughness whodemonstrated that Group (TiO2 NP + PMMA) and ZrO2NPs had the highest mean surface roughness, whereas Group (PMMA Only) had the lowest mean surface roughness. All three groups had surface roughness differences that were statistically significant, and it was established that adding TiO2 NP and ZrO2 NP to PMMA significantly altered its surface roughness. In comparison to ZrO2 NP, TiO2 NP addition alters the surface roughness of PMMA more (30).

Conclusion:

Within study limitation and following the current study's findings, the following conclusions can be made:

1. Hot cured acrylic resin substance that has been infused copper oxide using nanoparticles made it easier to get smoother surface with less roughness.

2. Using fiber lasers to cure surfaces was significantly affected the surface roughness of resin material.

Conflict of interest

The authors reported that they have no conflicts of interest.

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