Bond Strength of Flexible Resin to Cobalt-Chromium Using Different Designs of Laser Surface Treatments

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Abstract

Objective: This study was oriented to evaluate the effect of different laser surface treatment designs on improving the shear bond strength of the flexible resin to cobalt chromium denture base.

Materials and methods: 30 specimens of flexible resin bonded into cobalt chromium denture base material were prepared for this study. They were divided according to the type of surface treatment as follow: Group I without any treatment (control group), Group II was treated with laser in line design. While Group III was treated with laser in a mesh design. The shear bond strength was measured using the Instron testing machine.

Results: The results revealed that the highest mean values for the specimens treated with laser in mesh design while lowest mean values for the specimens of laser treated with line design and control group. Data analysis was done using one-way ANOVA and LSD-test at a significant level (p-value <0.05).

Conclusion: within the limitation of this study, mesh laser surface treatment of Cobalt-Chromium was improved the bond strength.

Keywords: Shear bond strength, flexible resin, cobalt chromium, laser treatment.

قوة ارتباط الاكريليك المرن بالكروم كوبلت باستخدام تصاميم مختلفه من المعامله السطحيه بالليزر

نوال عبد صبار و أ.م. حوراء خالد عزيز

الخلاصة

الهدف: تم توجيه هذه الدراسة لتقييم تأثير تصاميم مختلفه من المعاملة بالليزرعلى تحسين قوه الربط القصي من الراتنج المرن لقاعده طقم الاسنان الكروم كوبالت

المواد والطرق: تم تحضير 30عينه من الراتنج المرن المرتبط بقاعدة طقم الاسنان الكروم كوبالت في هذه الدراسة. تم تقسيمها حسب نوع المعاملة السطحية على النحو التالي: المجموعة الأولى دون أي معامله (المجموعة الضابطة)، المجموعة الثانية

عوملت بالليزر بشكل خطوط. بينما المجموعة الثالثة عوملت بالليزر بشكل شبكه. تم قيا س قوه القص باستخدام ماكنه الاختبار Instron.
النتائج: كشفت النتيجة ان اعلى معدلات القيم للعينات المعاملة بالليزر بشكل شبكه بينما أدنى القيم كانت للعينات المعاملة بالليزر بشكل خطوط والعينات الضابطة. تم تحليل البيانات باستخدام اختبار one –way ANOVA واختبار LSD بمستوى معنويه (P-value<0.005)
الاستنتاج: في حدود هذه الدراسة معامله الكروم كوبالت بالليزر بشكل شبكه يحسن من قوة الربط.
الكلمات المفتاحيه: قوه الربط القصي، الراتنج المرن، كروم كوبالت، معامله بالليزر.

Introduction

Cobalt-chromium (Co-Cr) alloy is the most widely used dental alloy for fabrication of metal framework of RPD because of its rigidity and ease of fabrication [1]. One of the alternative materials to the heat-cure resin is the flexible acrylic as it has very little or almost no free monomer in the material [2]. Therefore, flexible acrylic (Valplast Nylon) satisfies both dentist and patient as more esthetic yet fully functions [3]. One of the complications of removable partial dentures is debonding of the acrylic resin from the cobalt-chromium framework [4]. Metal-resin bonding systems may be categorized as mechanical, chemical or a combination of the two. Framework design must incorporate certain elements that provide mechanical retention of the resin [5].

Progress in laser technology has shown a quick adoption for being used for dental applications since its invention in 1960 [6]**.** Recently, the laser has been found to effective in alteration the surface of materials [7]**.** However, the use of lasers in dental material processing has been limited [8].

Indication of laser treatment may be a suitable alternative to airborne-particle abrading or other surface pretreatment techniques for enhancing the bond strength of dental materials to metal surfaces [9].

As the laser surface treatment was used to enhance the micromechanical retention, but the effective design of this treatment on the bond strength of resin to metal alloy has not been investigated. So this study was oriented to evaluate the effect of different designs of laser treatment on the shear bond strength between the flexible acrylic and Cobalt-Chromium metal.

Materials and methods

Samples grouping

30 metal samples were prepared from Cobalt-Chromium alloy and divided into three groups according to the design of laser treatments that was applied (N=10) and as follow:

Group I: it referred to the metal samples without surface treatment as a control group.

Group II: it referred to the metal samples with laser surface treatment in line design by a linear movement.

Group III: it referred to the metal samples with laser treated in a mesh design.

Mold Design

A metal mold was designed to have a rectangular shape of dimension (8mm X 12mm) which enable to reproduce wax patterns of the samples, within a rectangular plate (20 mm X 20 mm X 2 mm) [10] (Figure 1).

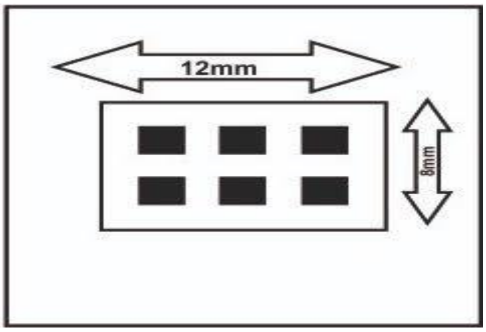

Figure (1): Diagram represents the dimension of the sample

Wax Pattern Preparation

The preparation of a wax pattern was done by melting the sheet wax into the metal mold and the access wax was removed from border of the metal mold and the pattern was split from the mold using cold water and then the spruing of the wax pattern was made by the attachment of sprues to the certain areas of a wax patterns.

The conventional methods that was utilized for denture framework construction used in this study for investing, wax burnout and casting procedures of Cobalt-Chromium metal. After that, the samples were finished by cutting all metal sprues using abrasive wheel. After casting, the metal surfaces were polished with Aluminum oxide with 110 µm particles size for 5 seconds at 80 psi, at 45-degree angle. There was 5 mm distance from the metal surface and the nozzle of the machine [11]

Laser surface treatment design

The Fiber laser was (Jinan Jin Qiang 20W laser, China) working at 1064 nm applied energy level, 20-100 kHz, 150 ns pulse repetition time and up to 7000 mm/sec scanning speed. The application tip was moved from the bottom to the top by linear movement and maintained in light contact with the metal surface to form line design, while for mesh design the linear movement made in two directions from top to bottom and from left to right side to get mesh form that was ordered from the computer connected to the laser machine (Figure 2).

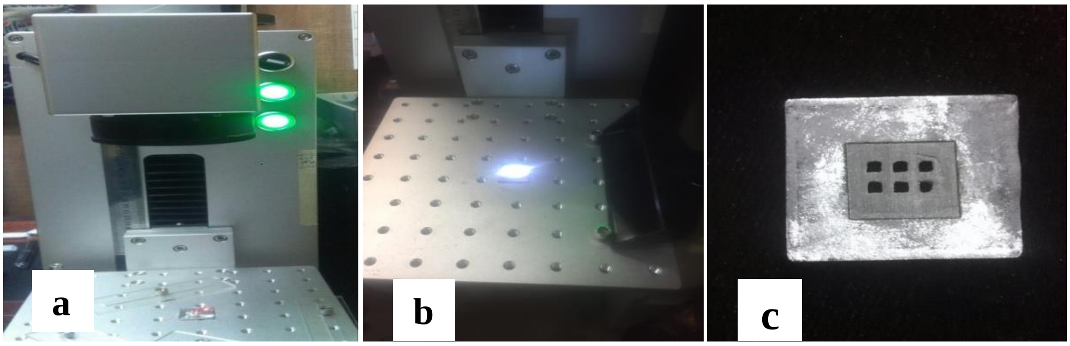

Figure (2): a. Laser structuring machine, **b.** The metal sample was placed on the system table at the effective focal position, **c.** The metal specimens after laser treatment.

Application of flexible resin:

The wax pattern to the metal samples of the shear bond test was shaped in rectangular wax block (12mm length, 8mm width, and 6 mm height) was sealed in the central area of the metal samples [10] (Figure 3).

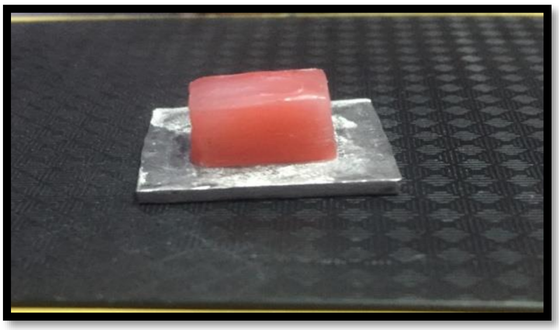

Figure (3): Wax pattern for the metal sample for flasking process

The mold prepared in conventional procedure and wax elimination was performed using boiling water then the metal flask was opened. The flask was allowed for cooling at room temperature. then the valplast denture base material (linchen dental, china) was injected according to manufactures instruction in the electrical furnace that was heated at 287°Cand valplast cartridge placed in metal cylinder preheated inside the furnace for 11 minutes to allow the granules inside the cartridge to melt. At the same time, the flask was preheated inside a furnace set at 65°C, removed from the oven and placed inside the injection unit in horizontal position in its correct position with the aid of the projection present at the base of the injection unit in this position the injection opening was at the top surface of the flask and the molten material was injected inside the flask with a pressure of 5 bars, after 5 minutes the pressure was released and the flask was removed from the injection unit, then it left for cooling at room temperature.

Specimens were thermal cycled in in artificial saliva for 3000 times. The temperature was between 5°C to 55°C with a dwell time 60 seconds for each temperature and transferring time from one bath to another bath was 10 seconds [12].

Shear bond strength measurement:

The shear bonding was calculated using a Universal tensile testing machine (Instron, England), and a knife-edge shear testing apparatus. Each specimen was placed in a flat position controlled by a clamp of metallic jig (Figure 4). The cross head loading force was applied parallel to the resin-metal interface until fracture at a cross-head speed of 1 mm/minute to split the specimens at the flexible Acrylic-Cobalt-Chromium metal interface, and the fracture loads were recorded in Newton [13].

Figure (4): Sample mounted in the Instron machine

The shear bond strength values were calculated from the following equation: -

Shear bond strength = *F/A* [ASTM, 1986].

F **= force at failure (Newton).**

A**=Minimum cross sectional area (mm).**

Data were analyzed to conclude the descriptive results as means and standard deviation table and figures. One-way ANOVA was used to detect the significant differences among study groups at a level of significance (P<0.05).

Results

Descriptive statistic of shear bond strength between flexible acrylic and the Cobalt-Chromium for all groups showed the highest mean values for the groups of mesh design laser treatment then followed by the linear design while the lowest value for control groups without any treatment (Figure 5, Table 1).

Table 1: Descriptive statistics of shear bond strength ($N/mm^{2)}$ of all study groups.

	Sum of Squares	Df	Mean Square	F-test	Sig.	P-value
Between Groups	215.462	2	107.731	202.766	0.000	HS*
Within Groups	14.345	27	0.531			
Total	229.807	29				

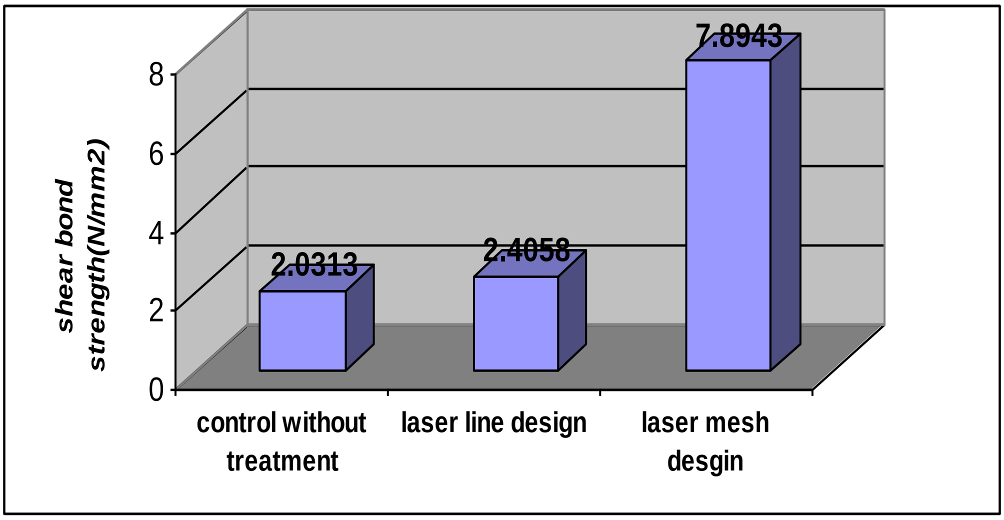

Figure (5): Bar chart of the shear bond strength in all study groups.

For further analysis in comparison of means values of the shear bond strength test the One-way ANOVA-test was showed there were highly significant differences between all the tested groups (Table 2).

Table 2: One-way ANOVA of shear bond strength between flexible resin and Cobalt – Chromium according to different laser surface treatment designs.

	N	Mean	Std. Deviation	Std. Error	Minimum Value	Maximum value
GI(control group)	10	2.0313	0.322	0.1020	1.80	2.80
GII(laser treated with line design)	10	2.4058	0.348	0.1102	1.993	2.981
GIII (laser treated with mesh design)	10	7.8943	1.169	0.639	5.871	9.743

*HS: High significant (P<0.01)

For comparison between the tested groups the LSD-test was showed there were highly significant difference between the control group and mesh design laser treated group, as well as there was highly significant increase for the mesh treated group in comparison to line design treated groups, but there was non-significant difference between the liner laser treated and control group (Table 3).

Table 3: LSD-test between the groups of different surface treatment.

	Mean Difference	Std. Error	Sig.	P-value
Group I & Group II	0.37450	0.3259	0.261	NS*
Group I & Group III	5.86300	0.3259	0.000	HS**
Group II & Group III	5.48850	0.3259	0.000	HS**

*NS: Non Significant(P>0.05)
**HS: High significant (P<0.01)

Discussion

In general, laser can provide an easy, safe, clean and time saving surface treatment that results in suitable surface pits and roughness for greater micromechanical bonding strength [14].

The result of this study was showed there was non-significant between the control group and linear design of laser treatment but there was a highly significant increase in shear bond strength with mesh laser treatment this may be attributed to the size and the amount of the irregularities or grooves produced by the mesh laser treated was quite sufficient to allow the flow of the flexible resin, here the viscosity of the acrylic could have enabled it to penetrate into the regularities of the bonding surface [15], that leads to increased surface area and mechanical locks in the bond site and result in stronger bond strength [16].

In addition to the result of the ablation process and the formation of crater-like scratches probably achieves micro-mechanic retention and it causes to increase the bonding values. In the laser irradiated group preservation of the oxide layer and presence of micro irregularities may be the main cause of higher bond strength compared with the control group. The extent of the superficial changes on the metal surface depends on the energy density of the laser radiation as well as on the type of irradiated metal alloy [17].

Furthermore, use of liner form resulted no difference in the bond strength when compared to control group the reason of that the type of resin used was the valplast flexible resin that need more mechanical retention because it appear to be unable to provide enough diffusion ability on the surface of the metal to provide strong bond which resulted from insufficient wetting of the flexible resin as a result of its higher viscosity and the lack of polymerizable resin spreading on the metal surface because the material is being thermally molded directly in the denture base [18], therefore more mechanical retention was needed to have better bond between the flexible resin and metal denture base.

This result in agreement with the previous study that showed laser etching resulted from the highest bond strength [5] also it confined with previous researchers who found the laser treatment exhibited higher bonding values compared with control groups [4].

Conclusion

With the limitation of this study, we concluded there was increased in the shear bond strength values for the specimens treated with mesh design laser treatment in comparison to line design laser treated and the control groups.

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