Effect of Nd:YAG Laser Surface Treatment on Wettability of Thermoplastic Acrylic in Comparison with Heat-Cure Acrylic resin

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Abstract

Aim of the study: This study's goal was to determine how laser surface alteration affected wettability of injectable thermoplastic acrylic and heat cure acrylic denture base materials.

Materials and methods: Injectable thermoplastic acrylic resin (Deflex) and heat cure acrylic (Procryla) were used in this study to produce forty-disc shaped specimens, 20 specimens for each material type. The control group was made up of ten samples of each type of plastic denture base material. The other ten samples were treated with a nano-pulse fiber-optic lens Nd:YAG laser. The results were looked at with the Kruskal-Wallis test and the unpaired t-test (a=.05).

Results: Compared to the control groups, the laser-treated groups were more likely to stick together.

Conclusions: After a Nd:YAG laser was used to treat the surface, both molded acrylic and heat cure acrylic became easier to wet.

Keywords: Thermoplastic acrylic, heat cure acrylic, Nd: YAG laser, wettability test.

Introduction:

Many studies have shown that after a period of time having detachable dentures, patients always end up with dentures that don't fit well. This is because soft and hard tissue changes cause bone loss (1, 2). The use of thermoplastic resins over conventional powder-liquid denture base materials has a number of advantages. They provide excellent esthetics and are quite comfortable for the patient when using tooth or tissue-colored materials. Along with being exceptionally stable and resisting heat polymer unzipping, these also show good wear properties, high resistance to wear, high resistance to creep, and resistance to solvents.

To improve retention, denture lining materials are used to soften the tissue sides of detachable teeth and oral prostheses, reduce localized pressure, and provide a more evenly distributed force (3, 4). A number of factors, including poor material quality, surface contaminants like saliva, improper curing or processing, aging and degradation, and inadequate surface preparation, have been linked in studies to the failure of the soft liner and denture foundation (5, 6).

Increase surface area and improve adhesion by mechanically roughening the surfaces using sandblasting, air abrasion, or roughening chemicals like monomer. Laser is one of these techniques for roughening because of its simple, quick, and uniform results. By using a laser to treat denture base resin, the binding site should be made better, mechanical locking should make the bonds stronger, and the surface should be made more wet (7).

One of the most crucial tools for measuring bond strength is the wettability test, which evaluates the contact angles produced by various liquids with specified surface tension and surface energy characteristics (17). With a wettability test, it's easy and quick to find out how well a material or coating sticks to the surface below. This tester lets you find out if surface preparation is needed, find out if the surface's wettability has changed in a way that could make the bond stronger throughout a treatment zone, and judge how well the surface was prepared (8).

Materials and methods:

Injectable thermoplastic acrylic and heat fix acrylic denture base materials were used to make 40 samples. These samples were split into four groups, with two groups {TC (Thremoplastic Control) and HC (Heatcure Control)} of both acrylic materials that had no laser treatment. The surfaces of the other two test groups {TT (Thremoplastic Treated) and HT (Heatcure Treated)} were treated with a Nd:YAG laser with the following settings: The power is 15 watts, the door is 0.09, the speed is 40 m/s, the frequency is 20 Hz, and the spacing is 12 mm.

Specimen preparation

Plastic templates with dimensions of (25 mm x 2 mm ± 0.1mm) in both diameter and thickness were utilized to create the disc-shaped specimens. In order to create the plastic specimen shapes for the surface wettability test, high accuracy computer numerical control (CNC) was used (Figure 1).

Figure 1: Mold design for disc-shaped specimens

The mold for the heat-curd acrylic specimens was made by putting the plastic designs in silicone putty impression material. Both were then put in tooth stone in the lower half of a flask over a vibrator. Separating medium was painted over the set dental stone, silicone putty impression material, and plastic patterns. A fresh mixture of dental stone was then poured onto the upper member of the flask, which was then topped off with the upper half. To construct a mold for the specimens, the flask was opened after the tooth stone had been set. The plastic designs had been attached to the silicone putty impression. After that, the steps of making, packing, and handling the heat-cured plastic samples were done the way the maker said to. The heat cure acrylic polymer and monomer were mixed and packed in the flask and then processed at 74 °C for 90 minutes and 100 degrees for 30 minutes.

With a few minor exceptions for the injectable flask for thermoplastic resins, the procedure for making injection-ready thermoplastic acrylic specimens was the same as that used to make heat-cured acrylic specimens. In accordance with the instructions given by the manufacturer, the capsules were put in the DEFLEX MAD automatic customization device and put into the flask under pressure for 10 minutes while being exposed to pressure (5-7Bar) and heat (265°) (Figure 2).

With an acrylic bur and a stone bur, all of the extra material and flashes were removed from the acrylic samples. The water was then continually cooled while 600-grit sand paper was utilized. All specimens with pores were discarded (9). (Figure 3). Afterwards, all the specimens were cleaned ultrasonically in an ultrasonic cleaner filled with distilled water for 20 minutes to remove any residual by-products (10).

Figure 2: disc shaped specimens of thermoplastic acrylic after deflasking

Figure 3: Heat cure acrylic specimens finishing.

The laser treatment application

With the following settings (15 watts of power) were used Nano-pulse with fiber-optic lens Nd :YAG laser: (Velocity: 40 m/s) (frequency 20 Hz, hatch 0.09) For the surface treatment on ten injectable thermoplastic test group specimens and ten heat-cure acrylic test group specimens, the offset distance was 12 mm. With the help of a laser professional, the laser was used at the Institute of Laser for Postgraduate Studies at the University of Baghdad/Iraq. After putting on safety glasses, a metal plate was put under the discs (Figure 4). Laser treatment continued while the laser handpiece was held upright and at a certain distance (12 mm) from the specimens, as shown in figure 4.

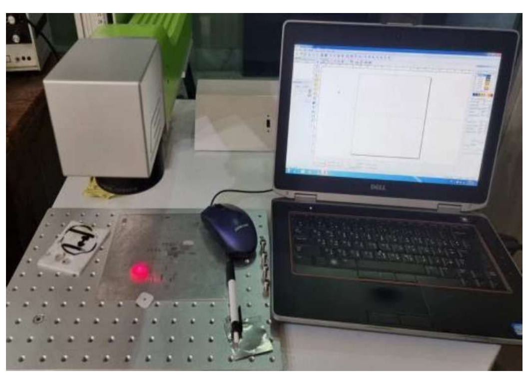
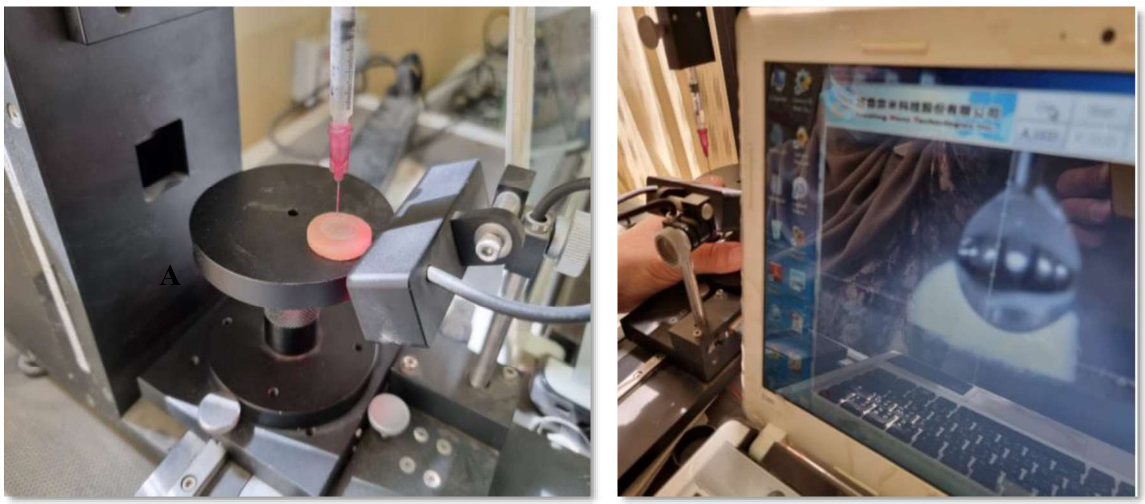


Figure 4: Acrylic (disc shape) specimens during treatment with Nd: YAG laser

SEM (Scanning Electron Microscope): To analyze the surface topography after laser modification of both test groups. SEM analysis was conducted to evaluate the morphological changes in the thermoplastic acrylic and heat cured acrylic surfaces following Nd:YAG laser surface treatment.

Surface wettability test: Experiment aws carried out to examine how laser changed the wettability of both acrylic denture base materials using the sessile drop method of distilled water (1 ml). As a consequence, any surface energy changes brought on by laser contact in the heat cure and thermoplastic could be quantified. The trials were place at a temperature of 20°C in an atmosphere. Every minute while the three minutes that each experiment lasted, a profile picture of the sessile drops was taken. After measuring the contact angles, a mean value was then calculated. Calculations revealed that the experimental error-related standard deviation was ± 0.2° (Figure 5).



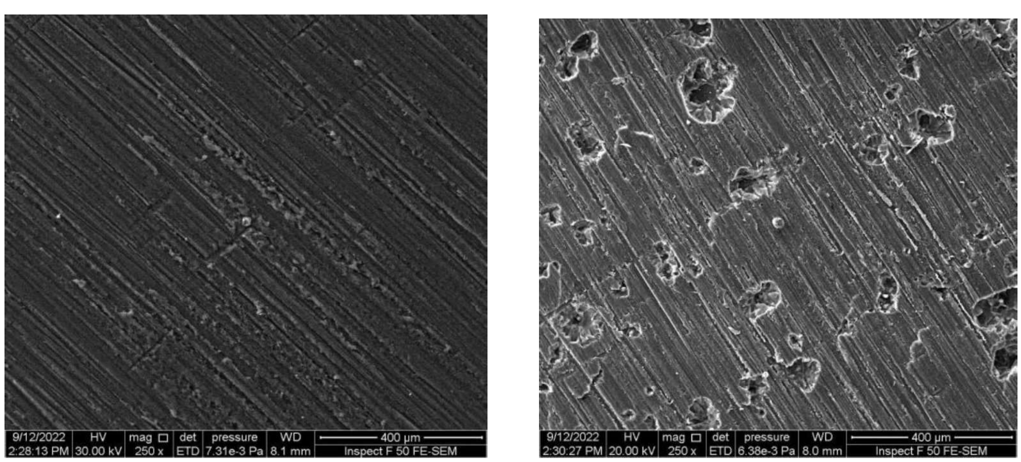
A B

Figure 5: (A, B): Show the wetting and surface energy characteristics of the wettability test

The SPSS version 19 computer program was used to do a statistical analysis of the collected data.

Results:

The morphological changes can be noticed in the images of the SEM of the surfaces in figure (6) of the different test groups with and without laser surface treatment (Figure 6). The surface of the injectable thermoplastic acrylic (group TT) and heat cured acrylic (group HT) had irregularities and many small pits on the surface caused by treatment with Nd:YAG laser as compared with two control groups TC and HC.



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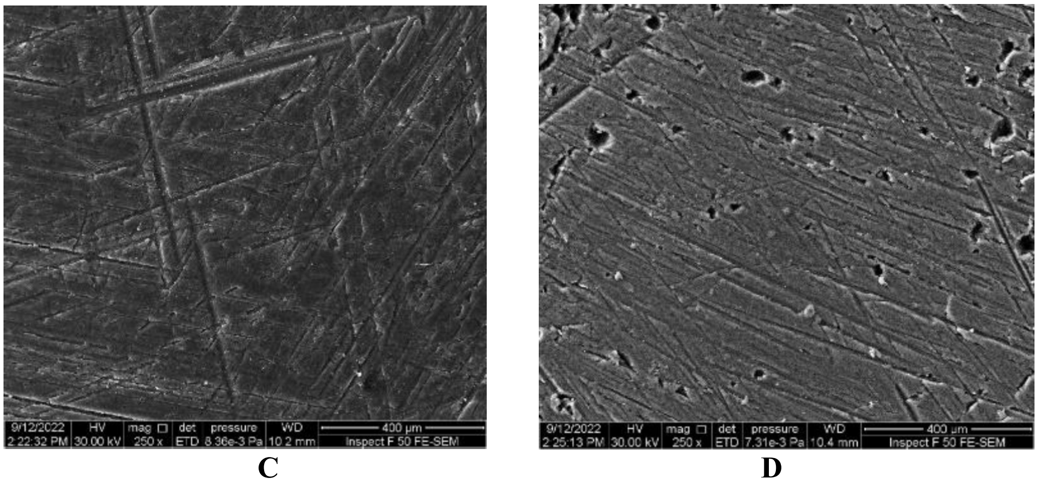

Figure 6: Scanning electron microscope (SEM) images, at magnification ×250, of the surfaces of specimens with and without lase treatment. (A) group TC, (B) group TT, (C) group HC and (D) group HT.

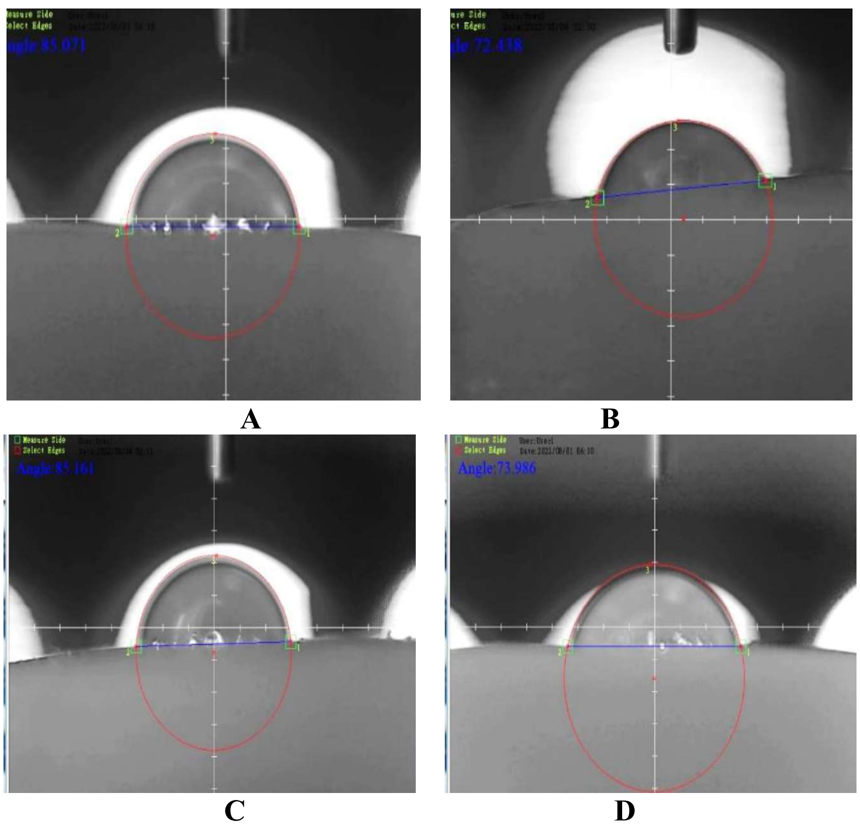

Figure 7: Digital images of goniometer measurements of contact angle; (A) group TC, (B) group TT, (C) group HC, and (D) group HT.

The current results in the table (1) and figure (7, 8) shows that the mean of contact angle in (group HC) was the highest which meant that this group had the least wettable surface. On the other hand, the highest wettability was observed for laser treated group (TT) with the lowest contact angle and followed by (HT) group. The student independent-samples Kruskal-Wallis test for wettability test in table (1) demonstrated that the mean values between study groups was significantly high, t-test (29.565) and P = (0.000 HS).

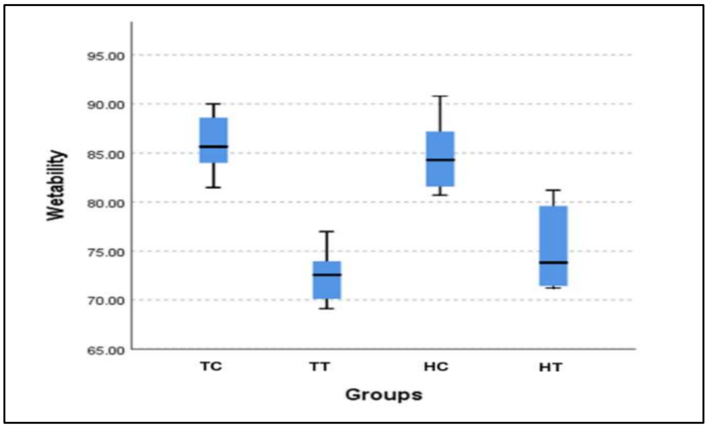

Figure 8: Surface wettability test of the study groups (values in µm)

Table 1: Descriptive statistics and independent-samples Kruskal-Wallis test of the of the surface wettability test values of treated and untreated groups (θ).

		Descriptive statistics				independent-samples Kruskal-Wallis		
Study Groups	N	Mean ± S.E.	S.D.	Min.	Max.	t-test	df	P -Value
Group TC	10	85.97± 0.897	2.83	81.50	90.00	29.565	3	0.000 HS
Group TT	10	72.49 ± 0.754	2.38	69.10	77.00			
Group HC	10	84.83 ± 1.165	3.68	80.70	90.80			
Group HT	10	75.03 ± 1.199	3.79	71.20	81.20			

Surface wettability test findings indicated a very significant difference between the thermoplastic acrylic group TC and the group TT, and also between the heat cured acrylic group HC and the group HT, as shown in table (2).

Table 2: Pairwise comparisons of statistical data of the wettability test values between treated and untreated groups.

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.
Group TC - HC	-3.650	5.227	-0.698	0.485 NS
Group TC - HT	-20.400	5.227	-3.903	0.000 HS
Group TC - TT	22.950	5.227	4.390	0.000 HS
Group HC - HT	16.750	5.227	3.204	0.001 HS
Group HC - TT	19.300	5.227	3.692	0.000 HS
Group TT - HT	2.550	5.227	0.488	0.626 NS

Discussion:

For nearly 50 years, dental offices have used thermoplastic acrylic denture base materials. The useful characteristics of these materials have caused their use to grow over time. Modern materials and technology have made it possible to make dentures that last longer than the ones that have been used in the past. Thermoplastic materials have the following qualities: Superior biocompatibility, shape retention, absence of irritants and dangerous chemicals. Immediate dentures, dentures following resection, complete and partial dentures, and temporary dentures are all on the rise after dental implants (11). The results of SEM indicated that the surface treatment with Nd:YAG laser promoted some degradation, vaporization and dissolution of the thermoplastic acrylic material and heat cured acrylic surface when compared with the control (untreated) group. The denture base material developed obvious pits, cavities, and depressions as a result of the laser surface treatment. The results corroborate Tugut et al.'s (2012) findings that Er:YAG laser irradiation caused denture base resin surface irregularities and several tiny pits (12), and they also align with Oguzhan et al.'s (2015) analysis of SEM images to evaluate the effects of laser treatments on the surface of acrylic resin (9). Both engineers and scientists have a clear interest that surface wettability is one of the primary impacts on denture base material's surface energy by wetting and adhesion. Wettability, which is considered essential to obtain good bonding characteristics, depends on roughness as well as surface tension. The results do not appear to be affected by surface tension, while roughness seems to be the primary factor in how widely water drops spread (13). The current study's findings revealed significant distinctions between the study groups, as the groups treated with Nd:YAG laser showed an increase in the mean values of average surface wettability when compared with the untreated groups (control groups). This is as a result of lasers' primary function of altering the surface features of materials to enhance their wettability attributes and changes in the material's surface energy. Also, the results indicated that the surfaces of acrylic denture base materials treated with laser in group TT and group HT showed a decrease in the contact angle. This leads us to the interpretation that for this the original untreated surfaces are significantly smoother than the obtained after laser treatment as shown in SEM. Increased surface wettability after laser treatment enhances fluid flow and uniformity throughout the polymer surface, and may enhance the adhesion. The possibility of modifying the wettability characteristics of acrylic materials using different types of laser has been abundantly proven by (14). According to (14), the wettability properties of the material were found to change to varying degrees when the Nd:YAG laser interacted with the surface of acrylic resin. When a laser beam is used to treat the surface, the melting and vaporization of the polymer surface, along with certain halls, pits, and fossa with limited depth, may lead to a surface that is rough all over. When compared to the untreated (control) groups, the treated groups' surface wettability ratings went up by a lot. Demonstrating the practical importance of the laser as one of the applications. The laser surface treatment obviously caused porous topography, as shown by the presence of irregular pits and micro-retentive morphological topographical modifications. Experiments on wettability were performed by (15) in accordance with (7) to examine the effects of sandblasting and laser treatments on the bonding of acrylic resin and resilient liners at the interfacial level. They found that lasing PMMA before adding a flexible material made the surface easier to wet than control samples. Furthermore, it was shown in (16) that minuscule holes through which the liner might flow, cementing the binding, could be etched into the acrylic resin surface using laser beams at 3 W, 10 Hz, and 300 mJ.

Conclusion:

1. Laser surface treatments alter the surface morphology of both types of acrylic resin materials, as seen in SEM photos.
2. Surface injectable thermoplastic acrylic and heat-cured acrylic treated with a Nd:YAG laser had higher mean surface wettability than the untreated control group.

We observed that laser surface treatment promotes wettability, which may help denture base materials stick to soft polymer plastic dental covers over the long term in this study. For a soft tooth cushion to be used for a long time, it needs to stick well. According to the results of this study's statistical analysis, laser treatment improved surface wettability compared to untreated controls.

Conflict of interest:
Authors declare no conflict present.

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