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ORIGINAL ARTICLE

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Assessing different patterns of laser welding with Nickel-Chromium (Ni-Cr) alloy for structures applicable to fixed prosthesis

Avaliação de diferentes parâmetros de soldagem a laser em liga de Níquel-Cromo levando em consideração estruturas aplicáveis à Prótese Fixa.

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ABSTRACT

Objectives: Among all desired requirements to dental prosthesis, marginal adaptation and passive fit are the most important. In some cases, in order to achieve these goals, it is necessary to cut and weld the teeth / implant-supported framework. Nowadays, the laser welding process shows a great advantage in comparison to other methods. The aim of this study was to evaluate the optimal laser welds point that is more appropriate to Ni-Cr prosthetic framework. **Material and methods:** A total of 60 specimens of Ni-Cr (35 mm x 4 mm) were designed and welded using a Nd:YAG laser device model EV 900. They were fixed in a metal piece 0.27 mm between the ends to be welded. All specimens were welded with 21 laser pulses diametrically opposed (frequency of 1.0Hz, load time 3.0 ms and 0.5 mm of diameter pulse). They were divided into three groups according to the electric current of the laser weld: A – 180A; B – 200A; C – 220A; and D- control group with no welding process. To determinate the flexural mechanic strength, all specimens were submitted to a three-point bending test. **Results:** The results obtained were: Group A = 553,76 Mpa; B = 751,02 Mpa and C = 802.13 Mpa. The control group was 1040.9 Mpa. ANOVA and Tukey's test were performed and statistical significance differences were observed between group A and B as well as between group A and C. However, no significant difference was observed between B and C. The group D (no welding process), significant difference was observed between A, B and C. **Conclusion:** According to the methodology used, the groups B and C, among the welded groups, produced higher

RESUMO

Objetivos: Entre os requisitos de uma prótese fixa estão a adaptação marginal e seu assentamento passivo. Em alguns casos, para alcançarmos estes requisitos, devemos realizar o seccionamento e soldagem da infraestrutura metálica. Os procedimentos de soldagem a laser apresentam várias vantagens em relação aos outros processos de união. O objetivo deste trabalho foi avaliar os parâmetros ideais para soldagens a laser em de infraestruturas protéticas em Ni-Cr. **Material e métodos:** Foram confeccionados 60 infraestruturas (35 mm X 4,0 mm), que foram soldadas utilizando um aparelho de solda a laser Nd:YAG modelo EV 900. As amostras foram fixadas em uma peça metálica, mantendo padronizada uma distância de 0,27 mm entre as extremidades a serem unidas. Todas as amostras foram soldadas com 21 pulsos diametralmente opostos (frequência de 1,0 Hz, tempo de carga de 3,0 ms e 0,5 mm de diâmetro do pulso) e foram divididas em três grupos experimentais, alterando-se a intensidade da corrente elétrica da solda a laser: A) 180 A; B) 200 A; C) 220 A e D) grupo controle -sem processo de soldagem. Para se determinar a resistência mecânica flexural, todas as amostras foram submetidas ao teste de flexão de três pontos em máquina de teste universal. **Resultados:** Os resultados médios obtidos foram: grupo A) 553 Mpa, B) 751,0 Mpa, C) 802,1 Mpa e para a amostra controle foi de 1040,9 Mpa. Foram realizados o teste estatístico paramétrico ANOVA e o teste de Tukey, e foi observado diferença estatisticamente significante entre os grupos A x B e grupos A x C. No entanto, não foi observado diferença significante entre os grupos B x C. No Grupo D (sem processo de soldagem) foi observado diferença significante quando comparado com os grupos A, B e C. **Conclusão:** De acordo com a metodologia utilizada,

values of mechanical strength than the group A. The groups B and C were similar.

o grupo C produziu os maiores valores de resistência flexural, seguidos pelos grupos B e A respetivamente.

KEYWORDS

Dental Soldering; Dental prosthesis; Flexural strength.

PALAVRAS-CHAVE

Soldagem em odontologia; Prótese dentária; Resistência a flexão.

CLINICAL IMPLICATIONS

The quality of attachment is responsible for guarantying the strength of prosthetic frameworks. It also affects passive fit of teeth-supported fixed prostheses or implant abutments.

INTRODUCTION

Passive fit is among the several factors affecting longevity of dental prostheses, provided that it does not induce force over abutments when prostheses are not exerting any masticatory function. Unlike natural teeth, implants do not have the physiological mobility necessary to compensate for minor distortions appearing during the indirect process of prosthesis manufacture. For this reason, passive fitting is critical in Implantodontics, particularly because the tension produced by non-passive fitting may cause mechanical flaws including fracture of prosthetic components; adverse biological reaction, such as microfracture of bone tissue and marginal ischemia zones; and uneven tension over abutments, all of which might hinder implant longevity [1,2]. When teeth-supported, lack of fit might lead to bone resorption and/or infiltration.

Lack of fit might be caused by several factors, including low-quality material and poor welding. When the prosthetic infrastructure is fused in a single piece, it increases the probability of unfitting [3]. Whenever unfitting of the prosthetic structure is detected, whether by means of clinical probing, visual or radiographic examination, and single-screw testing (in case of implant-supported prostheses), the metallic structure is cut with the aid of a carborundum disc, repositioned with the aid of chemically cured acrylic resin and subsequently welded. Welding is an alternative used to reach best marginal adaptation of metallic frameworks fixed prostheses to their respective abutments, improving the uniformity in the distribution of masticatory forces, with regard to one-piece casting [4-6].

Also in relation to soldering, the conventional welding technique (brasing) needs extra material added to the welding process. This material should have a melting point lower than the pieces being welded not only to prevent the latter from undergoing potential distortions, but also to allow the weld to flow smoothly on the surface [7]. It also presents the following disadvantages: rough morphology, porosity, little resistance to corrosion, significant distortion, little mechanical strength and a large area affected by heat [8-10]. With a view to addressing these issues, new welding methods have been developed, including laser welding.

Laser welding has several advantages: greater mechanical strength [11], potential to be used when joining different material [12], greater resistance to corrosion and favorable properties for welding of non-noble alloys. Another major advantage of laser welding in comparison to other methods is its power of being limited to a small area due to having a concentrated amount of energy which limits the heat-affected zone (HAZ) to a minimum [13,14].

The quality of laser welding is directly related to the amount of energy which, in turn, relies on the electric current, diameter and time

of laser beam exposure. The aim of this study was to establish the ideal parameters by Nd:YAG laser welding into cast Ni/Cr alloy.

MATERIAL AND METHODS

The alloy employed in this study was Nickel-Chromium Wironia Light (Bego-Bremen - Germany). A total of 60 specimens alloy were prepared (4.0 mm in diameter and 35.0 mm in length), and two specimens alloy non-welded were used as control (4.0 mm in diameter and 70.0 mm in length). After casting, test specimens were divested and subjected to airborne particle abrasion with glass beads (CNG Soluções Protéticas - Brazil) at 55 PSI (Figure 1).



Figure 1 - Cylinders of Ni-Cr alloy.

A device made of hard aluminum alloy and fixing screws was developed to attach the specimens so as to keep them in steady position during the welding procedure (Figure 2). For standardization purposes, the specimens were attached to the device at a distance of 0.27 mm between endpoints. This distance was set on the basis of the width of carburundum discs (Dedeco 5503) typically used to cut the metallic structure of dental prosthesis (Figures 3 and 4).

Welding was carried out using an EV-900 laser welder manufactured by Elettronica Valseriana (Evlaser – Casnigo - Italy) (Figure 5). Argon gas was used throughout the procedure.

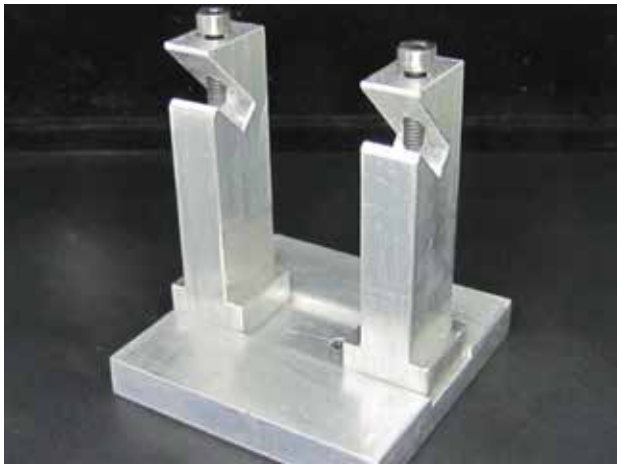


Figure 2 - Device made of hard aluminum alloy and fixing screws to attach the specimens so as to keep them in steady position during the welding procedure.



Figure 3 - Distance set on the basis of the width of carburundum discs.

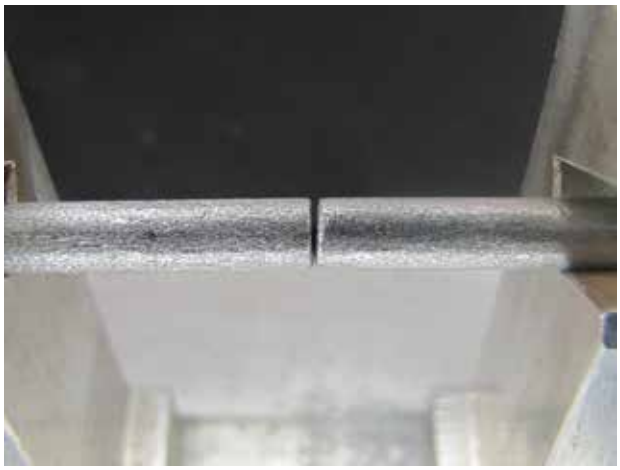


Figure 4 - The specimens attached to the device at a distance of 0.27 mm between endpoints.

Welding trials were performed by changing the laser beam current, frequency, time of exposure and diameter so as to establish its penetration at the center of the specimens. New trials were performed to determine the number of laser beam pulses necessary to cover the entire circumference. The best results were yielded with the following: 21 sites around the specimens, current of 200 A, frequency of 1.0 Hz, diameter of 0.5 mm and time of exposure of 3.0 ms. Based on these data, and by changing the electric current of the laser beam pulse in +/- 20 A. Three groups were created, in which 20 specimens were welded as follows: Group A) 180 A, 1.0 Hz, 0.5 mm^2, 3.0 ms and 4,7.106 J/cm^2; Group B) 200 A, 1.0 Hz, 0.5 mm^2, 3.0 ms and 5,2.106 J/cm^2; and Group C) 220 A; 1.0 Hz; 0.5 mm^2, 3.0 ms and 5,8.106 J/cm^2 . Two specimens were not welded and comprised Group D) — the control. The period of exposition to laser beam in total/specimen was 0,063 seconds.

To assess the mechanical strength of laser welding, the samples were subjected to a flexural strength test carried out by means of a universal testing machine (QTest – MTS Systems Corporation - USA) set at 0.5 mm/min (Figure 6). The test was considered complete with the fracture of the welded specimens. Data were interpreted with the aid of Origin 6.1 (OriginLab Corp.) software. Final results were subjected to Analysis of Variance and Tukey's test.

RESULTS

After the flexural strength test was carried out, the lowest and highest values (expressed in Mpa) of welded specimens fracture, as well as the arithmetic mean of the samples in each group were as follows: Group A) 295.90, 769.40 and 553.80; Group B) 572.80, 942.90 and 751.00; Group C) 634.10, 893.70 and 802,13; and Group D) 1020.00, 1061.80 and 1040.90. Data were



Figure 5 - EV-900 laser welder manufactured by Elettronica Valseriana.



Figure 6 - Flexural strenght test carried out by means of a universal testing machine set at 0.5 mm/min.

also subjected to variation coefficient: Group A) 25.84%; Group B) 15.56%; Group C) 12.21%; and Group D) 2.84%. Results reveal that group A had the greatest standard deviation, followed by groups B, C and D (Figure 7).

Data distribution proved normal, with deviation within the limits of critical values set at an alpha level of 1% (P-value > 0.01). Analysis of variance (ANOVA) was then indicated. Tukey's test was performed to assess potential differences among groups. The test evinced statistically significant difference between groups A and B (P < 0.01), with B greater than A; groups A and C (P < 0.01), with C greater than A. The difference between groups B and C was not significant. Tre group D significant difference was observed between A, B and C (P < 0.01) (table 1).

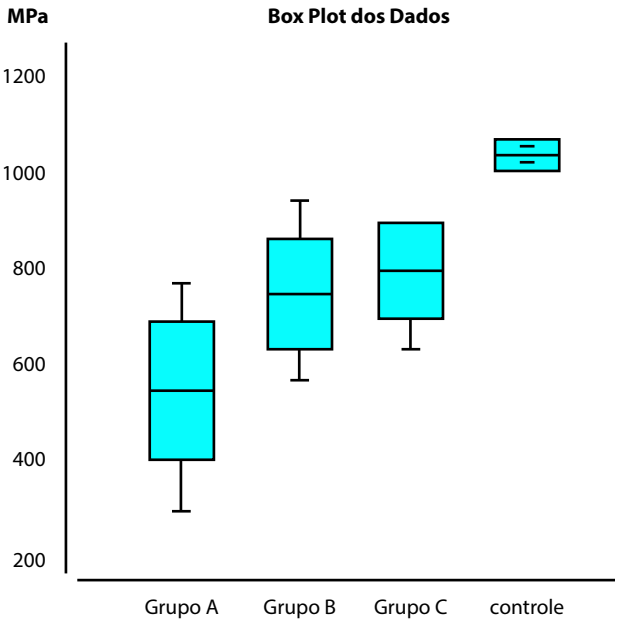


Figure 7 - Distributional characteristics of group A, B, C and control group, as well as the level of the scores.

Table 1 - Mean Felxural strength and standard deviation. Different letters indicate statistical differences (Tukey's test)

Groups	Flexural Strength
Group A	553.76 + 143.08a
Group B	751.00 + 116.85b
Group C	802.13 + 97.91b
Group D	1040.90 + 29.58c

DISCUSSION

One of the most important requirements necessary to maintain longevity of oral rehabilitation is passive fit of tooth or implant-supported prostheses. Passive fit is understood as the ideal seating. It occurs when the metallic prosthetic structure exerts zero force over implants or abutment teeth during placement. In general, lack of passive fitting has been associated with biomechanical issues of implant-supported prostheses [1].

Passive fit is ensured by several means, namely: good impression, good planning, use of quality material, proper implant positioning, proper dental preparation, etc. Whenever unfit of the prosthetic structure is detected, whether by means of clinical probing, welding is rendered necessary. The metallic structure is cut, repositioned with the aid of chemically cured acrylic resin and sent to the prosthesis laboratory for welding. This process results in better seating and adaptation of tooth or implant-supported metallic structures, in comparison to one-piece structures [4-6].

Welding is a metallurgical process that consists in joining two metals by fusion, with or without filling metal, so as to form a junction [14] of which quality is paramount in determining the material strength.

Brasing, also known as conventional/direct welding, is among the most common welding techniques. With the aid of a welding torch, a metal alloy is added to the welding process. This alloy should have a melting point lower than the pieces being welded [7]. This soldering presents the following disadvantages: rough morphology [10], porosity [9,15], little resistance to corrosion, significant distortion during welding [4,16], and little mechanical strength when compared to other welding methods [10].

With a view to addressing these issues, new welding methods have been developed, including laser welding. According to the literature, laser welding has several advantages, namely: greater mechanical strength [11], a small area affected by heat [12-13], little tension around implants [1], potential to be used when joining different material [12], greater resistance to corrosion, and favorable properties for welding of non-noble alloys, such as Ni-Cr. Another major advantage of laser welding in comparison to other methods is its power of being limited to a small area due to having a concentrated amount of energy which limits the heat-affected zone (HAZ) to a minimum[13,14].

Moreover, laser dismisses the need for welding alloys and shielding, which reduces working time and allows us to work directly on the dental cast [13].

Laser beam penetration depth is particular to each type of metal, since they differ in terms of the absorption, thermal conductivity and melting point. In general, the absorption rate of laser and the thermal conductivity of metal is what determine laser beam penetration depth [17]. Ni-Cr alloy was chosen in this study due to its significant strength to the adverse conditions that affect the oral environment; for instance, great mechanical efforts, and also due to its lower cost in comparison to gold alloys. For these reasons, Ni-Cr alloy has been increasingly used within Brazilian territory.

The space between endpoints also influences the process of welding, since it might lead to a higher or lower incidence of porosity [18]. For this reason, space dimensions should vary between 0.0 and 0.5 mm. Thus, a distance of 0.27 mm, which equals to the thickness of the carburundum disc (Dedeco 5503) typically used in dental practice to cut metals, was established.

Should laser beam penetration be too shallow, it may result in incomplete fusion [13]. Moreover, should molten metal be located at the outward bounds of the sample, only, it weakens fusion and strength of the material as a whole. A solution to this problem would be the superimposition of laser pulses diametrically opposed to each other [13,19], which allows the entire width of the sample to be completely filled by welding. Laser beam strength is determined by two parameters: energy and duration of pulse. Importantly, laser strength is responsible for laser beam depth whereas the duration of pulse is responsible for welding point width. The more the energy, the smaller the welding point width and the deeper the laser beam penetration [17]. Nevertheless, should energy levels be too high, despite providing greater strength, it will increase the risk of distortion [20], since the metal will be increasingly molten. On the other hand, should energy levels be too low, laser beam penetration is insufficient, which end up weakening the fusion [16].

Laser equipment is well known to amplify light by stimulating the emission of radiation. Yttrium-aluminum-garnet (YAG) doped with neodymium (ND) crystals is used to emit laser beams (Nd:YAG laser) to weld dental alloy [21], and according to the literature, all studies used this type laser [1,2,4-6,10,17,20-26]

The flexural strength (Mpa) of the specimens was obtained using a universal testing machine (3-pont) [10,20,21,23-25] and a load cell of 500 Kg, speed of 0,5 mm/min applied on the welded interface. The specimens were fixed to two supports separated by a 20-mm distance Loading was applied up to plastic deformation of the specimens or its rupture [21,25].

In this study, the best results were obtained in-group C: 802,13 Mpa. Similar researches with Ni-Cr alloy have shown results between 460 Mpa, 749 Mpa and 1030 Mpa [10,25,26]. Several factors may influence the mechanical strength of welded joints, for example, alloy composition, diameter of

prosthetics framework, welding equipment parameters, joint design [22] and filling materials [25]. Regardless of alloy, non-welded specimens presented significantly higher tensile strength and flexural strength than laser-welded [10,21,23- 25].

CONCLUSION

On the basis of the methods applied for this study, it is reasonable to conclude that:

When subjected to the flexural strength test, group C welding yielded the similar mechanical strength values as group B, being both greater than the group A;

The control (group D) had the greatest mechanical flexural strength in comparison to all the other welding methods.

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