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Chapter 17

Welding Techniques in Dentistry

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Additional information is available at the end of the chapter

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1. Introduction

Welding involves a metallurgical union process that relies on base metal fusion, i.e. the constituent metal of the structure, with or without filler metal, to form the soldered joint. Thus, a definition of welding proposed by the AWS is an "operation which aims to get localized coalescence produced by heating to a suitable temperature, with or without applying pressure and filler metal, producing parts with strong welded union, nonporous and free of corrosion. According to some authors, when the welding conditions are suitable, the mechanical strength of a welded union is equal to or greater than the base metal intact.

Currently, over 50 different welding techniques have some industrial use and are the most important methods for permanent union of metals. This importance is further evidenced by the presence of welding processes in different areas, such as: aerospace, aviation, automotive petrochemical, nuclear, and medicine.

In dentistry, welding between abutment elements, during construction of the metal framework or even after ceramics application, has been used by the vast majority of dentists to solve problems related to laboratory distortions that are reflected in prostheses' misfit in the marginal area. The welding technique has the advantage of working with segments of the prosthesis to generate prosthetic framework with lower distortion, which enables better fit to the abutments. It promotes uniform stress distribution and minimizes trauma and failures in the bone, implant, and prostheses.

In addition, the recent and promising use of titanium (Ti) alloys in dentistry has been driven mainly by the desire to produce structures of low weight and high resistance to chewing efforts, since titanium presents favorable biological and mechanical properties, including: low density, excellent biocompatibility, good resistance/weight ratio, and low modulus of elasticity.

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However, its high melting temperature, which is close to 1,700°C, and high reactivity with the nitrogen, hydrogen, and oxygen from air, when subjected to high temperatures, end up making it more fragile. Titanium, therefore, requires argon gas for inert gas protection during its manufacturing process.

Thus, the achievement of welded joints in dentistry has been enhanced by the development and incorporation of knowledge of other areas, such as engineering; this allowed the emergence of new techniques and equipment to improve welding, such as Laser Welding, Tungsten Inert Gas (TIG) Welding, and Plasma Arc Welding (PAW). These new techniques are alternatives to conventional brazing, which use a gas torch.

This chapter seeks to present the welding techniques applied to dentistry, as well as scientific studies related to welding techniques.

2. Welding processes in dentistry

Although it is relatively common practice in dentistry to obtain one-piece cast frameworks in order to avoid the soldering step, it is a process that incorporates numerous errors and can lead to an unsatisfying result.

One-piece cast metal frameworks over teeth should be avoided, because their apparent fit is at the expense of tooth movement, developing areas of pressure and traction in the periodontal ligament. The same is not true of the frameworks over implants. Osseointegrated implants are rigidly connected to the surrounding bone, and this connection lacks the inherent resilience of the periodontal ligament. It has been documented that movement of implants within bone is limited to 50–150 μm. In case of a misfit between implant and abutment, or between abutment and prosthesis, it is bone deformation that causes implant movement. Thus, compressive and tensile loads could be directed to the restoration, which could result in a loosening of the prosthesis and abutment screws, fracture of the restoration, bone micro-fractures surrounding the implants, and even fracture of the implant.

The fabrication of a metal framework of multiple elements cast in one piece is no more suitable for dental work, because it is potentially prejudicial to framework fit. Casting separated fragments for subsequent welding is preferred. Barbosa et al. (2010) comparatively analyzed, by SEM, the vertical and horizontal fit between UCLA abutments and implants used in frameworks of five elements that were cast in one piece after laser welding. Three different materials were used: titanium CP (grade 1), Co-Cr alloys, and Ni-Cr-Ti alloys. The passive fit of the frameworks was evaluated by testing the single screw and the stresses generated around the implants, by means of photoelasticity. There was a statistically significant improvement in the frameworks fit for all materials after sectioning and laser welding.

The welding processes are advised, regardless of the extension of the metal structure, on prosthesis over teeth or implants. In dentistry, different welding techniques are used, among which we highlight the brazing, TIG and PAW welding, and laser welding.

2.1. Brazing

2.1.1. Definition

The brazing process, also called oxygas or welding with direct flame, produces a coalescence of metals by heating the parts to be welded with a flame. The process needs another type of alloy, called a solder alloy, which is used to join two or more metal parts, both with or without the same metal, at a temperature greater than 450ºC and less than the melting point of the metal base. To execute this type of welding, an oxygen-propane torch is used with circular movements of the flame over the joint. The parts to be joined are heated until they are red hot, and then the reducing zone of the flame is directed obliquely to the weld area. The investment is left on the bench until it has fully cooled.

2.1.2. Technical description

2.1.2.1. Soldering space

A minimum space of 0.2–0.3 up to 0.5 mm is obtained (Figure 1) for welding. This can be accomplished with aluminum oxide disks or stones or fine diamond burs. To assess whether there is enough space for the weld, a radiographic film or paper card may be placed in the gap. The surface should be finished and polished properly, leaving it clean and without irregularities.

To obtain a uniform solder thickness, it is important to obtain a homogenous space throughout the extension of the area to be welded. Irregular spaces with thick, sharp discrepancies can cause contraction of the solder and result in traction of retainers, which are displaced from their original positions on the investment.

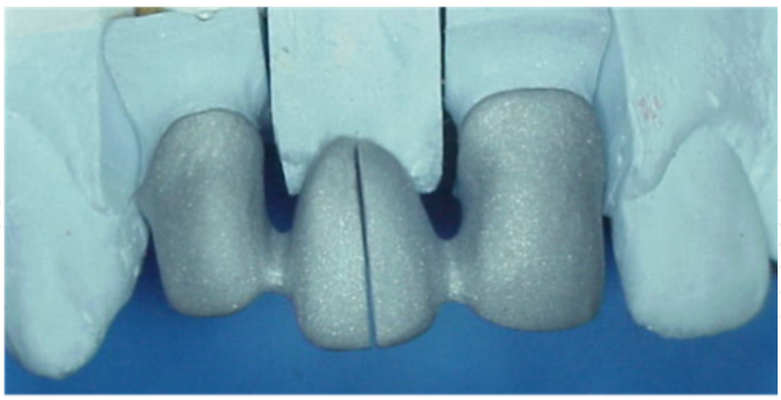


Figure 1. Sectioned framework cast in Ni-Cr alloy with correct space for soldering with the brazing technique.

2.1.2.2. Inclusion and soldering

The various stages below should be followed:

1. Inclusion of frameworks at investment suitable for welding or for casting, forming a block approximately 1.5–2.0 cm in height (Figure 2);

2. Take the investment to the furnace to eliminate moisture and dehydration;
3. Remove the investment from the furnace and wait until it has cooled completely;
4. Clean the areas to be welded with aluminum oxide jet;
5. Apply flux in the joint area and start heating. When heated to red hot, position the welding rod, which is held with clamps, in the area to be welded. The solder melts and flows into the joint under influence of heat and flux (Figure 3);
6. The investment is cooled slowly after the filler metal has completely covered the surface of the joint;
7. Divest and clean with instruments and aluminum oxide jets.



Figure 2. Framework inclusion in soldering investment for high temperatures.

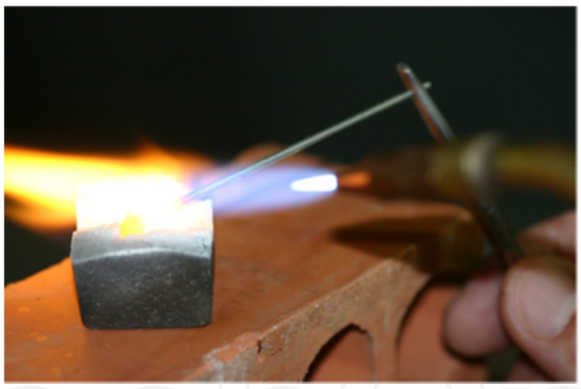


Figure 3. Brazing process using filler metal.

2.1.3. Advantages

- It has been used for years, therefore well known;
- Low cost;
- Relative effectiveness.

2.1.4. Disadvantages

- Problems such as oxidation of the parts joined by weld;
- Joint porosity and overheating of the union during the welding process can promote small structural defects and failure of the rehabilitation treatment.

2.2. Tungsten Inert Gas (TIG) Welding and Plasma Arc Welding (PAW)

2.2.1. Definition

TIG and PAW welding are techniques in which a union is obtained by heating materials by an arc established between a non-consumable tungsten electrode and the part to be welded (Figure 4).

The electrode and the area to be welded are protected by using an inert gas, usually argon or a mixture of inert gases (argon and helium). The basic equipment consists of a power supply, a torch with a tungsten electrode, a shielding gas source, and an opening system for the arc. The main difference between TIG and plasma welding is the use of a constrictor torch that concentrates the electric arc in plasma welding (Figure 5). Filler metal can be used or not.



Figure 4. Ceramic torch, with tungsten electrode, positioned over the sample.



Figure 5. Plasma welding machine for Dentistry.

2.2.2. Technical description

To accomplish this welding technique, it is necessary for the equipment to be regulated for the purpose of welding. The equipment allows for the adjustment of both the pulse and current. After adjusting the machine, screw into one of the claws a structure without use and position the parts to be welded with hands or through specific tables of equipment, which position the parts to be joined. The argon activation is done by a foot pedal, so to start the welding process, press the foot pedal until the argon flows, and then pull off the structure in the electrode without pressing. Maintain steady hands; the buzzer will indicate when contact is made. Quickly release the pedal. The weld will be made, and the flow of argon will continue for a few seconds. It is possible that in the first few attempts the electrode will stick to the piece being necessary to regrind the same.

2.2.3. Advantages

- This allows execution of welds of high quality and excellent finishing, particularly in small joints;
- The thickness of the joint allows for welding in any position, e.g. repairing removable partial prosthesis;
- Excellent control of the weld pool, i.e. the region being welded;
- Expending less time;
- It can be executed directly in the working model;
- The equipment is affordable compared to that of laser welding;
- Allows welding in regions near the resins and porcelains;
- Allows welding with the frameworks in close contact or with minimal space for welding, using filler metal.

2.2.4. Disadvantages

- The electric arc welding processes, such as TIG and plasma welding, are characterized by the imposition of a large amount of heat to achieve fusion of the base and filler material, which causes important microstructure transformations. These transformations occur in a region called the HAZ (Heat Affected Zone), which is a base metal region whose structure or properties were changed by temperature variation during welding. These changes generate a complex region of stresses and deformations, leading to results that are not always desired, including material distortion, residual stresses, generation of fragile microstructures, grain grow, cracks, fissures, and changes in mechanical, physical, and chemical properties, among others;
- Insufficient weld penetration in butt type joints (Figure 6A);
- The presence of porosities in the region of the union (Figure 6B) that is due to the inclusion of argon gas, which is necessary to maintain the inert atmosphere during the welding procedure and thus minimize interaction with air elements. These bubbles and crashes act as initiators of fractures and points of stress concentration, and can lead to the failure of welded structures in a short period of time.

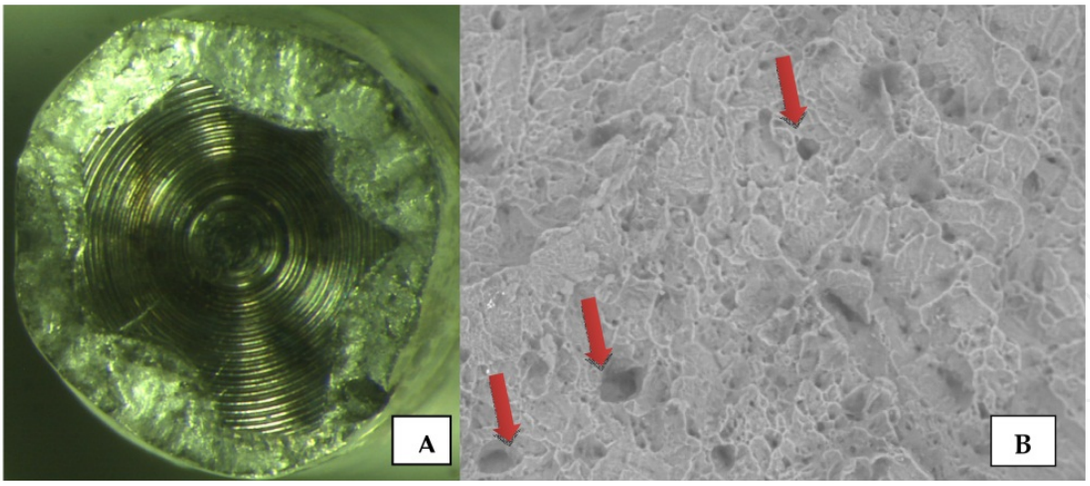


Figure 6. A) Insufficient weld penetration; B) Presence of bubbles and porosities.

2.3. Laser welding

2.3.1. Definition

It is a union process based on localized fusion in the joint, through bombardment from a high-intensity, concentrated, monochromatic and coherent light beam. The area to be welded is protected by using an inert gas, usually argon or a mixture of inert gases.

When the light beam reaches the surface of the metal, the metal absorbs its energy, converting it into heat that penetrates into the interior of the metal by conduction. Owing to a high concentration of heat, the metal is taken to its melting point, and a series of events culminates in the formation of a keyhole or spots that will be filled with the melted metal.

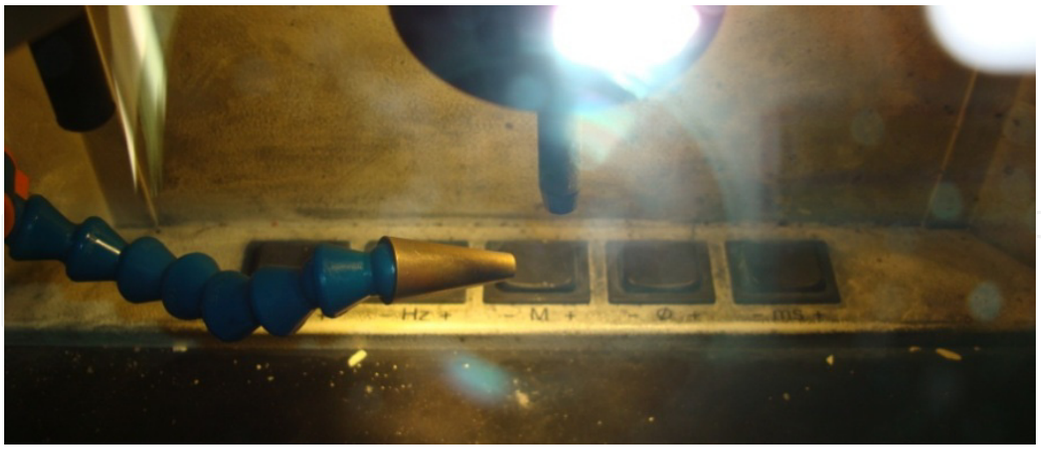


Figure 7. Laser welding machine (output of the light beam and the shielding gas).

2.3.2 Technical description

Looking through the eyepiece of the working chamber, the technician controls with his feet the number of pulses issued for welding. There are rubber gloves inside the working chamber to manipulate the structure to be welded.

2.3.3. Advantages

- it produces a keyhole that concentrates the energy absorbed in a small region, resulting in high penetration and formation of a narrow heat affected zone (HAZ) that results in less distortion compared to conventional welding methods;
- It can be executed directly in the working model;
- Expending less time;
- Both of which are optimizing steps needed for the brazing technique;
- Allows welding in regions near the resins and porcelain;
- Allows welding with the structures in close contact or with minimal space for welding, using filler metal.

2.3.4. Disadvantages

- Unions soldered by laser welding suffer from resulting defects in, among other things, residual stress. Typically, the residual stress introduced into welding joints is a consequence of thermal stress caused by the heating and cooling cycles of the welding process—this affects the mechanical behavior of laser-welded structures;
- The presence of porosities in the region of the union (figure 8A) that is due to the inclusion of argon gas, which is necessary to maintain the inert atmosphere during the welding procedure and thus minimize interaction with air elements. These bubbles and crashes act as initiators of fractures and points of stress concentration, and can lead to the failure of welded structures in a short period of time;
- Insufficient penetration of the laser beam, causes a big bubble or internal failure (figure 8B). According to some authors, the depth of penetration of the weld is the main factor that affects the values of resistance for laser-welded frameworks. Therefore, for better results, the adjustment of equipment is a key point, especially for larger diameters;
- High cost of the equipment.

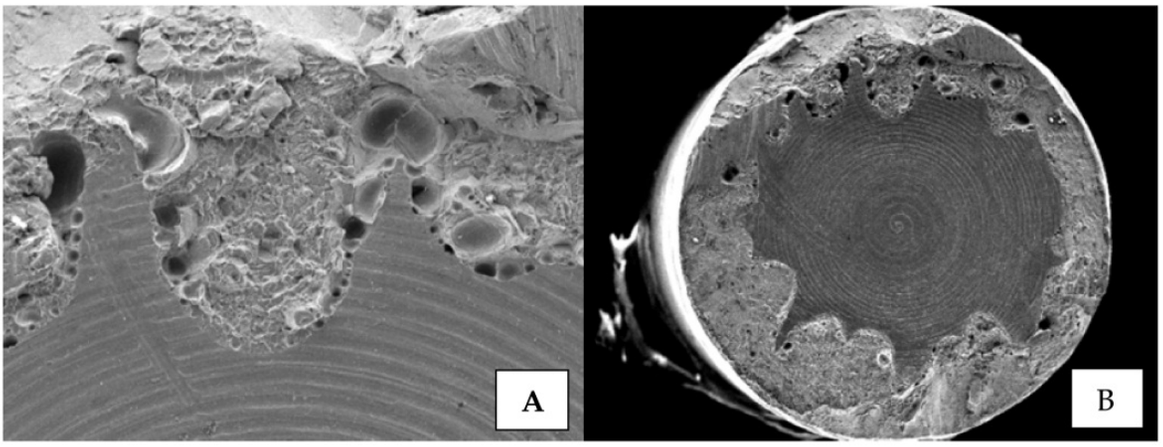


Figure 8. A) Presence of bubbles and porosities, B) Insufficient laser beam penetration.

Type of Welding	Advantages	Disadvantages
Brazing	- It has been used for years - Low cost - Relative effectiveness	- Oxidation of the parts joined by the weld - Joint porosity and overheating of the union during the welding process
Laser	- High penetration and formation of a narrow heat affected zone (HAZ) that results in less distortion compared to conventional welding methods - Procedures can be done directly in the working model - Expending less time - Optimizes steps needed for the brazing technique - Allows welding in regions near resins and porcelains - Allows welding of the structures in close contact - Filler metal may or may not be used	- Residual stress that affects the mechanical behavior of laser-welded structures - The presence of porosities in the region of the union - Insufficient penetration of the laser beam - High cost of the equipment
TIG/PAW	- High quality and excellent finishing of the weld - Allows for welding in any position - Excellent control of the weld pool - Expending less time - Procedures can be done directly in the working model - Accessible cost of the equipment - Allows welding in regions near resins and porcelains - Allows welding of the structures in close contact - Filler metal may or may not be used	- Generates a complex region of stresses and deformations, leading sometimes to undesirable results, such as material distortion, residual stresses, generation of fragile microstructures, grain grow, cracks, fissures, and changes in mechanical, physical, and chemical properties, among others - Insufficient penetration of the laser beam - Presence of porosities in the region of the union

Table 1. Shows a summary of the advantages and disadvantages of different welding techniques.

3. Employment of titanium alloys in dentistry

Until the 1970s, the main material used in fixed and removable prostheses frameworks was gold; however, with the increase in the price of gold, lower-cost alloys were introduced, which were comprised of nickel, beryllium, and cobalt. Over the years, important issues have been reported in relation to the allergenic capacity of nickel and carcinogenic power of beryllium. This has led to a constant search for biocompatible materials that meet dental requirements in chemical, physical, aesthetic, and economic aspects.

Thus, the use of titanium (Ti) in dentistry has been increasing in recent decades due to its favorable physical, mechanical, and biological properties, such as: low density, excellent biocompatibility, corrosion resistance, good resistance/weight ratio, low thermal conductivity, low thermal expansion coefficient, low modulus of elasticity, and relatively low cost. Figure 9 is an example of the metallic framework for the Brånemark Protocol made with titanium.

However, many practical problems are associated with the use of Ti and its alloys because of its high melting point of nearly 1,700ºC, which necessitates high processing temperatures. Also, its high chemical reactivity with oxygen, nitrogen, and hydrogen elements, especially at high temperatures, make Ti fragile, since significant concentrations of these elements are introduced into its surface layer. Contamination with these elements during the process of Ti union and its alloys can result in modification of the microstructure, which causes profound effects in its mechanical properties such as lower ductility and lower tensile strength values, even when soldered in welding machines with inert gas protection.

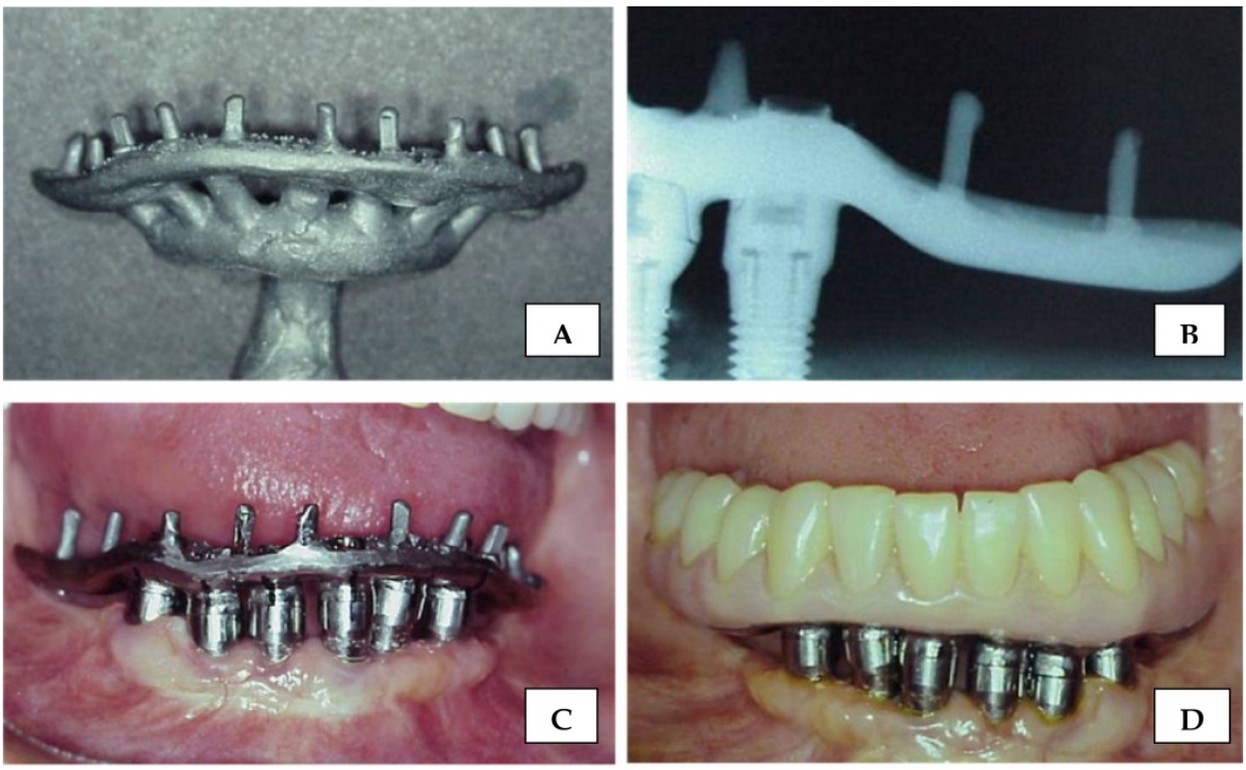


Figure 9. A) Titanium framework; B) X-ray to verify the quality of the laser welding; C) Clinical fit over the implant abutments; D) Installed prosthesis.

Thus, conventional methods that use oxygen flame welding are unsuitable to be used for Ti welding. TIG welding, laser welding, and brazing with infrared radiation are techniques that have been used for metals with gaseous protection, minimizing contamination by oxygen during the welding process and preserving the unique properties of the metal.

4. Use of welding technique to obtain prefabricated frameworks

The use of dental implants in the rehabilitation of edentulous patients is a consolidated treatment modality with high success rates. However, a large proportion of people in the world lack access to this treatment, due to high costs. Research in optimization, simplification of the original Brånemark protocol, such as the use of new technologies, alternative alloys to noble alloys, and new welding methods are presented as viable alternatives to the popularization of the implant in the rehabilitation of edentulous patients.

Therefore, studies using alternative frameworks to the Brånemark protocol have been done, using a titanium and titanium-aluminum-vanadium (Ti-6Al-4V) alloy, in the form of prefabricated bars welded in titanium abutments for construction of simpler frameworks. This reduces costs and the steps required to produce prosthesis, while increasing the speed of treatment; besides this, the alloy offers a great fit and passivity.

Thus, a series of studies involving prefabricated bar welding has been developed at the Federal University of Uberlândia, in partnership with the School of Dentistry, Mechanical Engineering and Technical College of Health. These studies seek to evaluate the use of prefabricated welded bars with different welding techniques. Despite being a line of research that is still unfinished, some of them are shown here.

One of the precursor studies compared the fit of metallic infrastructures welded by laser and brazing under different conformations (Simamoto-Júnior et al. 2008). In this study it was found that the laser-welded structures did not have the best fit as expected, since these have a smaller ZAC. Namely, other technical factors were directly related to the quality of the welded infrastructures' settlement and not just the heating zone factor.

Thus Simamoto-Júnior et al. (2008) evaluated the effect of the type of welding at the interface of three elements of fixed prostheses, which were processed from two master models with implants that were positioned aligned (straight) and misaligned (arc). Twelve models were divided into four groups (n=3) to compare the fit quality of the processes between laser welding and brazing: LA= laser welding/arc, BA= brazing/arc, SR= laser welding/straight, and BR= brazing/straight. At the end of each laboratory stage, casting/grinding, and welding, the structures were placed on the master model for evaluation of the abutment/implant interface, and the quality of both the horizontal and vertical fit were checked (Figure 10). It was expected that laser-welded frameworks would result in better fit, since these have a lower HAZ and, therefore, would cause more minor distortions. As mentioned previously, this did not happen.

This result motivated the study of Silveira-Júnior et al. (2009), which explored the influence of abutment screw tightening force before laser-welding procedures on the vertical fit of metal frameworks over four implants (Figure 11). The hypothesis was that laser welding would result in better fit for the frameworks of implant prostheses, if the tightening force applied to the abutment screws was controlled before the welding procedure. To construct the frameworks, prefabricated titanium abutments and cylindrical titanium bars were joined

to compose three groups: GMT, GT10 and GT20. Before welding, manual torque that simulated routine laboratory procedures was applied to the GTM group. In GT10 and GT20, the abutment screw received 10 and 20 Ncm torque, respectively. Although the statistical results have not demonstrated differences in the three groups, it is not known whether this experience technique could influence the results. Therefore, the authors recommended a torque controller device to guarantee standardized framework tightening before welding, particularly by inexperienced technicians.

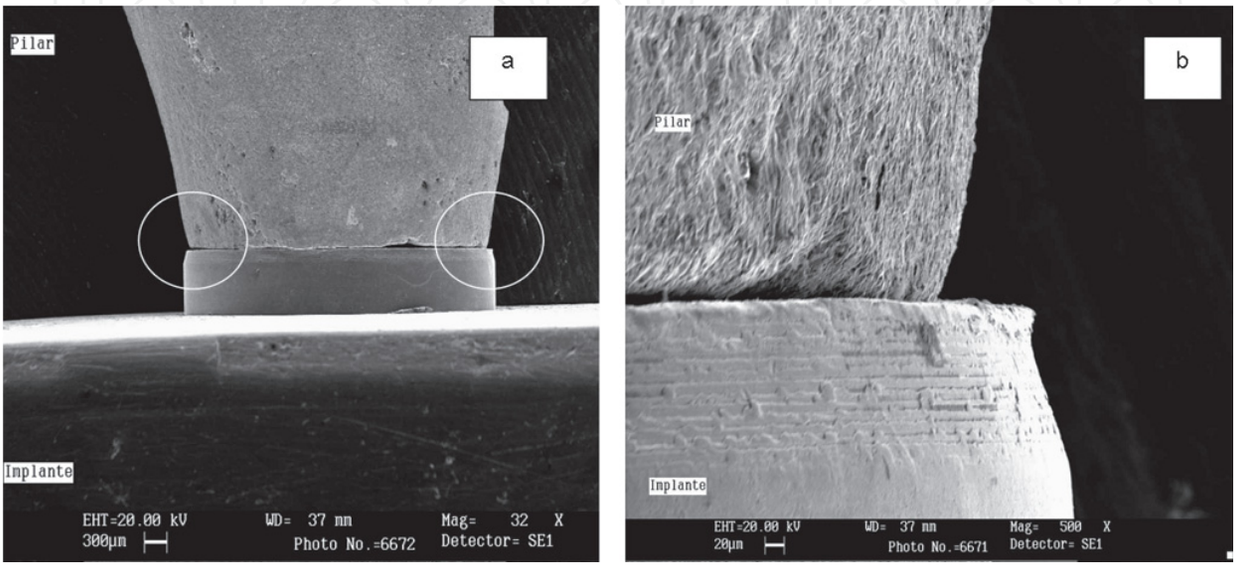


Figure 10. A) UCLA abutment on the implant using a lower zoom, detailing the areas to be analyzed; B) Image increased by 500x of the area to be evaluated.

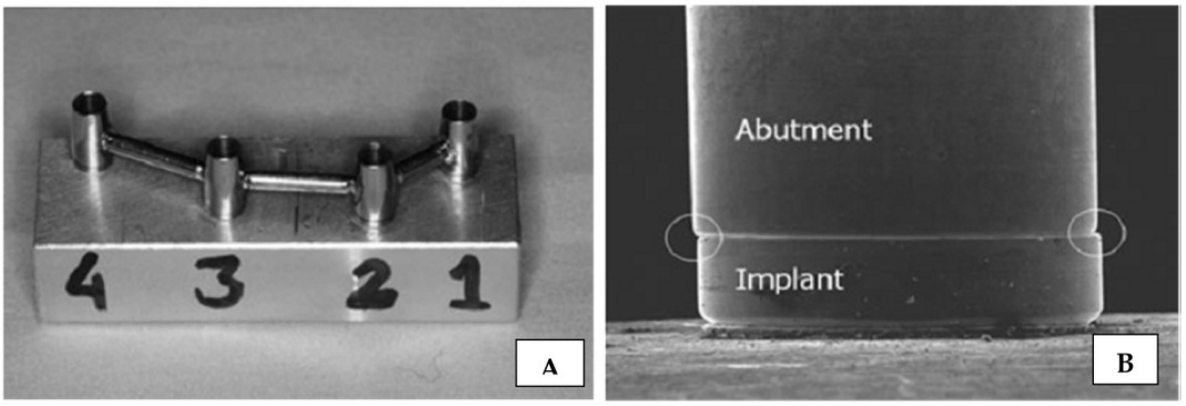


Figure 11. A) The prosthetic framework with Ti abutments, tightened directly on the implants, after the abutments received varied torques and were welded using the laser technique. B) Evaluation of horizontal and vertical fit of the implant/abutment interface by Scanning Electron Microscopy (SEM).

The distal extension of pre-fabricated steel infrastructures was studied by Oliveira et al. (2010). They evaluated the maximum force required to fracture or bend cantilevers, using three different configurations of cylindrical prefabricated titanium bars, grade 5 (Ti-6Al-4V), welded by the TIG method (Tungsten Inert Gas); the control group consisted of frameworks welded by the laser method. They were divided into four groups (n=6). These groups

included a control group (GC) comprised of simple distal bars with 3.18mm diameter that were welded using the laser method, and three experimental groups, all welded by TIG method: with simple distal bars of 3.18mm diameter (GDS); with 2.5mm diameter double distal bars welded together (GDD), and with double distal bars with mixed diameters of 2.5 mm and 3.18 mm welded together (GDDM). The results showed that the control group presented statistically significant differences with the GDS and GDD groups, with higher values of strength; when compared to GDDM, there were no statistically significant differences. Therefore, it is concluded that GDDM, in relation to the other groups, is the most promising method, since its performance is similar to that of titanium frameworks welded using the laser method (Figure 12).

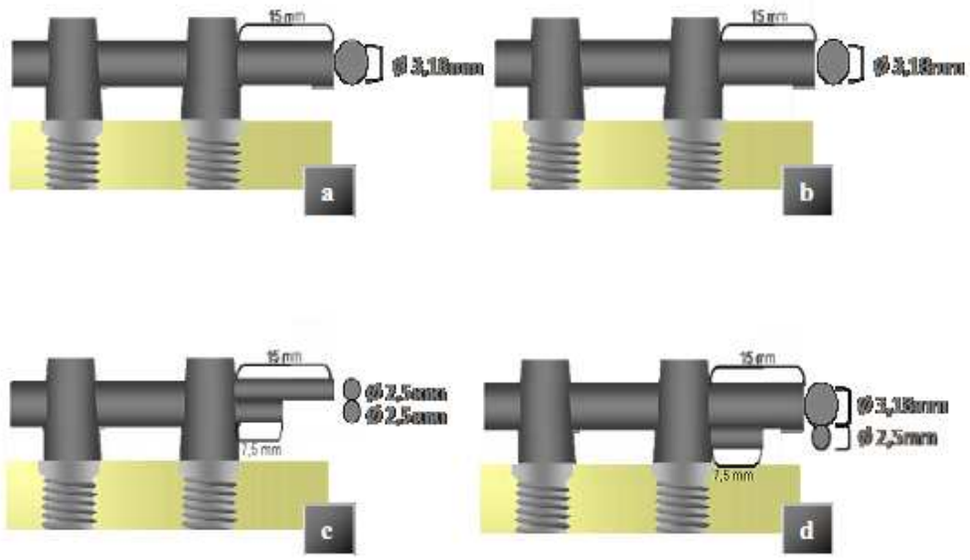


Figure 12. Schematic illustration of the different configurations of the distal bars to be evaluated: (a) GC (b) GDS (c) GDD (d) GDDM.

Silva et al. (2011) evaluated the effect of different plasma arc welding parameters on the flexural strength of titanium alloy beams (Ti-6Al-4V). Forty Ti-6Al-4V and ten Ni-Cr alloy beam specimens were prepared that were 40 mm in length and 3.18 mm in diameter, and were divided into 5 groups (n=10). The titanium beams for the control group were not sectioned or subjected to welding. Groups PL 3-10, PL 3-12, and PL 3-14 contained titanium beams sectioned and welded at a current of 3 A for periods of 10, 12, and 14 months, respectively. Group Ni-Cr-Be consisted of Ni-Cr beams welded using conventional torch brazing. Torch-brazed Ni-Cr alloy beams and non-welded titanium bars served as negative and positive controls, respectively. After the beams were subjected to a three-point bending test, the values obtained were analyzed to find the flexural strength (MPa). No significant differences were observed between the plasma welded groups ($p>0.05$). The Ni-Cr-Be group presented lower flexural strength results, although they were statistically similar to the PL 3-14 group. The weld penetrations were not significantly different between the plasma welded groups ($p=0.05$). This study provides an initial set of parameters for use of plasma welding during the fabrication of titanium alloy dental components. The plasma arc welding

technique used with Ti-6Al-4V alloy showed improved performance over conventional torch brazing with Ni-Cr alloy.

Studies comparing plasma and laser welding were made by Castro et al. (2012) that evaluated the mechanical resistance of TI-6AL-4V alloy submitted to the processes of Plasma and Laser welding by means of tensile test and Finite Element Models (FEM). Forty-five dumbbell-shaped rods (n=5) with different central diameters were created from Ti-6Al-4V bars: CG (Control group) with 3 mm diameter and intact bars and PL2.5, PL3, PL4 and PL5 groups with 2.5, 3, 4 and 5 mm diameters submitted to Plasma welding process and L2.5, L3, L4 and L5 groups with 2.5, 3, 4 and 5 mm diameters submitted to Laser welding process. The results demonstrated that the control group showed higher values to tensile strength than test groups. There was statistical difference between control group and test groups but not among test groups to percentage of elongation. There was a positive correlation between welded area percentage and tensile strength in all the specimens in the test groups and a negative correlation between these parameters and the diameters of the specimens. There were no statistical differences between welding processes. The authors conclude that the diameter of 2.5 mm and 3.0 showed the highest values of tensile strength and percentage of welded area and appears to be the best option for the union of prefabricated bars for the use in prosthetics frameworks for both Plasma and Laser welding.

5. Use of welding techniques for repair of fracture prosthesis

In cases where there is a fracture of the metal framework or even where the metal structure is in need of some repair after loss of an implant, for example, the laser welding process known as TIG and PAW is indicated.

Laser welding is a safe process and can be accomplished around regions of ceramic and resin without risk of damage, because of its reduced HAZ, bond strength of the weld that is compatible with the metal source, and preservation of the metallic framework anatomy. Like laser welding, TIG and PAW welds exhibit reduced ZAC compared to brazing, they allow thickness joint to be welding in any position and allows welding in regions near the resins and porcelain. Moreover, it allows welding with the frameworks in close contact or with minimal space for welding using filler metals.

Two cases of prosthesis repair are presented in sequence. The first one shows the welding of fractured structure porcelain fused to metal, and the second shows the reconstruction of a structure after the loss of an implant.

5.1. Clinical case 1

Figures 13–16 display the employment of laser welding in the repair of a fractured metal ceramic fixed implant-supported prosthesis.

In this case, the patient presented the dentist with a fractured metal ceramic fixed implant-supported prosthesis (Figures 13A and 13B).

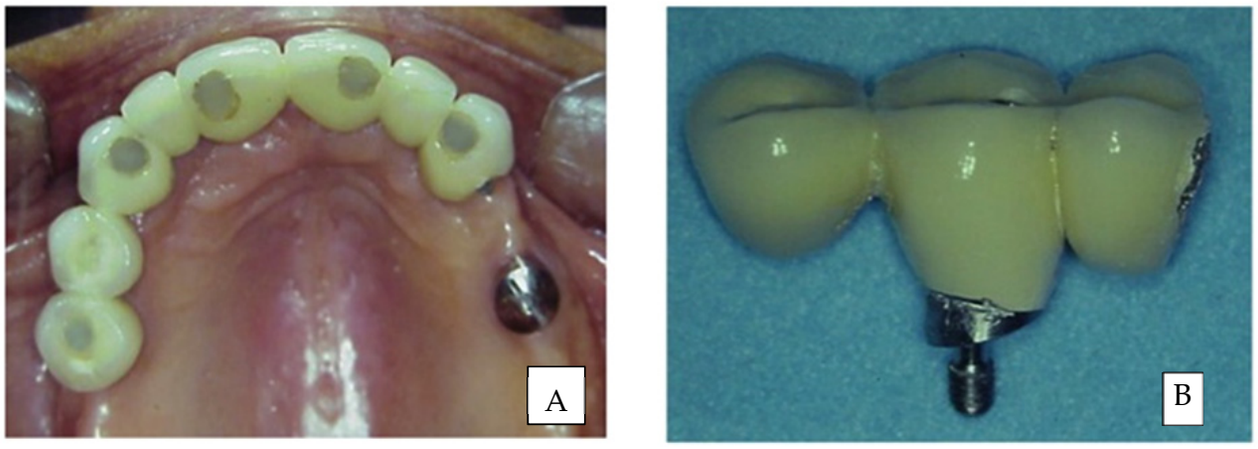


Figure 13. A) Occlusal view of a fractured metal ceramic fixed implant-supported prosthesis; B) Fractured part of the prosthesis.

Then the prosthesis was reseated intraorally and was removed for welding through drills and acrylic resin in order to keep the piece in the correct position (Figures 14A and 14B).

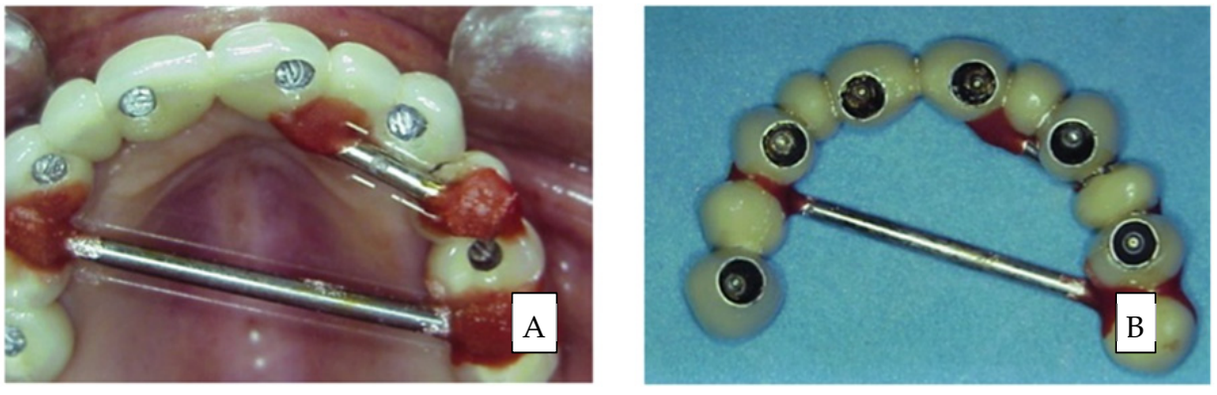


Figure 14. A) Prosthesis positioned intraorally and recorded for welding; B) Prepared structure for inclusion.

After the piece was removed from the patient's mouth, a plaster model index was made in the correct position (Figure 15A) and the piece was welded with laser welding (Figure 15B).

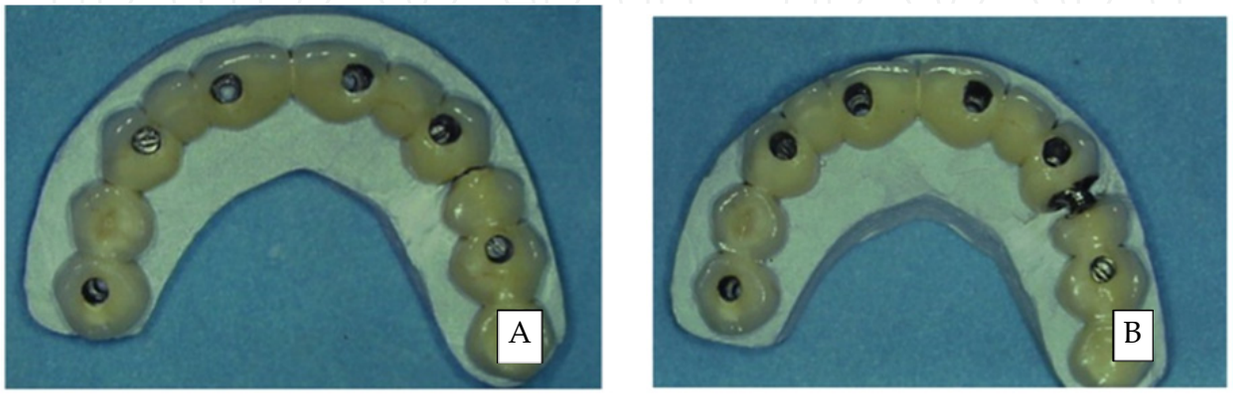


Figure 15. A) Plaster model index for welding; B) Union of the fractured region by means of laser welding.

After the welding composite resin has been applied over the welded region and again installed in the patient's mouth (Figures 16A and 16B).

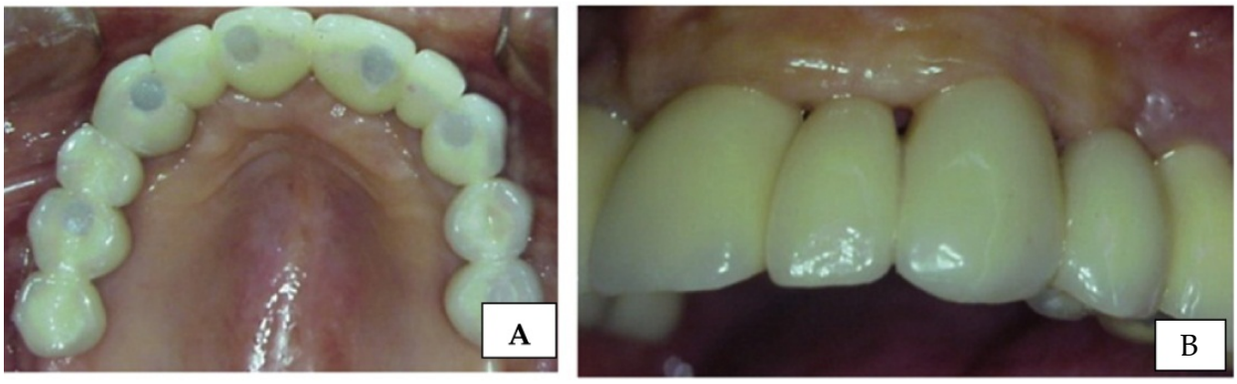


Figure 16. A) Repair terminated with composite resin; B) Details of finishing repair in the welded region.

5.2. Clinical case 2

In this case, the patient was already using a mandibular fixed implant-supported prosthesis over three implants when one of them was lost. Procedures were scheduled to replace the implant and readjust the prosthesis that the patient already used (Figure 17).



Figure 17. Prosthesis that the patient already used.

This required the assembly of top and bottom templates in the articulator (Figure 18A) and the subsequent construction of a silicone wall (Figure 18B). This device has the function of registering the resin teeth positioning with respect to antagonistic teeth, since the metallic framework of the prosthesis should be sectioned.

Before the welding procedure, the teeth were removed and also all excess acrylic resin around the metal (Figures 19A and 19B). Already at the clinical stage, the lost implant was removed and immediately replaced with another in virtually the same position. For this a surgical guide was used.

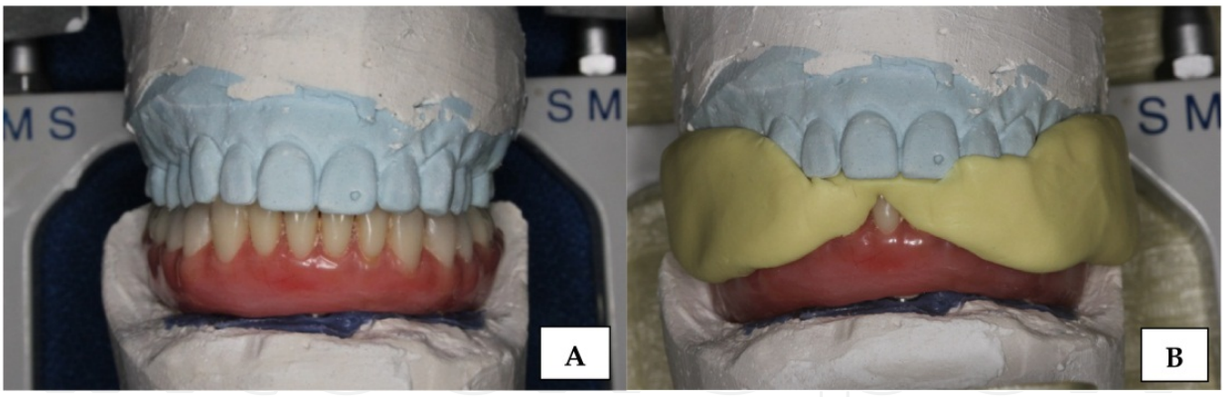


Figure 18. A) Articulating the prosthesis in a semi-adjustable articulator; B) Registration in silicone.

After installing the new implant, the prosthesis and its segmented fragment were screwed into the mouth over the implants. There was a small difference in leveling between these two parts (Figure 20), which was expected because it would be impossible to reposition the implant in an identical position to the previous one.

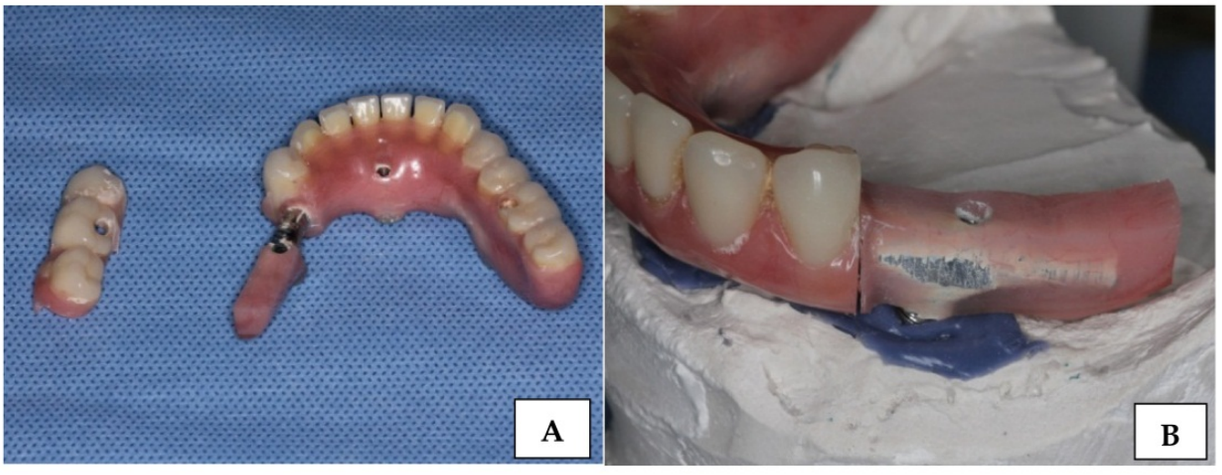


Figure 19. A) Teeth removal; B) Removal of excess resin.



Figure 20. Metal framework cut and repositioned on the new implant.

The fragments were reattached in the mouth with chemically activated acrylic resin for subsequent welding in the laboratory (Figure 21).

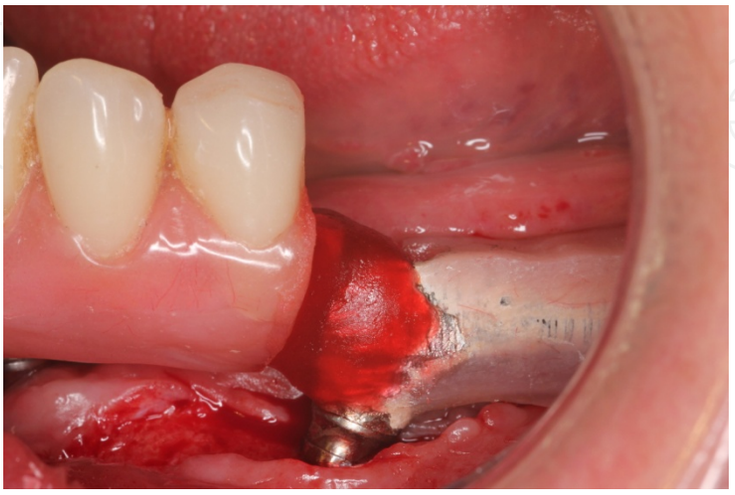


Figure 21. Reattachment of fragments with chemically activated acrylic resin.

In the laboratory it was necessary to adjust the working model. The analogue component of abutment concerning the lost implant was removed and replaced. The analogue was screwed under the sectional fragment and the whole set was screwed over the other two remaining analogues (Figure 22).



Figure 22. Analogue positioning according to the implant position in the patient's mouth.

New plaster was poured around the new analogue to secure it in order to implement the next steps (Figure 23).



Figure 23. Plaster to fasten the new analogue.

The welding of the segments was done with TIG welding (Kernit IND. e Comércio Ltda, Indaiatuba – SP-Brazil) (Figures 24A and 24B) without the need of filler metal. Note that the covering material of the rest of the prosthesis was not damaged, even in the areas closest to the welding.

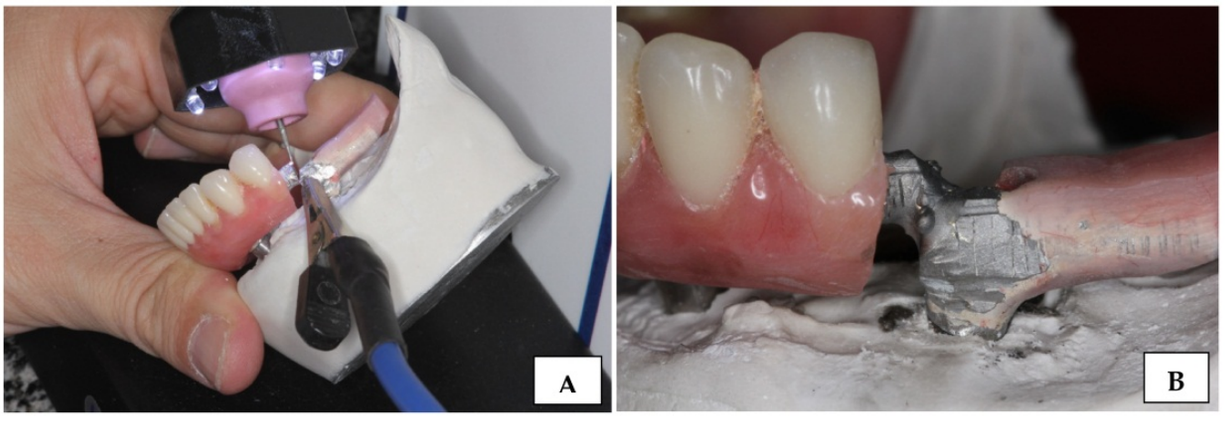


Figure 24. A) TIG welding of the metal bar; B) Structure after welding.

After the welding the teeth were repositioned on the bar using the silicone registration that had already been cut and fixed onto the top model (Figure 25A). The resin teeth were already embedded in the registration, and between these and the bar there was a space that was filled with acrylic resin to fasten them (Figure 25B).

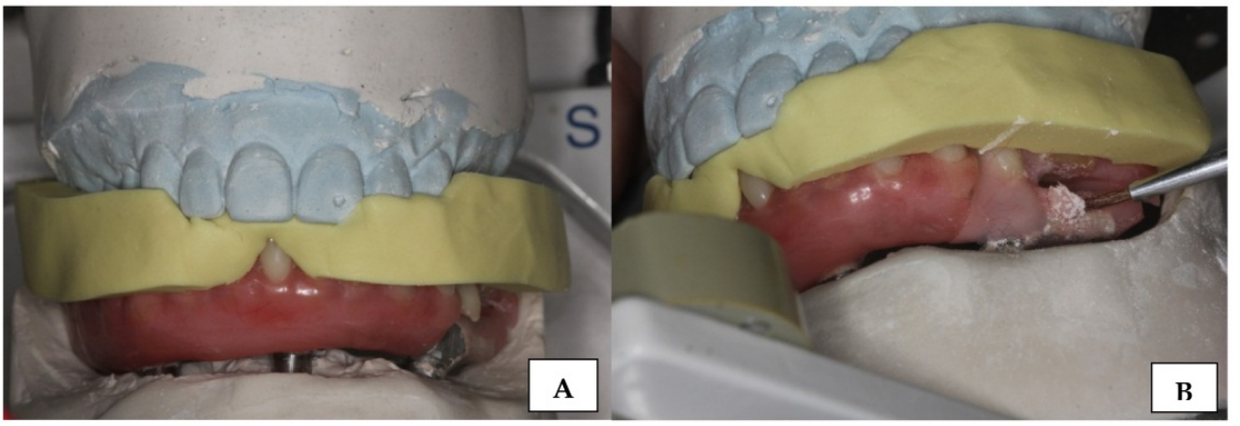


Figure 25. A) Silicone registration positioned; B) Fixation of teeth with acrylic resin.

After insertion of chemically activated acrylic resin in the same color as the rest of the prosthesis, finishing and polishing were performed (Figure 26).



Figure 26. Final appearance of the piece.

6. Conclusion

The information available in the literature and the research shows that the mechanical behaviors of the plasma-, TIG-, and laser-welding techniques do not show major differences in their behavior; laser welding had an increased availability of studies and follow-ups, compared to the other methods. In addition, all feature similar advantages, such as: the ability to be performed on a plaster model; allowing welding in areas close to the resin and ceramic; allowing welding in any position, and requiring less chair time.

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