BOND STRENGTH OF ACRYLIC SOFT LINER TO ND:YAG LASER-TREATED THERMOPLASTIC ACRYLIC DENTURE BASE MATERIAL

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ABSTRACT

Aim of the study: Using surface roughness and tensile bond strength tests, the objective of this investigation was to ascertain the impact of laser surface modification on the binding strength of injectable thermoplastic acrylic denture base material to acrylic-based soft-liner material.

Materials and methods: Acrylic base soft liner material was bonded to injectable thermoplastic acrylic resin (Deflex). Forty specimens were created (20 disc, 20 dumbbells) 10 of each specimen type as control specimens, and 10 were treated with nano pulse Nd: YAG laser. The data were analyzed using the Kruskal-Wallis test and unpaired t-test (a=.05) and the roughness test was performed utilizing a double column universal test machine.

Results: Compared to the control groups, the laser group had much increased roughness and tensile bond strength.

Conclusions. Following Nd:YAG laser surface treatment, the tensile bonding strength between acrylic soft-liner material and thermoplastic acrylic was increased.

KEYWORDS

Thermoplastic acrylic, Nd:YAG laser, tensile bond strength, surface roughness test

PAPER INDEX

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1. BACKGROUND

Following a time of wearing removable dentures, several studies found that patients invariably have badly fitting dentures as a result of bone resorption that caused soft tissue shape changes (1, 2). The use of thermoplastic resins has a number of benefits over traditional powder-liquid systems. With tooth or tissue colored materials, they offer outstanding esthetics and are quite pleasant for the patient. These exhibit excellent wear characteristics, high fatigue endurance, high creep resistance, and solvent resistance in addition to being extremely stable and resisting thermal polymer unzipping. In order to create more uniformly distributed force, minimize localized pressure, and improve retention, the tissue surfaces of removable dentures and maxillofacial prostheses are cushioned with denture lining materials (3, 4).

Studies confirmed the issue of failure between the soft liner and denture foundation owing to many factors that have a negative impact on the bonding strength (5, 6). The binding site should be improved and stronger bonds should result from mechanical locking and increased surface roughness brought about by laser treatment of denture base resin (7). It is quick and easy to determine how well a material or overlay is connected to the substrate beneath using the tensile bond strength (pull-off) test. With the help of this tester, you can decide if surface preparation is necessary, spot relative changes in potential surface strength throughout a treatment region, and assess the effectiveness of surface preparation (8).

2. MATERIALS AND METHODS:

Forty specimens were prepared from injectable thermoplastic dentures base materials and grouped as follows:

1. Group TC: Twenty specimens of injectable thermoplastic acrylic denture base material without laser treatment.

2. Group TT: Twenty specimens of injectable thermoplastic acrylic denture base material subjected to surface treatment with Nd: YAG laser with power: 15 watt, hatch: 0.09, speed: 40 m/s, frequency: 20 Hz, and distance off 12 mm.

According to the tests required for this study the specimens were be divided into two shapes; disc-shaped and dumbbell-shaped.

2.1. PATTERN SHAPES AND DIMENSIONS FOR MOLD PREPARATION

The molds for the disc-shaped specimens were used with dimensions of (25mm x 2mm ± 0.1) diameter and thickness respectively. They were prepared by using high accuracy Computer numerical control (CNC) to make the plastic shapes for the specimens for measuring the surface roughness test. Dumbbell-shaped 3D printed patterns with dimensions of 75 mm in length, 12 mm in diameter at the thick part, and

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7 mm at the thin portion were utilized to create the mold for the dumbbell-shaped specimens used for the tensile bond test (9). (figure 1).

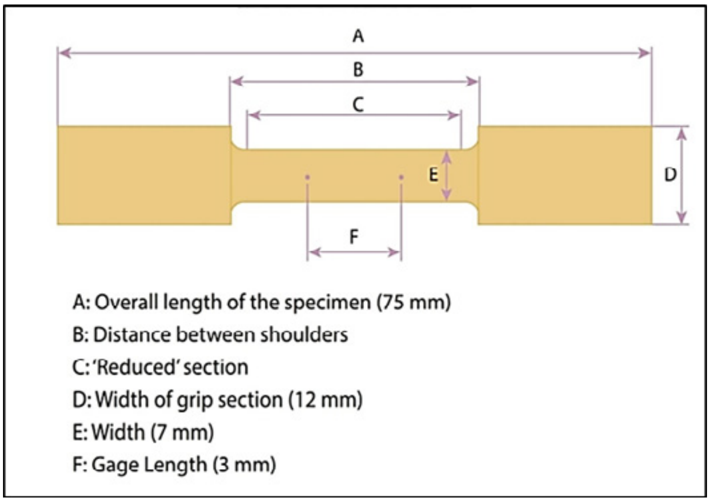

Figure 1. Mold design for dumbbell-shaped specimens

Plastic patterns were invested in silicone putty impression material, the dental stone was proportioned and prepared following the instructions of the manufacturer (W/P ratio: 20ml/100g) and after which it was poured into the aluminum flask's lower half and set over the dental vibrator. Putty and plastic designs were added to the flask's lower half, and then the plastic patterns were cleaned out. Then injectable acrylic cartridges were inserted in the DEFLEX MAD automated programmable device and injected into the flask based on the guidelines provided by the manufacturer, under pressure (5-7Bar) and heat (265° ± 10°) for 10 minutes (15min).

With the use of an acrylic bur and a stone bur, all the surplus and flashes from the acrylic specimens were removed. Next, 600-grit sand paper was used while the water was continuously cooled. All porous specimens from the specimens gathered for the study were discarded. For the finished dumbbell shaped specimens, Before completing, a water-cooled diamond-edged saw was used to remove 3 mm from the thin middle (9) figure 2.

(A)

(B)

Figure 2. (A) disc shaped specimens of thermoplastic acrylic after finishing. (B), dumbbell shaped specimens before cutting from midsection.

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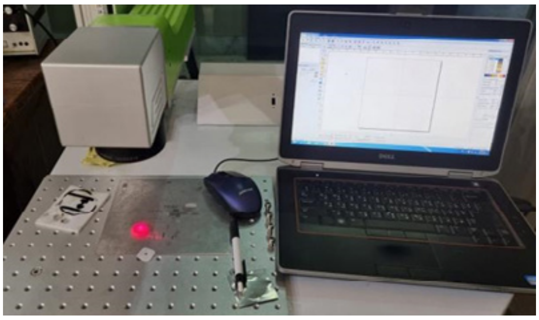
20 injectable thermoplastic acrylic test group specimens were handled by Nd: The following settings were used for the surface treatment using a YAG laser (Nano pulse with fiber optic lens): (15 watts of electricity) (Velocity:40 m/s) (hatch 0.09) (20 Hz frequency) (Offset distance: 12 mm). The application for a laser therapy was made at the Institute of Laser for Postgraduate Studies of the University of Baghdad/Iraq, under the direction of a laser specialist. The metal plate was placed underneath the acrylic disc after donning protective eyewear, the laser handpiece was held vertically and at a certain distance from the specimens to continue the laser therapy, as shown in (figure 3, 4).



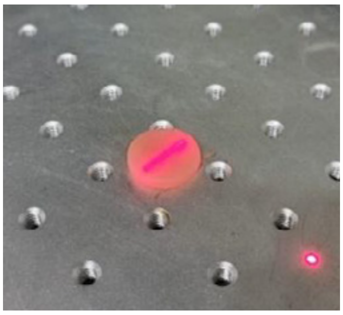


Figure 3. Acrylic (disc shape) specimens during treatment with Nd:YAG laser

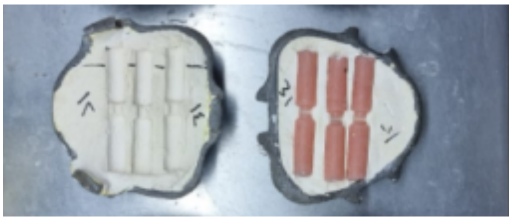


Figure 4. Tensile bond strength test specimens before soft liner application (dumbbell-shaped).

For curing the soft liner inside the flask, a digital water bath which is thermostatically controlled was used. Following the instructions of the manufacturer. The flask was removed from the water bath and set aside for bench cooling at room temperature. The flask was opened when it had finished cooling down completely, and the samples were taken out. For deflasking and finishing, before testing, each specimen was immersed for 48 hours in distilled water at 37°C in an incubator. (10).

2.2. SURFACE ROUGHNESS TEST

RA mechanical profilometer was used to analyze roughness. Each specimen had measurements made at several locations for subsequent statistical analysis. The Ra (roughness—arithmetic mean value of all deviations from the midline's roughness profile throughout the measurement length) method is used to examine the data (11).

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2.3. TENSILE BOND STRENGTH TEST

The dumbbell-shaped specimens of the current study were used for this test for the acrylic denture base group, including investigation of failure type: cohesive, adhesive, and mixed. The specimens was placed in the same metal grip former, which is fixed at the bottom of the testing machine. The load is applied until failure occurs and the maximum breaking forces are recorded in Newtons.

The outcome of the Nd: YAG laser treatment of the surface on (1) the enhancement of the tensile bond strength of both thermoplastic, and (2) surface roughness. Where the data for this study were gathered, processed, and arranged was evaluated for each of these. The collected data were analyzed statistically.using the SPSS version 19 computer software.

3. RESULTS

3.1. SURFACE ROUGHNESS TEST

The descriptive statistics for the roughness test are shown in figure (5) and table (1). The injectable thermoplastic acrylic group demonstrated significantly higher roughness values after treatment with the Nd:YAG, while the control groups demonstrated the lowest roughness values.

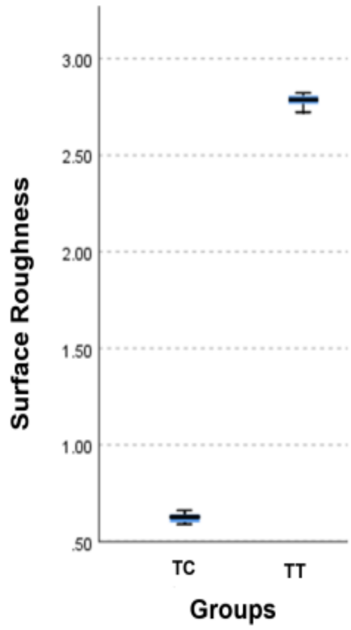

Figure 5. Surface roughness test of the study groups (values in µm)

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Table 1. Descriptive statistics and t test of the surface roughness test values of groups with and without laser treatment (µm).

		Descriptive statistics				Inferential statistics		
Groups	N	Mean ± S.E.	S.D.	Min.	Max.	t-test	df	P -Value
Group TC	10	0.62 ± 0.007	0.02	0.59	0.66	148.4306	9	0.0001 HS
Group TT	10	2.78 ± 0.009	0.03	2.72	2.82			

3.2. TENSILE BOND STRENGTH TEST

In figure and table (6), the means of the various test groups for the tensile bond strength test are displayed (2). The group's mean tensile bond value (TT) was greater than the (TC) value for the control groups (no laser surface treatment). The results of the tensile bond strength test in table (4) showed a very significant difference between the groups that received treatment.(27.728, P= 0.0001 HS) when compared. The findings of the pairwise comparisons test for tensile bond strength results between research groups in table (5) revealed a highly significant difference between (Group TC and group TT).

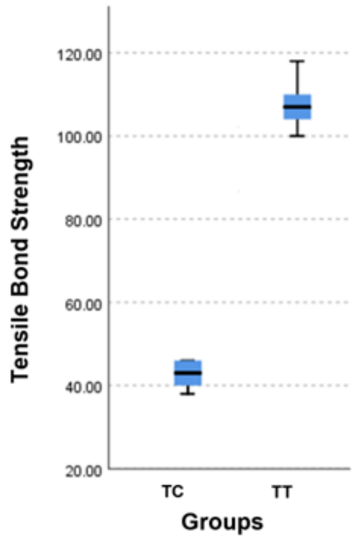

Figure 6. Tensile bond strength of the study groups (values in N).

Table 2. Descriptive statistics data and t test of the tensile bond strength test values of Nd-YAG laser treatment groups and untreated groups (values are in N).

		Descriptive statistics				Inferential statistics		
Groups	N	Mean ± S.E.	S.D.	Min.	Max.	t-test	df	P -Value
Group TC	10	42.80 ± 0.90	2.86	38.00	46.00	27.728	9	0.0001 HS
Group TT	10	108.00 ± 1.66	5.25	100.00	118.00			

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Failure modes are described in (table 3). The injectable thermoplastic acrylic group showed mostly cohesive failures 80% with laser treatment and 100% adhesive failure without laser treatment.

Table 3. Modes of failure in each group of specimens

Study Group	Adhesive	Cohesive	Both
Group TC	20	0	0
Group TT	0	16	4

3.3. DISCUSSION

Dental practices have been using thermoplastic acrylic denture base materials for nearly 50 years. Due to these materials' beneficial qualities, their use has expanded in the interim. Their continued advancement has led to the creation of new classes of increasingly cutting-edge materials and technology that enable the creation of dentures that are stronger than standard dentures. The following traits of thermoplastic materials exist: Excellent biocompatibility, no residual monomer, no allergenic or harmful chemicals, ability to keep form. The use of TMs for immediate dentures, post-resection dentures, full and partial dentures, and interim dentures following implantation is increased. because to their excellent flexibility and accuracy as well as their range of hues. (12).

Surface treatment with a laser beam led to preferred surface roughness results, the laser beam produced surface changes by ablation that cause melting and vaporization of the polymer surface and produce that causes some halls, pits and fossa of limited depth which may result in uniform surface roughness. Surface roughness values of treated groups significantly increased when compared to the untreated (control groups), which was caused by the laser's significance as one of the practical uses. This was used in increasing and improving bonding and adhesion between denture base resins material and soft liner. Noticeably, the laser surface treatment produced porous topography with irregular pits and micro-retentive morphological topographical changes. This study agreed with (13) claimed that a different approach to surface treatment to get a stronger bond strength between two materials, the laser, has been suggested. Furthermore, (14) shown that treating the surface of denture base resins with the laser has been said to be a simple and safe process. Additionally, the recent findings support the claims made by (15), who claimed that the PMMA's surface had been modified by lasing in order to expand its surface area and add mechanical locking.

In the present study, we discovered that employing the laser to treat the surface effectively increases the binding strength, resulting in long-term adhesion of denture base materials with acrylic-based denture liners made of soft polymers. Therefore, a strong adherence is required for the long-term use of a soft denture liner. When a soft denture liner is required as the basis for a denture, strong adhesion is required for long-term use. The significant difference in surface roughness between the treated group and the control group was attributed to the effect of laser surface treatment in

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increasing the bonding of denture base materials and soft denture liners. Because the laser has an impact on the surface that increases tensile bond strength, the use of modification methods like lasers is required to prevent these issues.

According to the statistical analysis of the current study, applying a laser to a surface to treat it strengthened the tensile bond in the laser-treated groups compared to the control groups. Additionally, the Nd: YAG laser created pits or other abnormalities that the soft lining material was able to penetrate, enhancing the connection in the laser-treated groups. Soft lining materials may therefore pass through any defects or pits left behind by the Nd: YAG laser.

The use of a laser for surface treatment enhanced the tensile bond strength in the groups treated with the laser compared to the control groups, according to the results of the statistical analysis carried out in the current study. Additionally, in the laser-treated groups, the soft lining material was able to infiltrate the abnormalities or pits, strengthening the connection. As a result, soft lining materials may penetrate imperfections or pits created by the Nd: YAG laser. (17) conducted tensile experiments to assess how sandblasting and laser treatments affected the bonding of acrylic resin and robust liners at the interfacial level, consistent with (7) They found that lasing PMMA prior to applying a resillient material led to stronger mean tensile bonds than control specimens. Also, (16) shown that preparing the acrylic resin surface with laser beams at 3 W, 10 Hz, and 300 mJ produced tiny holes the liner could enter, strengthening the binding. The increase in cohesive failures after laser treatment suggests an improvement in the tensile bond strength of the acrylic-based soft lining to the injectable thermoplastic acrylic resin because the adhesion between these materials may be stronger than the intermolecular forces of the relining material. Results that increased the tensile binding strength of the resin-based soft liner to the acrylic resins were similar with the findings of (18,19), which demonstrated cohesive failures. The alternative hypothesis, according to which Nd: YAG laser treatments enhanced the thermoplastic acrylic denture resin's tensile binding strengths to the denture base soft liner, was accepted and the null hypothesis was rejected.

4. CONCLUSION

1. As demonstrated in this work, laser surface treatments change the surface morphology of acrylic resin.
2. Nd: YAG laser treatment of surface injectable thermoplastic acrylic then relined with acrylic-based soft lining resulted in higher mean surface roughness and surface than seen in the untreated control group.
3. Injectable thermoplastic acrylic surface treatment with Nd: YAG laser (power: 15 watt) (speed: 40 m/s) (hatch 0.09) (frequency: 20 Hz) (distance off: 12mm), has shown that when employed as a surface treatment agent, it effectively strengthens the tensile bond between the thermoplastic acrylic denture base material.

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