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Araştırma/ Research Article

FRACTURE STRENGTH OF SOLDERED AND LASER WELDED ORTHODONTIC BANDS AND WIRES WITH AND WITHOUT FILLING MATERIAL: A PRELIMINARY REPORT

GÜMÜŞ LEHİM İLE ARA MADDE KULLANILAN VE KULLANILMAYAN LAZER İLE LEHİMLENEN ORTODONTİK BANT-TEL BAĞLANTILARININ KIRILMA DAYANIKLILIĞI – ÖN RAPOR

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ABSTRACT

Aim: The aim of this study was to compare the fracture strength of orthodontic band-wire joints made by conventional silver soldering and different laser welding procedures and detect the effects of the surface preparation with sandblasting to the fracture strength of the laser welding.

Materials and Methods: Forty specimens were divided to four groups (n=10); group 1; brazing with silver solder, group 2; laser welding (Desktop Compact Laser, Dentaurum,Germany) with sandblasting (with 50 µm aluminum oxide), group 3; laser welding with filling material and sandblasting, group 4; laser welding with filling material without sandblasting. The fracture strengths were measured using a universal testing machine (Lloyd Instruments plc.). Data were analyzed by ANOVA and Tukey's *post hoc* test ($p=0.05$).

Results: Silver soldering showed the highest fracture strength value and it significantly differed from the laser welding groups. Although group 3 (with filling material and sandblasting) showed great strength, laser welding groups did not show any statistically significant differences between each other.

Conclusions: In conclusion, silver solder showed the highest mechanical property. Laser welding with filler material and sandblasting showed sufficient strength for clinical use and can be used for the band-wire joining while orthodontic appliance fabrication.

Key words: Laser Welding, Silver Solder, Fracture Strength, Sandblasting

ÖZ

Amaç: Bu çalışmanın amacı ortodontik bant-tel lehimlenmesinde kullanılan konvansiyonel gümüş lehim ile farklı lazer lehim kombinasyonlarının kırılma dayanıklılığı açısından karşılaştırılması ve kumlama ile yüzey preperasyonunun veya ara madde kullanımının lazer lehimlemenin kırılma dayanıklılığı üzerine etkilerinin değerlendirilmesidir.

Gereç ve Yöntem: Çalışmada standardize edilmiş bir bant-tel konfigürasyonu kullanılmış; 40 örnek 4 gruba ayrılmıştır. Grup 1'deki örneklerin birleştirilmesinde konvansiyonel gümüş lehim; grup 2'de kumlama ile yüzey preperasyonu yapılmış lazer lehim (Desktop Compact Lazer, Dentaurum, Almanya); grup 3'de kumlama yapılmış ve ara madde eklenmiş lazer lehim; grup 4'de kumlama yapılmaksızın ara madde eklenen lazer lehimleme kullanılmıştır. Verilerin analizinde ANOVA ve Tukey post-hoc testi kullanılmıştır.

Bulgular: Konvansiyonel gümüş lehimleme en yüksek kırılma dayanıklılığını göstermiş; diğer bütün lazer lehim kombinasyonlarıyla arasındaki farklılıklar istatistiksel olarak anlamlı bulunmuştur($p<0,05$). Lazer lehim kullanılarak oluşturulan gruplar arasında; grup 3 en yüksek kırılma dayanıklılığını göstermesine rağmen; farklılıklar istatistiksel olarak anlamlı bulunmamıştır.

Sonuç: Gümüş lehimleme lazer lehimlemenin değişik kombinasyonlarına göre yüksek mekanik özellik göstermiştir. Ara maddenin kullanıldığı ve kumlama işleminin yapıldığı lazer lehimleme klinik kulanım için yeterli dayanıklılık göstermiştir ve ortodontik amaçla bant-tel lehimlenmesinde bir alternatif olarak kullanılabilir.

Anahtar kelimeler; Lazer Lehimleme, Gümüş Lehimleme, Kırılma Dayanıklılığı, Kumlama

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INTRODUCTION

Bonded attachments are used routinely as part of fixed orthodontic appliance therapy; however, bands remain popular for molars instead of bonded tubes.[1,2] Orthodontic bands have important advantage during treatment supplying the main body for solder the other metal appliances.

Orthodontic appliances such as quad helix, nance button, transpalatal and lingual arches and rapid palatal expanders are subjected to a large number of forces generated during masticating resulting in a complex distribution of stresses within the junctions between band and soldered appliance. The strength of soldered joints used to fabricate the orthodontic appliances is critical to their success [3,4] because broken appliances may cause different complications which include soft tissue irritation, anchorage lost, uncontrolled teeth movement and swallowing or aspiration of the broken parts.[4]

Conventional silver soldering is frequently used to join the parts of orthodontic appliances.[5] In conventional dental brazing - defined as soldering over a temperature of 450°C - the parent metals are joined with different types of metals, which may reduce corrosion resistance because of galvanic corrosion between metals.[6-8] The high corrosion rates can influence the biocompatibility[9-11] and mechanical strength.[9]

Laser welding using a pulsed Nd:YAG (neodymium-doped yttrium aluminium garnet; Nd:Y3Al5O12) laser is a current technology and has been developed for joining purposes in the dental laboratory and offers clear-cut advantages compared to the various soldering methods.[7] Laser welding can weld metals without solder or with material consisting of the same parent metal; hence, the corrosion resistance and biocompatibility may be increased. Besides these advantages, these industrial machines are still characterized by their large size, high cost, and fixed-lens beam delivery systems, all of which may limit their use.[12] Also when lasers are irradiated under a microscope, the eyes are at a high risk and eye protectors used with laser devices might be insufficient to protect the eyes.[13] The mechanical strength of laser welded joints are affected by the wave length, peak pulse power, pulse energy, output energy, pulse duration, pulse frequency, spot diameter of the laser-welding machine, and the type of metal used. [14,15]

Fracture strength is defined as the stress at which a welded joint fails via fracture and is determined with a tensile test, which charts the stress-strain curve. If a welded joint is deformed with ultimate tensile strength via loading, it will continue to deform until breaking point. The final recorded point at the stres strain-curve is recorded as fracture strength.[12] Various studies[9,16] evaluated different soldering techniques and demonstrated that usage of filling material positively influenced the fracture strength of the welded joint. In one recent study, Bock et al.[9] compared the mechanical strength of different joints made by conventional brazing and laser welding with and without filling material and found the highest fracture strength for laser welding with filling material and 3 mm joint length.

On the other hand, the effects of the sandblasting on the fracture strength of the laser welded joints were not evaluated in the studies regarding laser welding tecnique. Sandblasting has become the preferred surface treatment especially for metal bonding in orthodontics today. This procedure involves spraying a stream of aluminum oxide particles under high pressure against the metal surface. For optimum mechanical strength, 80 to 100 per square inch (psi) of air pressure is required. Aluminum oxide with a particle size of 50 micrometers has been found to be the most desirable for use in sandblasting.[17-20] Sandblasting roughens the surface of all metals (including stainless steel), and as a result, increases the surface area for both chemical and mechanical bonding.[21]

To our knowledge there is no research in the literature with regard to the comparison of the fracture strength of the silver soldering and laser welding with and without sandblasting of the orthodontic band-wire. Visually, laser beams behave in the same way as light beams. Bright surfaces can reflect a large part of the laser beam, thus reducing the amount of energy available for welding. Due to the reflection of the laser beam from the metallic surface, joint quality may be failed, therefore sandblasting of the metallic surface before the welding may be recommended.

The aim of the present study was to compare the fracture strength of the different joint of the orthodontic band-wire combinations made by conventional silver soldering, sandblasted laser welding without filling material and laser welding with filling material with and without sandblasting.

MATERIALS AND METHODS

A standardized orthodontic band (Dentaurum, unwelded Lower 1. Molar band, Ispringen, Germany) to wire (Dentaurum, Round 0.9 mm stainless steel, hard for TPA, Ispringen, Germany) joint configuration was used. Forty molar bands were embedded into standardized acrylic blocks and 7 mm length soldering/welding area were produced with standard plaster mold (Figure 1). The specimens were divided into four groups (n=10). The band to wire joints were made using different methods: group 1; brazing with conventional silver solder (Dentaflux universal soldering flux, Dentaurum, Ispringen, Germany) (Figure 2), group 2; laser welding (Desktop Compact Laser, Dentaurum, Ispringen, Germany) with sandblasting (with 50 µm aluminum oxide, for 10 seconds) (Figure 3), group 3; laser welding with filling material (0.5 mm CoCr laser welding wire, Dentaurum, Ispringen, Germany) and sandblasting (Figure 4), group 4; laser welding with filling material without sandblasting (Figure 5). Laser parameters and welding conditions were in accordance with the manufacturers' recommendations (224 V, 0.8 ms, 2 mm). All of the conventional silver soldering specimens were produced by the same technician of the Hacettepe University, Faculty of Dentistry, Department of Orthodontics and laser welding specimens were produced by the same researcher (S.A.).

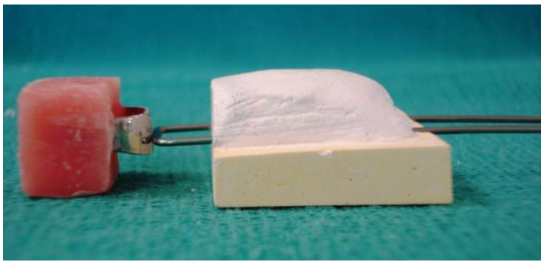

Figure 1. Molar band and with standard plaster mold which standardized soldering/welding area.

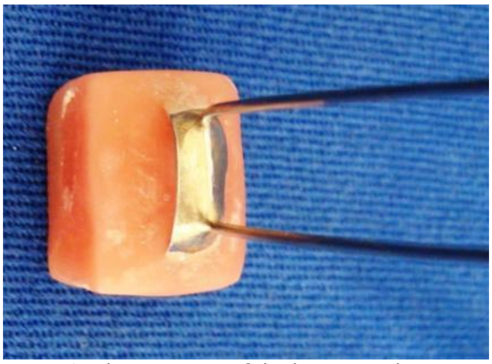

Figure 2**.** The specimen of the brazing with universal silver solder in Group 1.

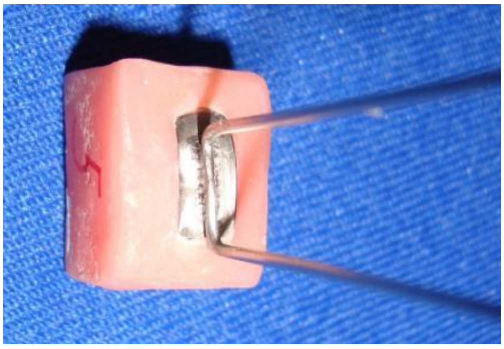

Figure **3.** The specimen of the laser welding with sandblasting without filling material in Group 2.

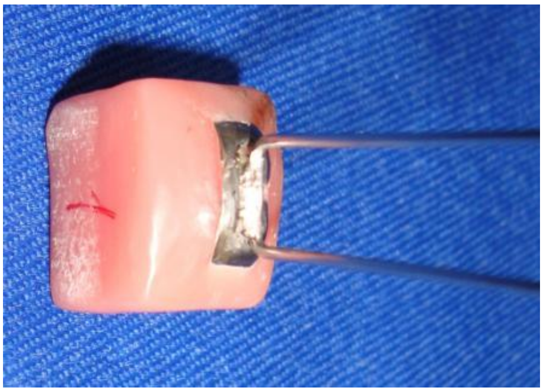

Figure 4.The specimen of the laser welding with sandblasting and filling material in Group 3.

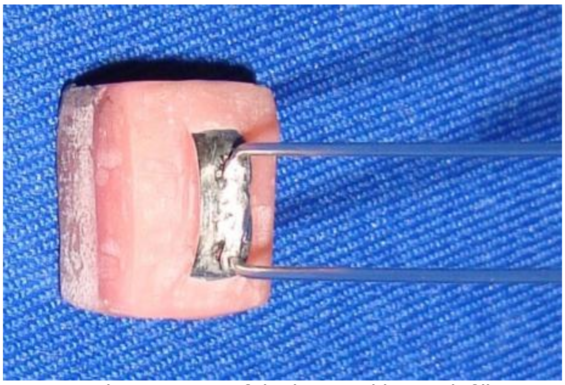
Figure 5. The specimen of the laser welding with filling material without sandblasting in Group 4.

The fracture strength measurement of different welding and brazing methods was carried out using a universal testing machine (Figure 6) (Lloyd Instruments plc, Fareham, Hampshire, UK). During the test, the loading was continued until the welded joint broke into two pieces. Additionally, the tensile test was terminated when the gap between pieces reached 2 mm even if no fracture occured. The wire length between the crossheads of the machine was set to a level of 5 mm. The full-scale load was set at 2000 N with a crosshead speed of 10 mm/minute.

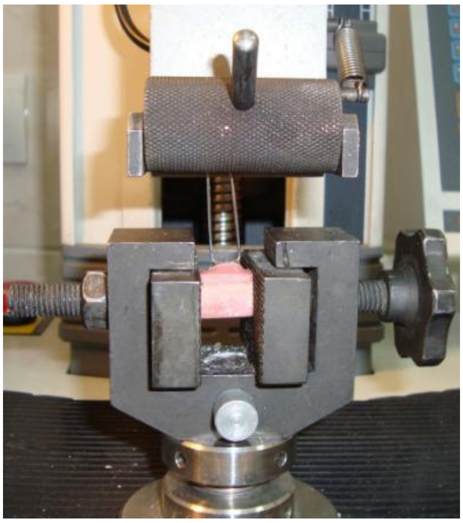
Figure **6.** The universal testing machine (Lloyd Instruments plc, Fareham, Hampshire, UK) which was used for fracture strength measurement

The data were analyzed using the Statistical Software Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) version 16.0 and the use of one-way analysis of variance (ANOVA) and Tukey's *post hoc* test. The level of significance was set at p<0,05.

RESULTS

Mean, minimum and maximum values and standard deviations of the tensile strength of the different joining methods are shown in Table 1. The highest mean value was observed in the silver solder group (523.70 ± 185.83 N) and the lowest mean value was found in group 2 (268.35 ± 54.20 N).

Table 2 shows the tensile strength differences of groups. Silver soldering showed statistically significant differences compared with all of the three laser groups (Tukey's *post hoc* test, $P < 0.001$, $P < 0.05$, $P < 0.01$ in groups 2, 3 and 4, respectively, Table 2). No significant differences were found between the laser welding groups.

Table 1. Descriptive statistic values of the soldered and welded specimens.

	n	*Means*	*SD*	*Min*	*Max*
Group 1	10	523.70	185,83	196,24	768,54
Group 2	10	268.35	54,20	181,41	341,94
Group 3	10	359.39	79,98	230,02	465,56
Group 4	10	352.62	92,95	278,10	603,64

SD; standard deviation, Min; minimum, Max; maximum.

Table 2. Results and Tukey's *post hoc* test comparisons of tension strength differences (Mpa) of the soldered and welded specimens (n=10) (ANOVA P<0.001).

	Group 1	*Group 2*	*Group 3*	*Group 4*
Group 1	**-**	**0.001*****	**0.014***	**0.010****
Group 2	**0.001*****	-	0.301	0.367
Group 3	**0.014***	0.301	-	0.999
Group 4	**0.010****	0.367	0.999	-

* P≤0.05, ** P≤0.01, *** P≤0.001

DISCUSSION

In the present study, the comparison of the silver soldering and different laser welding methods of the band to wire joint was carried out. Moreover, it was determined whether the sandblasting of the band and wire surfaces affected the fracture strength of the laser welding for the first time.

There are studies[9,13-18-26] which have evaluated mechanical behavior of welded or soldered wire-wire combination, but few study[9,13] is about orthodontic band-wire combination. Band-wire combinations are commonly used during fabricating the active or anchorage orthodontic appliances so that the mechanical behavior researches of this combination are necessary and important.

Absorption and reflection upon the metal surface is known to affect the penetration depth of the laser beam. To improve the laser beam absorption, generally metals which will be joined are sandblasted with alumina powders before laser welding. However, sandblasting roughens the surface of all metals (including stainless steel), and as a result, increases the surface area for both chemical and mechanical bonding.[21] But especially for the thin dental materials such as orthodontic bands or wires; no scientific evidence has reported that the sandblasted metallic surface is more resistant to stress. Also, sandblasting of the band surface may decrease mechanic advantages of the laser welding such as no corrosion and no oxidation. Hence, the effect of the sandblasting on the fracture strength of the laser welded joints was evaluated in the present study since there was no research regarding the effect of the sandblasting on welding in the literature.

The results of the present study showed that silver soldering had the highest fracture strength (523.70 N) and it was different from laser groups statistically significantly. There are different results in the literature based on the influence of brazing or welding on tensile strength. When band to wire joints were evaluated; Bock et al[9] demonstrated that the mean values of fracture strength did not differ significantly between laser welding with filling material (441.3 N) and brazing (406.7 N), but a slight tendency to lower means in laser welding without filling material (328.8 N). In a different study, Bock et al[22] showed no significant differences between the mean fracture loads for the band-to-wire joints between laser welding (354.4 N) and brazing (406.6 N), although there was less variability with the laser welding. In the present study, the laser welding groups which was held on equal conditions (with sandblasting) in those studies were group 2 (laser welding without filling material) and group 3 (laser welding with filling material). The means of the fracture strength of these groups were close to the value of literature; 268.35 N and 359.39 N, in group 2 and 3, respectively. Considering the strength of the group 3, it can be argued that laser welding method has sufficient strength for clinical use based on close strength value to the study of Bock et al.[22] When joining cobalt-chromium alloy frameworks, Zupencic et al[27] showed significant greater tensile strength in brazing group than laser welding. The possible reasons for differences between the results of the studies may be associated with several factors including the feature of the material used in research, welding or soldering system, operator' skills differences and differences in the welding parameters such as pulse power and pulse energy.

Although the highest mean was found in group with filling material and sandblasting, laser welding groups did not show any significant fracture strength differences among themselves. But slight difference between group 2 and 3, may be argued as an appearance of the tendency to greater strength value with addition of filling material, in accordance with the literature[9,13] Group 3 and group 4 was analyzed for the evaluation of the effects of sandblasting. Although sandblasted group 3 showed slightly greater strength than group 4 (without sandblasted), difference was not statistically significant. It may be argued that sandblasting have little or no effect to the band -wire joining while using the laser welding.

The high standard deviations for the mean fracture loads in the present study may indicate that the optimal joints were not achieved at all times which can be considered as one of the limitations of the present study and can be the reason for being the subject of future studies.

While choosing a welding technique in order to fabricate different orthodontic appliances, selecting may depend on the advantages and theseadvantages. Higher fracture load of the conventional brazing method with respect to laser technique can direct the clinician to prefer brazing method especially while joining larger areas such as band-wire combination. On the other hand the main advantage of the laser technique is the possibility of welding different types of dental alloys with different melting points. [24,28-29] Therefore, it can be conceivable with laser welding to connect different wires such as titanium-based alloy wires and stainless-steel or cobalt-chromium alloy wires for fabrication of different archwire combinations. On the other hand conventional soldering can not be concentrated on the small area of the wire's joint. However conventional silver soldering is one of the most preferred welding method in orthodontics since the cost of this method is cheaper than the other welding methods and it does not require any other equipment as laser welding.

CONCLUSIONS

-Fracture strength of the silver solder was found significantly higher than all of the laser welding procedures.

-Although laser welding with filling material and sandblasting showed the the most fracture strength among the laser welding joints, the differences between groups were not statistically significant.

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