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ASSESSMENT METHODS OF DIFFERENT LASER WELDED DENTAL ALLOYS

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Abstract: *The aim of this study is to assess the characteristics of laser welding, by different methods such as: scanning electronic microscope observation and metallography. The quality of welding can also be tested by non-invasive methods, which make possible its macro- and microscopic assessment. The alloys assessed are a titanium-based alloy, a standard Au–Pd alloy for the metallo-ceramic technique and a Cr-Co-Mo alloy. The conclusion of the testing is that laser welding is generally mechanically satisfactory.*
Key words: *welding, dental alloys, laser, non-invasive methods, metallography, scanning electronic microscopy*

1. INTRODUCTION

During the past years, laser welding has been extended to dental technique as it permits the joining of various pieces made of similar or different alloys, which might be difficult with other techniques. (Watanabe et al., 2006). For example, titanium or titanium-alloy pieces, welded pieces used during repair works of partials made of Co-Cr alloys, which permit the preservation of the components of the denture piece which might deteriorate during heating (composites or teeth) by using usual techniques. (Pop et al., 2007) It is equally possible, thanks to this welding method, to weld elements situated in inaccessible places, such as the inner part of an element, splinting extremely small and delicate elements, or splinting of extremely sensitive elements. (Reclaru et al., 2010)

The main advantage of the method is that of cold welding, even on a model.

The quality of laser welded joints of some dental alloys can be evaluated by invasive and non-invasive methods. Some of the invasive methods are: metallographic analysis and microhardness testing and non-destructive methods are: spectrographic and radiographic analyses. (Bortun et al., 2005)

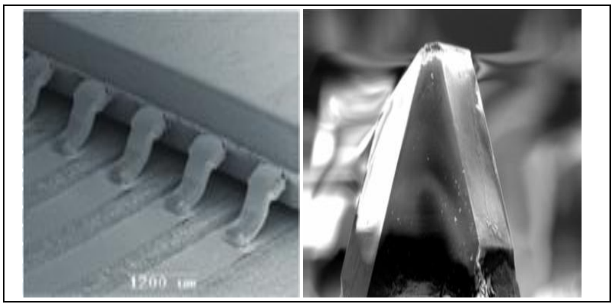
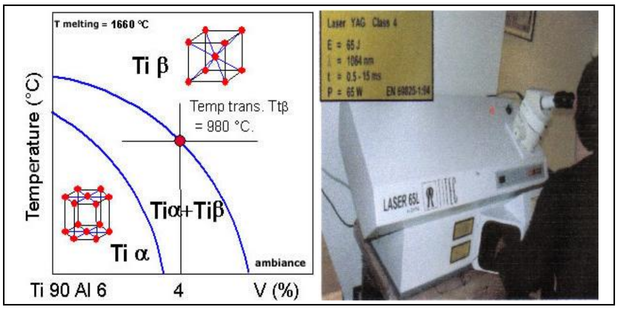


Fig. 1. Laser welding of electronic microcomponents (right) and diamond welded on steel for grinding instruments (left).

2. MATERIAL AND METHODS

The alloys assessed by scanning electronic microscope observation and metallography are the titanium-based TA6V4 alloy and a standard Au–Pd alloy for the metallo-ceramic technique.

The TA6V4 alloy is a titanium-based alloy containing 6% aluminum and 4% vanadium, mainly used in manufacturing prefabricated pieces for implantology. As the pseudo-binary phase diagram shows, at room temperature the alloy is bi-phased Tiα + Tiβ, with a slight phase percentage for Tiβ. The existence of the two phases Tiα and Tiβ, at room temperature, makes possible the creation of an alloy with a high mechanical resistance, due to the mutual interaction of the two phases. The alloy has an elasticity limit of 875 MPa.



a b

Fig. 2. a) Schematic pseudo-binary phase diagram of TA6V4. (right), b) LASER 65 L – TITEC with welding parameters (left)

During heating the Tiα turns into Tiβ at approximately 980^{o}C. During fast cooling, the Tiβ phase undergoes a so-called martensitic transformation forming a complex lamellar structure inducing significantly altered mechanical properties. These mechanical properties will be recovered by a low-temperature thermal treatment.

The Au–Pd alloy used in the the metallo-ceramic technique, welded by laser technique, is a standard alloy, containing 51.2% Au, 38.6% Pd, indium, gallium and ruthenium as additional elements.

The third alloy was the C alloy, which is currently used by the authors in making metallic components of partial dentures. Plates of this Cr-Co-Mo alloy were cast, their thickness varying from 0.4 mm to 0.9 mm, and they were welded with the laboratory Nd-Yag laser: LASER 65 L – TITEC.

3. RESULTS

Metallurgic analysis of the TA6V4 alloy sample, by metallography and scanning electronic microscope observation, after a single impulse laser impact, reveals the following: after cooling there is a melting area (MA), a thermally-affected area (TAA) and an area corresponding to the base alloy (BAA). The MA is mainly formed of Tiβ turned by martensitic transformation into Tiα'. The TAA is mainly composed of two sublayers developed near the MA, formed of a Ti' structure and, deeper down, of a complex Tiα + Tiβ + Tiα' structure. The BAA consists of the Tiα + Tiβ structure. The elasticity limit during high temperatures decreases and the resistance to wear is rather unaffected by laser welding.

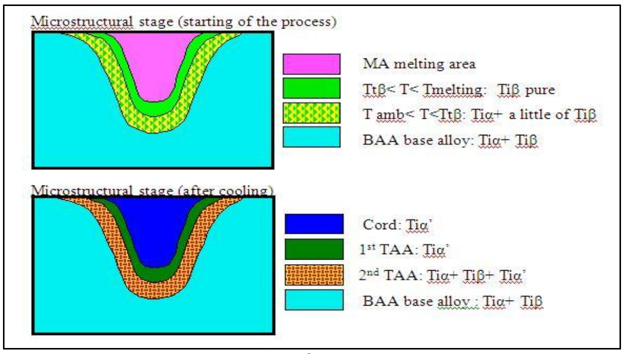


Fig. 4. Schematic description of the cord during welding

For the Au–Pd alloy used in the metallo-ceramic technique, the figures show the successive impacts leading to the welding of the two pieces. Like in the case of a titanium-based alloy, there is a very perturbed TAA and a lamellar structure of the melting area.

For the C alloy, the welding area, dyed in yellow, shows no fissures in the immediate vicinity of the welding – in the TAA – because the laser is used at very low temperatures and there are no contractions in the analyzed material. However, X-rays show radio-transparence in the fusion area, which indicates that the fusion is a superficial one and does not cover the entire thickness of the fused alloy. Although C alloy plates used are not very thick, welding does not cover the whole depth. This results in the fragility of the welding.

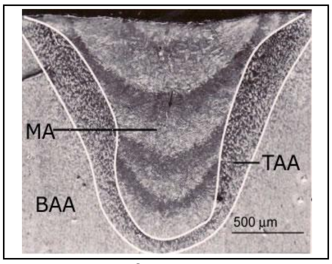


Fig. 5. SEM observation of the TA6V4 cord sample after a single impulse laser impact

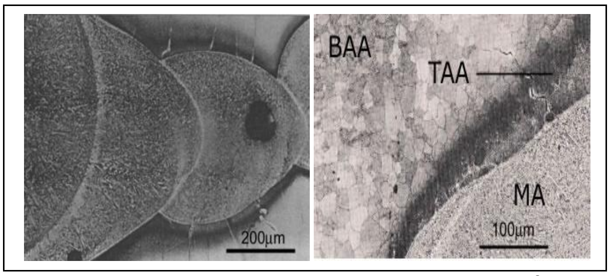


Fig. 6. Welded area: SEM (right) and metallography (left)

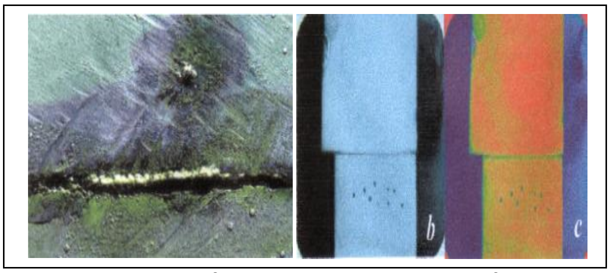


Fig. 7. Assessment of the welded area: a. basic fuchsin dye-staining; b. X-ray; c. pseudo-chromatization

4. DISCUSSION

In the case of TA6V4 alloy it is important to observe that the cooling speed plays an important role on its mechanical characteristics due to its influence on the phase transformation structures into a solid state. The elasticity limit during high temperatures decreases and the resistance to wear is rather unaffected by laser welding due to the fact that the cord has no porosities or other defects (cracks, snaps).

In case of the Au–Pd alloy for the metallo-ceramic technique, it appears that the resistance to fracture of the laser welded area is higher than in the case of brazing. On the other hand, the resistance to wear of laser welding is lower than that of brazing.

Laser welding is suitable to weld titanium and its alloys because they have higher rates of laser beam absorption and lower thermal conductivity than other dental casting alloys, such as gold alloys; however, due to the strong reactivity of molten titanium with oxygen, the incorporation of oxygen during laser welding may affect the joint strength. (Susz et al., 2011)

Concerning the C alloy, the main advantage of the method is that of cold welding, even on a model. Plate assessment shows that the fusion area - laser welding - seems microscopically fragile, being easily breakable. X-rays do not show fissures in the fusion area or in the thickness of the basic material.

5. CONCLUSIONS

As a rule, laser welding is mechanically satisfactory. (Szuhanek, 2010) In order to avoid problems, initially, both parts of the joined piece should be subjected to low level energy impacts, followed by greater energy for filling. (Baba& Watanabe, 2005) The success of the welding procedure also depends on the operator's dexterity and the choice of the welding parameters. (Achebo, 2010)

Further research will be carried out using more different types of dental alloys, in order to asses and compare their behavior when laser welding is performed and determine the proper parameters for each type of dental alloy.

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