

Changes in the Transverse Strength of Heat-Cured Acrylic Denture Base by Using Diodes Laser as Surface Treatment

Hawraa Khalid Aziz. ⁽¹⁾

Key words

diodes laser, Soft liner material, Heat cure acrylic, Transverse strength.

Abstract

Transverse test is considered to be appropriate for polymeric dental materials since compression and tension stresses are correlated to specific fractures that occur during flexural load. So the aim of the study is to evaluate the transverse strength of heat cured acrylic denture base material by using different surface treatment by laser treatment with diodes laser and air-abrasion AL₂O₃. The 60 specimens of heat cured acrylic denture base material were prepared for this study. They were divided into three groups according to type of the surface treatment and as follows: first group without any treatment (control group), second group is treated with air-abrasion (AL₂O₃). While third group is treated with Diodes laser, then each group subdivided into two groups according to addition of the soft liner: group a: specimens made from heat cured acrylic and soft liner, while group b: specimens made from heat cured acrylic only, each group consisted from 10 specimens. The results showed lowest mean values of the transverse strength for the control group than the specimens with AL₂O₃ group, and the highest mean values of diodes laser group but statically there was non-significant difference between the groups. In addition the mean values transverse strength of the soft liner bonded to the heat cured acrylic were higher mean than those without soft liner groups. Within the limitation of this study, there was no change in the transverse strength of the heat cured acrylic by using the diodes laser and air-abrasion AL₂O₃ surface treatment.

Introduction:

The transverse (Flexural) strength test, one of mechanical strength tests, is especially useful in comparing denture base materials in which a stress of this applied to the denture during mastication. The transverse (flexural) strength is a combination of compressive strength, tensile, and shear strength, all of which directly reflect the stiffness and resistance of a material to fracture ⁽¹⁾.

Transverse tests are further considered to be appropriate for polymeric dental materials since compression and tension stresses are correlated to specific fractures that occur during flexural load ⁽²⁾.

The transverse strength of acrylic resins depends on several factors, such as polymer molecular weight, polymer bead size, residual monomer level, plasticizer composition, amounts of cross-linking agent, internal porosity of the polymer matrix, denture base thickness, patient factory, type of polishing, and action of chemical agents ⁽³⁾. Considering that the overall longevity of dental prosthesis also depends on the physical properties of the denture base, and that denture base polymer may fail clinically due to flexural fatigue, the assessment of the transverse strength of acrylic resins has been reported to be reliable method to estimated resin behavior under different experimental

(1) Ass. Pro, Dental technologies Department, Colledge of health and Medical technology.

conditions. On the other hand, the denture lining materials are applied to the intaglio surface of dentures to achieve more equal force distribution, reduce localized pressure, and improve denture retention by engaging undercuts⁽⁴⁾. Denture liners have been shown to increase a patient's level of comfort during mastication⁽⁵⁾. They provide comfort for patients who cannot tolerate occlusal pressures or who present alveolar ridge resorption, chronic soreness, and knife-edge ridges⁽⁶⁾. Therefore denture lining materials have become important in dental prosthetic treatment but common clinical occurrence and major problem is the lack of a durable bond to the denture⁽⁷⁾. To solve this perplexing problem, researchers have considered altering the PMMA surface before applying a resilient material⁽⁵⁾. Sand blasting procedure involves spraying a stream of aluminum oxide particles against the material surface intended for bonding under high pressure⁽⁸⁾. Few studies have been done on the use of sandblasting denture base and information is conflicting on use of sandblasting to increase bond strength of acrylic resin denture base and soft lining material.

Researchers have attempted to identify other methods to improve the polymethyl methacrylate (PMMA)/ resilient liner bond. Since development of the ruby laser by Maiman in 1960, lasers have become widely used in medicine and dentistry⁽⁹⁾. Recently, lasers have been shown to provide a relatively safe and easy means of altering the surface of materials. Although lasers have not been used to roughen PMMA surfaces before application of a resilient liner, they have been used to etch metals before application of porcelain⁽⁵⁾. Lasers have also been used for processing dental materials, especially for fusing the materials on or into tooth surfaces⁽⁹⁾.

The Diodes laser operates at a wavelength of 904nm in a high-intensity pulsed or continuous waveform can be used for soft-tissue incision and ablation including gingival toughening esthetic contouring of gingival treatment of oral ulcers, frenectomy, gingivectomy⁽¹⁰⁾.

So the effect of the liner on the strength the base resin is great important in

deciding the suitability of that liner since soft liners usually need special bonding agents that interact with the surface layer of the denture base polymer and the soft liner, therefore the strength of the relined denture polymer is depended on the strength of both denture base polymer and the reline polymer and on the ability of the polymers to bond to each other⁽¹¹⁾.

So the aims of this study are:

1. Evaluate the effects of various surface treatments: air-abrasion with Al₂O₃ particles and Diodes laser surface treatment on the transverse strength of the heat cured acrylic resin denture base material.
2. Evaluate of the transverse strength of heat cured acrylic resin denture base material after addition of heat cured soft liner to acrylic resin denture base material.

Materials and method:

A total of 60 heat cure acrylic resin specimen (each specimen was made from PMMA denture base material. Rodax W.P. dental, Germany) were prepared for this study. They were divided in to three major groups according to the type of the surface treatment and each major group subdivided into two groups according to the addition of the soft liner material (Vertex™ Soft, Netherlands) (the first group made from heat cured acrylic only (bulk specimens) and the second group made from two layers heat cured acrylic and soft liner) (10 specimens for each group) as follow:

1. Group (Ia) with soft liner without any treatment.
2. Group (Ib) without soft liner and without any treatment.
3. Group (IIa) with soft liner with sand blast with Al₂O₃ (250 μm).
4. Group (IIb) without soft liner with sand blast with Al₂O₃ (250 μm).
5. Group (IIIa) with soft liner with Diodes laser treatment.
6. Group (IIIb) without soft liner with Diodes laser treatment.

Specimens preparation:

Transverse strength specimens prepared of a bar shaped specimen with dimensions of (65mm×10mm×2.5 mm) length,width,

thickness respectively⁽¹²⁾ (ADA specification No. 12, 1999) Figure (1).

The mould prepared by pattern was coated with separating medium and allowed to dry and then lower portion of the flask was filled with dental stone mixed according to the manufacturer's instruction.

The pattern was invested into the stone mixture, after setting of the stone, the stone and plastic patterns were coated with separating medium and the upper half of the flask was positioned on the top of the lower half of the flask and filled with stone. The flask was covered with the stone and left to set. After an hour the flask was opened and the standard specimen was drawn out. The proportioning and mixing of the acrylic powder and liquid followed the manufacturer's instruction. P/L ratio (22g of powder /10 ml of the liquid). A measured volume of liquid was placed in dry clean mixing vessel followed by slow addition of powder, the mixture was then stirred with wax knife and left to stand until dough stage has reached. The packing of heat cure acrylic was performed while the acrylic was in dough stage, as recommended by ADA specification No.12 (1999)⁽¹²⁾. The acrylic resin was removed from its mixing vessel and rolled; it was packed into the mould which previously has been coated with separating medium. The upper half of the flask was positioned in its place, then the flask was placed under hydraulic press with slow application of pressure to allow even flow of acrylic dough, then the flask was opened and by the use of a sharp knife the excess acrylic material was removed then the flask was tightly closed and clamped for curing. The Curing of the heat cure acrylic according to the manufacturing instruction the flask immersed into cold water and then increased the temperature to 70° for 60 minutes. After that the temperature was increased to reach 100° for the next 60 minutes. The total polymerization time took 2 hours. Then after cooling the flask was opened and the acrylic specimen was removed. All the accesses and flashes of acrylic specimens were removed with an acrylic bur and stone bur followed by using sand paper with continuous water

cooling. Polishing was accomplished for all the surfaces of the acrylic specimen except the surface that faces the relin material by using bristle brush and pumice with lathe polishing machine⁽¹³⁾. After which the acrylic specimen were measured using digital vernier (with an accuracy of 0.01) to end up with approximately dimensions. Then the acrylic specimens were conditioned in distilled water at 37° for 24 hours according to ADA specification No.12 (1999). Any porous specimen was discarded from the specimens that collected for the purpose of the study.

The surface treatment:

The specimens were treated by Diodes laser to ensure an equal distribution of the Diodes laser treatment on the entire surface bonding area of each acrylic block and to standardize the laser treatment for all acrylic blocks a method was created as follow:

An aluminum plate was cut (equal to dimensions of the acrylic block bonding surface area). Then the aluminum plate was perforated with a special turning machine. This has the ability to drill small perforations that are equal in diameter and equal in distance from each other. The perforations diameter was of 2mm which is suitable for the laser to pass through. 5-6mm distance was chosen between each two perforations (the smallest distance that machine can provide and under control without distorting the aluminum plate)⁽¹⁴⁾ as shown in Figure (2).

The laser device (Diodes, China) is the therapy laser, which is a class IV laser product CNC Built in at wavelength of 1050-1060 nm, and classified as a class IV laser according to the (ANSI) classification and is supplied with its protective eye-wears. A fixed distance was created by stabilizing the exit window of the laser hand piece and the metal plate. The distance chosen for this purpose is (9mm) according to the manufacturer instruction of Diodes laser device for each hole and standard distance in laser application for each acrylic blocks.

The laser treatment application was made under supervision of a laser specialist at the laser institute in Baghdad University. After wearing eye glass for protection, the

metal plate was put on the bonding surface of the acrylic block and the laser treatment was carried on by holding the laser hand piece vertically and at a fixed distance from the aluminum plate the exposure time was (15 seconds) for each hole in the metal plate⁽¹⁵⁾.

The acrylic block was stored in distilled water for 24 hours and ready for soft liner application⁽¹³⁾.

The specimens for Al₂O₃ treatment were sand blast by using laboratory air abrasive blaster with Al₂O₃ at air pressure of 4bars for one min. The specimens were held with special design fixture for standardization of distance between the specimen surface and nozzle of device 20mm⁽¹⁶⁾.

For the relined acrylic specimens preparation the proportion thickness of the acrylic resin to the soft liner was 1.5mm:1mm⁽¹⁷⁾, by the same method was followed for the preparation of acrylic specimens without soft liner (bulk specimens) the relined specimens were prepared by bar shaped pattern with dimensions of (65mm ×10mm×1.5mm) length, width, thickness respectively. The stone mould was obtained for these specimens by the same procedure was used for bulk acrylic specimens. After complete preparation of the acrylic specimens for the soft liner groups the acrylic specimen was placed in the same stone mould with dimensions of (65mm ×10mm×2.5 mm) that was used for fabrication of the bulk acrylic specimens to have the same thickness in all groups with and without application of the soft liner. The vertex soft lining material which was supplied as powder and liquid was placed into the prepared mould, according to the manufacturer's instructions (12 g: 10 ml) (p/l) and applied into the mould by a spatula. The flask was closed and pressure was applied by using a hydraulic press up to 100 Kpa for 10minutes, the pressure was then released and the flask was transferred into thermostatically controlled water bath to polymerize, and the cold water was then heated slowly at 70°C for an hour and a half, the temperature was then raised to 100 °C for one hour and a half, then it was removed; and allowed to cool slowly before opening it; after opening the excess

was cut with sharp knife then the specimen was removed from the mould .

The transverse strength test:

The transverse strength test was done by using the Universal Instron testing machine (Tinius Olsen, H50KT) which was used to measure the transverse strength values. The acrylic specimen was placed on bending fixture consisting of 2parallel supports, and the load was applied with cross head speed of 1mm/min by rod placed centrally between the supports making deflection until fracture occurred⁽¹⁴⁾ as shown in Figure (3).

The transverse bend strength was calculated in N/mm²⁽¹⁸⁾:

$$FS = \frac{3TL}{2bd^2}$$

FS=transverse strength (N/mm²)

T=Load at proportional limit (N)

L=Span distance (50mm)

B=width of specimen (10mm)

D=Thickness of specimen (2.5mm).

Statistical analysis:

The data was statistically analyzed with the computer program Statistical Package for Social Sciences (SPSS) version 21.0 for Windows. The means and standard deviations were obtained. Also, the one-way analysis of variance (ANOVA) were used for comparison of the effect of different surface treatment on the transverse strength of heat cured acrylic specimens. A 95% confidence levels were used.

Results:

Descriptive statistic of the results of the transverse strength values of the heat-cured soft liner with different surface treatment showed lowest mean values of the control group than the specimens with AL₂O₃ group, and the highest mean values of diodes laser group. In addition the mean values transverse strength of the soft liner bonded to the heat cured acrylic were higher mean than those without soft liner groups as shown in table (1), and figure (4).

In comparison of mean values of the transverse strength with and without addition of the soft liner t-test was showed there were non-significant different between the test groups as shown in table (2).

For the comparison the effect of the different surface treatment on transverse on the transverse strength of different surface treatment groups the ANOVA test indicated there were a non-significant different between all groups as showed in the table (3).

For the comparison of means values of the transverse strength of smooth and rough surface of the soft liner groups with bulk acrylic denture base material the t-test indicated there were a non-significant different between all groups as showed in the table (4).

Discussion:

The evaluation of acrylic denture base by transverse bending test is based on three point loading system, reflecting the loading arrangement in a clinical situation⁽¹⁹⁾. The flexural strength of a material is obtained when one loads a simple single beam, simply support (not fixed) at each end, with a load applied in the middle. Such a test is called a three-point bending or flexure test and the maximum stress measured in the test is called flexural strength⁽¹⁹⁾.

In comparison of the effect of the addition of the soft liner on transverse strength the results showed the means values of the transverse strength of groups with addition of the soft liner were higher than those without addition of the soft liner but the t-test was showed there were non-significant different between the tested groups this may be attributed to the effect of the soft liner material on the denture base by the ability of the lining material to bond to denture base essentially that the denture base material had better bonding with relined material that exhibit better strength after relining⁽¹¹⁾. This observation in agreement with **Elian, 2005** who concluded that addition of the soft liner increased the mean values of the transverse strength but statistically not significant⁽¹⁷⁾.

In comparison of the effect of different surface treatment on the transverse strength test values of the heat cure soft liner bonded to the acrylic denture base material. The results were showed that there no significance differences in

transverse strength between different surface treatment in the groups of the acrylic with and without use of the soft liner this could be explained by an increase in cross-linking, providing a sufficient number of bridges between linear macromolecules to form a three-dimensional network that in turn decrease water sorption, decreased solubility, and increasing the strength and rigidity of the resin as well as providing greater resistance to minute surface cracking⁽¹⁸⁾. The transverse bending strength as was calculated in N/mm² using the following formula:

The transverse bend strength = $3 \times \text{load} \times \text{length} / (2 \times \text{width} \times \text{thickness}^2)$ ⁽¹⁸⁾.

According to this equation, The significance of the length, thickness and width of the specimens in relation to the strength and deformation produced was clearly evident and thus could have been explained by the fact that AL₂O₃ and Diodes laser surface treatment may affect the surface and not the length or the width or the thickness of the specimen that in other words values of PMMA may give an indication that transverse strength was not affected by AL₂O₃ and Diodes laser surface treatments. This result was in agreement with **Rasheed, 2014** who concluded that the transverse strength was not affected by laser surface treatment⁽¹⁴⁾.

In comparison of the effect of the surface texture (smooth or rough) of soft liner in comparison to bulk acrylic denture base material. The result of this study showed increased in transverse mean values but statically non-significant difference in the transverse strength between the smooth and rough surface of the soft liner groups in comparison to the bulk acrylic denture base material. This result in agreement with **Usumez et al., 2004** reported that lasing of the PMMA before resilient-material application resulted in higher mean bond strengths than those of control specimens, but these increases were not statistically significant⁽²⁰⁾. But this result was disagreed with result of **Elian, 2005** who was concluded that there was a reduction in transverse strength in regard to the surface texture smooth and rough relined specimens⁽¹⁷⁾.

Conclusion:

Within the limitation of this study, there is no change in the transverse strength of heat cured acrylic resin after addition of

the soft liner as well as the transverse strength of the heat cured acrylic not affected by using the diodes laser and air-abrasion AL_2O_3 as surface treatment.

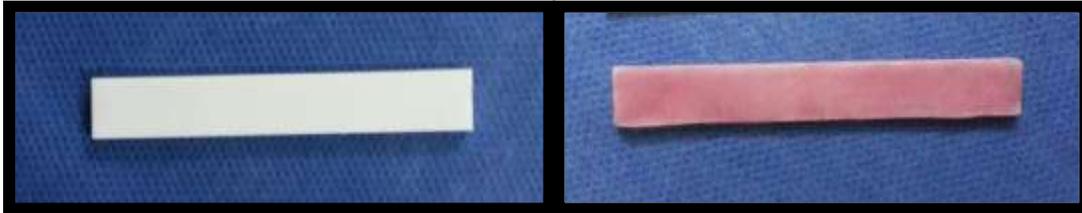


Figure (1):A. the plastic pattern B. An acrylic block of the transverse strength specimen.

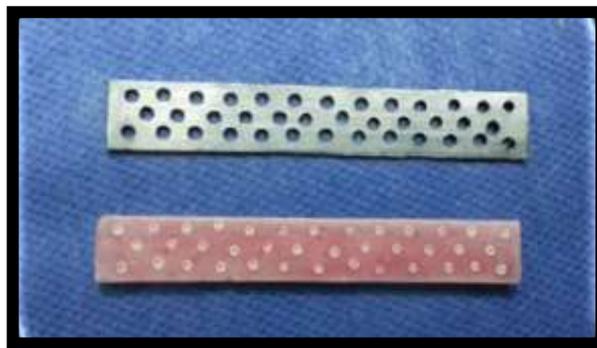


Figure (2): The aluminum plate and surface treated acrylic specimens.

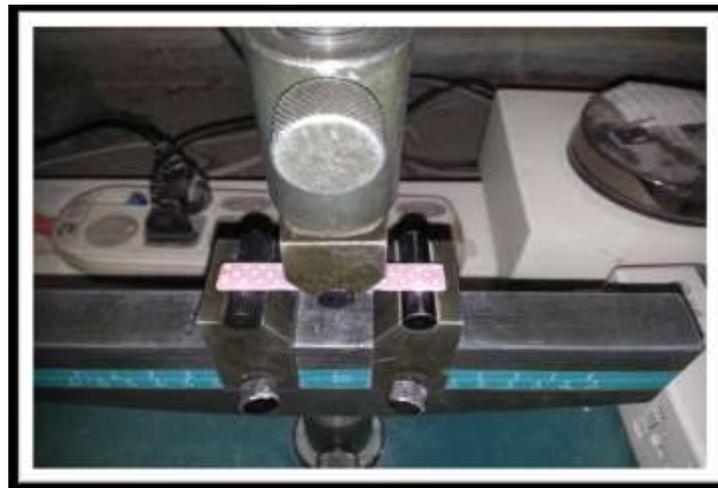


Figure (3): Transverse specimen during testing.

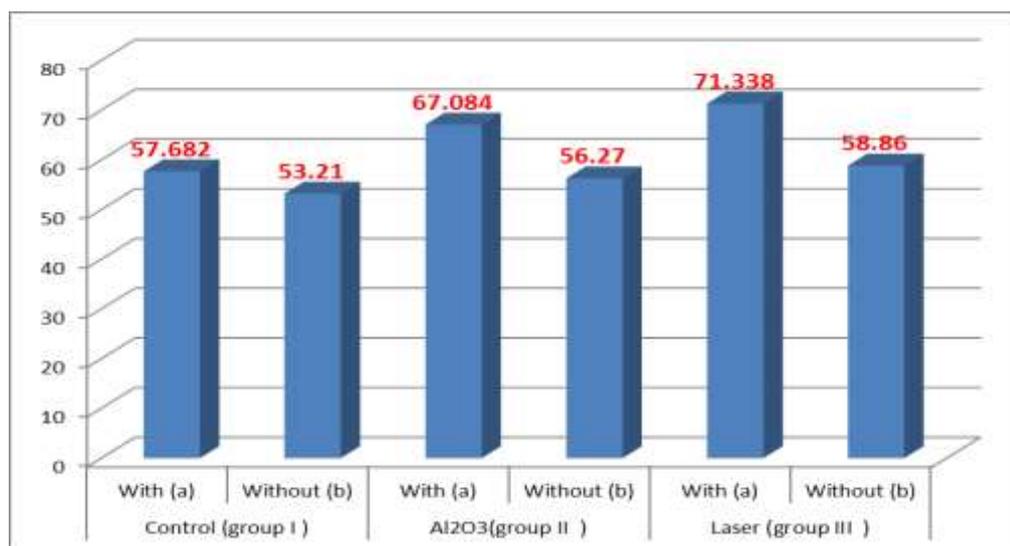


Figure (4): Bar chart showed the transverse strength with and without the soft liner in all groups in different surface treatment.

Table (1): Descriptive of transverse strength of all groups.

	Control (group I)		Al ₂ O ₃ (group II)		Laser (group III)	
	With (a)	Without (b)	With (a)	Without (b)	With (a)	Without (b)
Mean	57.682	53.21	67.084	56.27	71.338	58.86
SD	8.64976	6.25145	12.4226	4.7386	6.69311	9.0810
SE	3.66515	2.64892	6.6931	2.00788	2.83606	3.84789
Min.	49.44	45.91	49.44	49.44	61.21	45.91
Max.	70.63	60.04	83.5	61.21	78.87	68.28

Table (2): T-test between groups of transverse strength with and without addition of the soft liner.

	t-test	P-value	Sig.
Group Ia & Group Ib	0.834	0.451	NS*
Group IIa & Group IIb	2.765	0.051	NS*
Group IIIa & Group IIIb	1.901	0.130	NS*

*P>0.05 Non significant

Table (3): ANOVA-test between groups of transverse strength according to different surface treatment.

	F-test	P-value	Sig.
Between groups with soft liner (Group Ia & Group IIa & Group IIIa)	2.639	0.112	NS*
Between groups without soft liner (Group Ib & Group IIb & Group IIIb)	0.833	0.458	NS*

*P>0.05 Non significant

Table (4): T-test between groups of transverse strength of bulk acrylic (control group) and smooth, rough of soft liner .

	t-test	P-value	Sig.
Group Ia & Group Ib	0.834	0.451	NS*
Group Ia & Group IIb	0.431	0.689	NS*
Group Ia & Group IIIb	0.170	0.873	NS*

*P>0.05 Non significant

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