Effect of Er-YAG laser application on shear bond strength of polymethyl methacrylate to Cr-Co Alloy

İbrahim Duran[1], Çağrı Ural[1], M.Erhan Sarı[2], Emir Yüzbaşıoğlu[3], Betül Yılmaz[1], İdris Kavut[1]

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ABSTRACT

Effect of Er-YAG laser application on shear bond strength of polymethyl methacrylate to Cr-Co Alloy

Background: The aim of the present study is to investigate the effect of Er:YAG laser treatment on bond strength between Cr-Co alloy and the acrylic resin.

Methods: A total of 36 square-shaped metal alloy test specimens (10x10x3 mm) were prepared. Specimens of each alloy were randomly divided into three treatment groups (n=12). Specimens, left untreated were grouped as control, air abraded with Al2O3 and Er-YAG laser irradiated. Autopolymerized resin discs of 4 mm diameter and 5 mm in height were fabricated and aplicated on alloy specimens. The bonded specimens were stored in distilled water for 24 hours at 37°C in a humidor. They were then mounted in a loading jig and debonded in shear using a universal testing machine at a cross-head speed of 0.05 mm/min. The data were statistically analyzed.

Results: Among the three test groups the highest bonding values were obtained in sandblasted test specimens. Although, laser irradiated test specimens showed significantly higher test results compared with control group, they showed lower values than sandblasted test specimens.

Conclusion: Laser treatment is not effective as Al_2O_3 sandblasting for improving bond strength between the alloy and acrylic resin.

KEYWORDS

Acrylic resin, Er-YAG laser, metal alloy, surface treatment

ÖZ

Er:YAG lazer uygulamasının Cr-Co alaşımı ve polimetil metakrilat arasındaki makaslama bağlantı kuvveti üzerine etkisi

Amaç: Bu çalışmanın amacı Er:YAG lazer uygulamasının Cr-Co alaşım ve akrilik rezin arasındaki bağlantıya etkisinin araştırılmasıdır.

Gereç ve Yöntemler: Toplamda 36 adet 2 kare şeklinde metal alaşım test örneği hazırlanmıştır (10x10x3 mm). Örnekler rastgele 3 farklı yüzey işlemi grubuna ayrılmıştır (n=12). Yüzey işlemi uygulanmamış grup kontrol grubu, Al2O3 ile kumlanmış grup ve Er:YAG lazer uygulanmış grup olarak ayrılmıştır. 4 mm genişliğinde ve 5 mm yüksekliğinde otopolimerizan akrilik rezin metal örneklere uygulanmıştır. Yapıştırılan örnekler distile suda 24 saat 37°C' de bekletilmiştir. Daha sonra üniversal test makinesinin yükleme ucuna yerleştirilmiş ve 0.05 mm/dk hız ile kopana kadar itme uygulanmıştır. Data istatistiksel olarak analiz edilmiştir.

Bulgular: Üç test grubu arasında en yüksek bağlantı değerleri kumlanmış örneklerde elde edilmiştir. Lazer uygulanmış test örnekleri kontrol grubundan istatistiksel olarak daha yüksek değerler gösterse de kumlanmış örneklerden daha düşük değerler göstermiştir.

Sonuç: Metal alaşım ve akrilik rezin arasında bağlantı dayanımının güçlendirilmesi için lazer uygulaması Al_2O_3 ile kumlamadan daha etkili değildir.

ANAHTAR KELİMELER

Akrilik rezin, Er-YAG lazer, metal alaşım, yüzey işlemi

In partially edentulous patients, removable partial dentures (RPD) are widely used as a treatment modality. Cobalt chromium (CoCr) alloy is the most widely used dental alloy for fabrication of metal framework of RPD because of its rigidity and ease of fabrication (Ohkubo *et al*. 2000). Co-Cr alloys are relatively inexpensive and are approximately twice as rigid as Au alloys (Hansson *et al*. 1994, Mazurat *et al*. 1998).

Denture base resins are used with CoCr alloy in RPD fabrication and also the heat cured acrylic denture base resin polymethylmethacrylate is oftenly used (Kalra *et al*. 2015). Optimizing shear bond strength (SBS) at the resin-metal interface of a removable partial denture (RPD) is essential for the success of the prosthesis. A lot of research supports that greater adhesion between metal and acrylic resin increases bond strength and decreases fluid microleakage (NaBadalung *et al*. 1998).

[1] Ondokuz Mayıs University, Faculty of Dentistry, Department of Prosthodontics, Samsun, Turkey
[2] Ondokuz Mayıs University, Faculty of Dentistry, Department of Pediatric Dentistry, Samsun, Turkey
[3] Medipol University, Faculty of Dentistry, Department of Prosthodontics, Samsun, Turkey

One of the complications of removable partial dentures is debonding of the acrylicresin from the cobalt-chromium framework. The differences in the coefficients of thermal expansion between acrylic resins and alloys, and the polymerization shrinkage of acrylic resin, may result in separation of these materials (Behr *et al*. 1998). Methods to bond resin to dental alloys have been used for decades and several factors are involved in this chemical and physical bond. Denture base resins were attached to the CrCo frame work by mechanical retention and it can be achieved by mesh, beads, nail heads and struts (Kalra *et al*. 2015). Some other methods are also be used to improve the bonding between metal and resin such as chemical etching (Tanaka *et al*. 1986), electrolytic etching (Watanabe *et al*. 1988, Zurasky JE *et al*. 1987), sandblasting and metal primers (Livaditis *et al*. 1986).

Dental lasers have become widely used in medicine and dentistry. Technological advances during the last decade have resulted in the increased use of lasers in dentistry. Many of these advances have been directed at the use of lasers in clinical applications as an alternative to acid etching of enamel or dentin for bonding dental materials to the tooth surface (Arcoria *et al*. 1993). However, the use of lasers in dental material processing has been limited (Akova *et al*. 2008). Murray et al. (Murray *et al*. 2005) indicated that 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.

The aim of the present study is to investigate the effect of laser treatment on bond strength between Cr-Co alloy and the acrylic resin. The null hypothesis of the present study is laser applications with an output power of 400 mJ can be alternative to sandblasting with Al_2O_3 powders for surface treatments of Cr-Co framework metals.

MATERIAL AND METHODS

A total of 36 square-shaped wax pattern (10x10x3 mm) were prepared. The wax patterns were invested with a phosphate-bonded investment (Rematitan Plus (RP), Dentaurum Ispringen, Germany). The specimens were cast in vacuum using a casting machine under a vacuum pressure of 580 mmHg at a temperature of 1340 0C.The surfaces of the specimens were standardized by gradual wet grinding with 320-600-800-1000 grit silicon carbide paper for 10 s each on a grinding machine at 300 rpm (Buehler Metaserv, Buehler). All alloy specimens were embedded in orthodontic resin (Caulk, Dentsply International Inc. Milford Germany) using cylinder mold ensuring that one of the flat sides remains exposed for bonding. Each alloy specimens were used for bonding with auto-polymerized resin normally used for repairs. Specimens of each alloy were randomly divided into three treatment groups (n=12).Specimens left untreated were control group (group C). Airborne-particle abrasion of alloy specimens (Group S) was performed with 50 µm aluminum oxide (BEGO, WilhelmHerbst-Strabe I, Bremen, Germany)for 10 seconds at 60 psi , at 45-degree angle with a 10 mm nozzle to metal surface distance and specimens were cleaned with distilled water and dried using oil-free pressured air. The Er-Yag laser was an AT Fidelis (Fotona, Ljubljana, Slovenia) working at 2940 nm a dental handpiece angled 900 under water irrigation. The air and water pressure was set 2 bar. The application tip was moved from the bottom to the top and maintained in light contact with the metal surface. The Er-YAG laser treated groups were; Group Er 400; applied energy level 400 mj.

The specimens were then primed metal primer (Metal Primer II (MP) GC Corp, Tokyo, Japan) following manufacturer's instructions using a micro brush. Autopolymerized resin (Paladent 20, Hanau, Germany) discs of 4 mm diameter and 5 mm in height were fabricated using a polytetrafluoroethylene mold and a jog to hold the assembly. The sprinkle on technique was used to avoid entrapment of air bubbles at the interface. The specimens were cured in a pressure pot at 20 psi for 15 minutes.

The bonded specimens were stored in distilled water for 24 hours at 37°C in a humidor (100% relative humidity). They were then mounted in a loading jig and debonded in shear using a universal testing machine at a cross-head speed of 0.05 mm/min. The forces at which the bond failed were noted, and bond strengths were calculated in Mega Pascals (MPa) by dividing the force by the bonding area. The failure mode of each specimen was also evaluated under a low-power optical microscope at magnification (10X)

According to Kolmogrov-Smirnov test results all the data showed normal distribution and data were statistically analyzed with one-way analyses of variance (ANOVA). For multiple-comparison of mean values, Tukey's honest significant difference (HSD) test was used ($\alpha = 0.05$).

RESULTS

One-way ANOVA test results revealed that the surface treatments (sandblasting and laser treatment) have effected the bonding values significantly ($p>0.05$) (Table 1). All the mean values of the test groups were listed in Table 2 (Figure 1). Among the three test groups the highest bonding values were obtained in sandblasted test specimens (10.53±0.32). All the groups were showed significant differences and the lowest test values were obtained in control group (3.35±0.29).

Table 1.

The results of ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	327,32	2	163,66	1795,68	0
Within Groups	3,008	33	0,091		
Total	330,328	35			

Table 2.

The mean, min, max, and standard deviations of test groups

	N	Mean	Std. Deviation	Minimum	Maximum
Control	12	3,3450[a]	0,28666	2,94	3,76
Er-YAG	12	5,4692[b]	0,29737	5,12	5,98
Sandblasted	12	10,5333[c]	0,32066	10	11

** The same letter indicates the significant differences.*

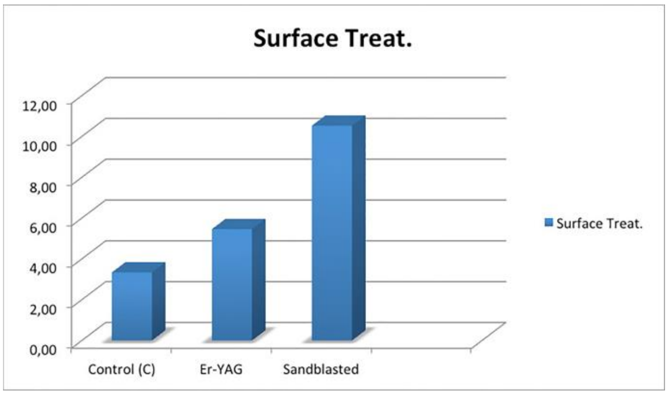

Figure 1.

The mean values of shear bond strength of specimens tested

DISCUSSION

The null hypothesis of the present study that the laser applications with an output power of 400 mJ can be alternative to sandblasting with Al_2O_3 powders for surface treatments of Cr-Co framework metals was rejected.

This study was designed to compare the shear bond strengths of sandblasted cast Co-Cr alloy to heat-cured repair acrylic resin after the application of three different surface treatments. The tests for cast alloy is clinically relevant so cast alloy was preferred instead of ingots. The interface between metal substructure and acrylic resin of the removable partial denture prosthesis has often been held responsible for many clinical problems including the potential for microleakage and accumulation of oral debris, microorganisms, and stains (Ohkubo *et al*. 2000). Strong bonding at the interface of the two surfaces improves the strength of the repaired unit and reduces stress concentration. The composition and integrity of the metal surface oxide layer is considered critical for bonding and for base metals preconditioning such as air abrasion and ultra-sonic cleaning can further increase the bond strength (Tanaka *et al*. 1986, Kim-Hai *et al*. 2003). In the present study except control group, airborne-particle abrasion was performed to compare the efficiency of Er-YAG laser application.

Airborne-particle abrasion group exhibited the highest bond strength values than the other groups. Sandblasting with alumina not only affected the micromechanical roughening of the surface, but it left alumina particles embedded in the surface, which was consistent with previous studies (Kern *et al*. 1993). The influence of alumina on these bonding mechanisms is not well known yet; therefore, it is necessary to improve the chemical bonds of resin to the alumina surface and to investigate the attachment strengths of alumina particles to the metal surfaces.

In this study, one group were sandblasted with 50 μm Al_2O_3 particles to create surface roughness. Sandblasting with Al_2O_3 particles removes contaminated layers and creates a roughened surface which provides mechanical interlocking for the acrylic resin as well as providing a great surface area for the bond. It has been reported that the sandblasting process makes the-alloy-water contact angle smaller and wettability greater. According to Yoshida et al. (Yoshida *et al*. 1999), metal sandblasting with Al_2O_3 particles could form a passive film made of Ni, Cr, and Co oxides. Ohno et al. (Ohno *et al*. 1986) defined the passive film of hydrated chromium oxyhydroxide and generalized this film by the formula: Crx(OH)3.2 nH2O, which is capable of forming on stainless steel and alloys containing Ni, Co, and Cr.

Recently Er:YAG laser systems have drawn a lot of attention in dentistry as a new method for surface treatment. Although there is a paucity of data on the effects of these lasers on restorative dental materials, it has been reported that Er:YAG laser system, with or without water, can ablate restorative materials, and produce fine crater-like scratches on related surface, with a diameter of 100 μm (Oskoee *et al*. 1986). In the present study Er-YAG laser application with an output power of 400 mJ did not improve the bond strength as Al_2O_3. In parallel to this according to Shiu et al. (Shiu P *et al*. 2007) Er:YAG laser irradiation with 400 or 500 mJ at 10 Hz was not an alternative method for surface treatment of base metal alloys. The results of their study showed that the surface roughness values were similar with control group after laser treatment of Er-YAG 400 mJ. Madani et al. (Madani *et al*. 2013) investigated the effect of Nd-YAG laser irradiation to alloy surface and found no significant difference on shear bond strength between resin cement and alloy. Er:YAG laser system, with or without water, can ablate restorative materials, and the presence of water does not decrease the efficiency of ablation, though it prevents temperature rise (Cernavin *et al*. 1999). The ablation process and the formation of crater-like scratches probably achieves micro mechanic retention and it causes, increase the bonding values. In the laser irradiated group preservation of the oxide layer and presence of microirregularities may be the main cause of higher bond strength compared with 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 (Shiu *et al*. 2007). The relatively lower test values between sandblasted group can be attributed to reflection of the laser light from polished metal surfaces. So it may be caused decreasing the power density of laser on the surface.

According to Banerjee et al. (Banerjee et al. 2009) for metal alloys the primed groups provided higher tensile bond strength than the nonprimed groups. In the present study one type of metal primer was used and ingots were not tested. According to a previous study (Banerjee *et al*. 2009), the metal primers promoted a significant increase in the adhesive bonding of acrylic resins to base metal alloy. Prime Plus (Bisco Dental Products) demonstrated higher bonding values than the MP. Altough the data for ingot specimens is not clinically relevant among the metal alloys they tested, primed ingot alloy showed the higher shear bond strength than the cast alloy (Yoshida *et al*. 1999).

In the present study, compared the shear bond strengths of sandblasted cast Co-Cr alloy to heat-cured repair acrylic resin after the application of different surface treatments. However, the effect of long term water immersion or thermal cycling effects, and also the effects of different metal primers were not simulated. These are the limitations of this study. Further studies needed for evaluating the effect of different metal primers on metal alloy and acrylic bonding. Also by using different lasers and different output powers may provide higher bonding values between metal alloy surface and acrylic resin.

CONCLUSION

Within the limitations of the present study it can be concluded that;

1. Er-YAG laser treatment exhibited higher bonding values compared with control groups, It may be concerned that Er-YAG laser irradiated surfaces may increase the bonding values,
2. However, laser treatment showed lower test values that sandblasted groups and it can be concluded that laser treatment cannot be an alternative to Al_2O_3 sandblasting for improving bond strength between the alloy and acrylic resin.

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Corresponding Author:

Dr. Mustafa Erhan SARI
Department of Pediatric Dentistry,
Faculty of Dentistry,
Ondokuz Mayis University,
55139, Kurupelit, Samsun, Turkey.
Phone: +90 505 2384285
Business Tel: +90 362 3121919
Fax: +90 362 4576032
E-mail: dterhansari@hotmail.com