Part 3 of a series

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Lightning in a Bottle

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Introduction >>

Previously, part one and two of this series of articles about phaser / laser welding in the dental laboratory explained the obvious differences between welding and soldering, emphasizing that the main prerequisite for successful welding is to "forget" the old solder rules. Consequently, the instalments included comparisons of the "full material weld" versus the "hollow seam", ways to avoid and use distortion and the "Lego Block" method used to join different alloys in one bridge. Part three of the series explains which welding wires to use as additional material for which alloys, more alternative ways of cutting and rejoining bridges and clarifies the working procedures when it comes to so called "hybrid" welding (i.e. joining precious and non-precious alloys).

Keywords: **joining, soldering, welding, tungsten inert gas welding (TIG), phaser mx1, laser, plasma arc welding, dental alloys, pure metals,**

CHOOSING THE RIGHT WIRES AS ADDITIONAL MATERIAL FOR PHASER/LASER WELDING >>

There are more than 1,400 alloys for dental restorations on the market today. To simplify the discussion, these alloys can be divided into the following alloy groups:

- High Gold content (precious) alloys
- Semi precious alloys
- Palladium base alloys
- Silver Palladium alloys
- Cobalt-Chrome alloys
- Nickel-Chrome alloys

In addition, the following "pure" elements are used in dentistry:

- Titanium
- Gold (99.9%) electroformed copings ("Galvano")

As stated in the DIN standard 13972-2 (1,2), welding wires have to be of the same alloy (or at least alloy type) as the parent material to be welded. These welding wires can be either cast in the laboratory (for some alloy groups) or bought from the alloy manufacturers as so called "laser-wires". Since they are sold by the gram, ordering these wires from the alloy manufacturer is actually more economical than casting them in the laboratory.

Note: it is often not recognized, but the most expensive dental alloys per gram in dentistry are dental solders!!!

Fig. 1: Adding an interproximal contact using "laser wire" of the same high gold content alloy pre-fabricated by the manufacturer.

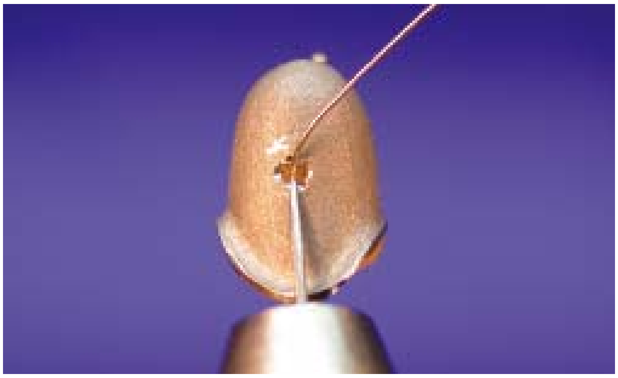

Fig. 2: Hole in semi precious alloy crown. The welding wire is placed into or over the hole.

Since the welding wires for different alloy groups need to fulfil certain specifications it is necessary to have a look at each of the groups individually.

1. High Gold content (precious) alloys
Semi precious alloys >>

These alloys are in general very easy to phaser / laser weld (Fig. 1 - 3). The alloy manufacturers provide welding wires for these alloys in various dimensions and, if desired, the lab can cast its own wires.

2. Palladium base alloys
Silver Palladium alloys >>

These alloy groups are (as seen also in soldering) not as easy to weld as alloys containing Gold. Especially Palladium base alloys with high Gallium content (or other low fusing elements) tend to separate metallic phases (Fig. 4,5).

Fig. 3: Depending on the surrounding material thickness, the hole can be closed with one phaser impulse.

Fig. 4: SEM picture showing the edge of the broken laser welding spot on a Pd base alloy. The arrows indicate metallic phase separation.

Fig. 5: close up on the metallic phase separation shown in picture 4.

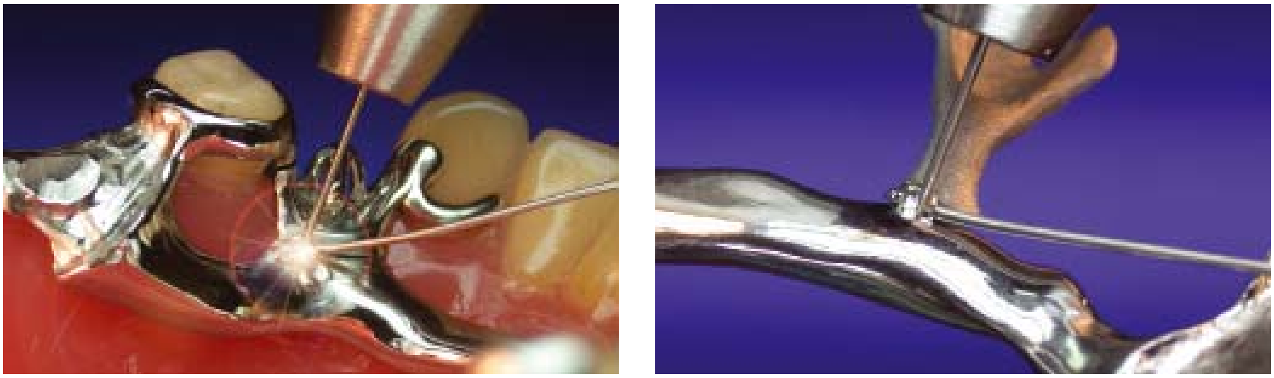

Fig.6 and 7: for Co-Cr welding always use machined carbon-free wires.

For Pd base alloy welding the best results can be achieved when using prefabricated high gold content welding wires as additional material.

Since Silver Palladium alloys (AgPdAu) also contain some Gold, wires of the same kind may be used, however, prefabricated Gold wires are the better choice for this alloy group as well.

3. Cobalt-Chrome alloys >>

To successfully weld Co-Cr alloys it is an absolute must to use machined carbon-free welding wires from the manufacturer. Using self-made cast Co-Cr wires will definitely lead to failure due to the carbon content that makes the welding very brittle (Fig. 6, 7).

4. Nickel-Chrome alloys >>

Ni-Cr welds nice and easy. Even though for Nickel-Chrome alloys it is no problem to use self fabricated (cast) wires, it is more comfortable and most likely also more economical to utilize machined “laser” wires supplied by the alloy manufacturer.

5. Titanium >>

Just like Co-Cr, for Titanium one must use machined welding wires from the Titanium supplier. With these wires, Titanium can be welded without any problems (3), however, the Argon inert gas nozzles on the laser have to be aimed perfectly towards the welding area (4). This is actually no problem with the phaser mx1 as the Argon gas is directed through the hand piece right onto the welding spot. The Argon inert gas is adjusted properly when the welding spot on Titanium is a shiny, silver color.

If the welding spot shows a blue discoloration during welding, the Titanium has reacted with oxygen. If the spot turns yellowish, the melt has reacted with nitrogen. Both gases are in air, and the discolorations indicate that a reaction with the air has taken place because the welding area has not been properly protected by the Argon inert gas.

Note: Yilmaz et al. proved in their study that welded non-precious alloys for porcelain bonding and Titanium had double the strength compared to soldered non-precious alloy specimen (5).

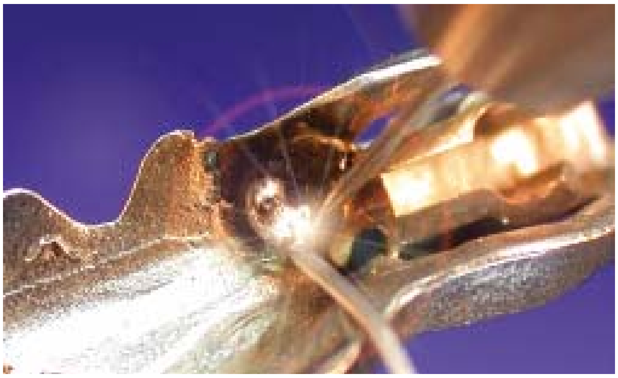

Fig. 8: Precious alloy attachment welded to Co-Cr partial using machined carbon-free Co-Cr wire.

Fig. 9: Telescopic secondary gold crown joined to Co-Cr partial. In this case the first fixing impulses are done without wire.

6. Gold (99.9%) electroformed copings ("Galvano") >>

These copings in general do not require any welding. However, if welding should become necessary a thin (0.2 mm – 0.3mm) gold wire of similar purity should be used. Since it is difficult to cast such thin wires in the laboratory, they must be obtained from the gold manufacturer.

7. Wire dimensions >>

In general, alloy manufacturers offer machined wires in any diameter between 0.2 mm and 1.2 mm (depending on the alloy). Since these wires are mainly used in welding to fill voids, the wire must be completely melted without overheating either wire or alloy. Diameters between 0.2 mm and 0.5 mm prove best for this purpose. When the wire is thicker, more energy is needed to completely melt it leading to unnecessary overheating.

When casting wires in the laboratory, the normal wax patterns start at 0.6 mm in diameter. This is already rather thick. For this purpose, it is recommended to use nylon fishing line, which is available in all different sizes, easy to invest and burns out clean. However, the question remains whether the casting machine available in the individual laboratory can cast these thin dimensions. Taking these aspects into consideration, buying the pre-fabricated wires from the alloy manufacturer seems the better choice.

8. Which wire to use for hybrid welding? >>

So far the quality of the adding wires has been discussed for joining two pieces of the same alloy (or in case of Titanium: metals). Table 1 summarizes this information. But which wire should be used when joining a high gold content and a Co-Cr alloy i.e. for attachment or double crown cases (Fig. 8 and 9)?

The following mental excercise helps us to understand the mechanisms and explain why we use Co-Cr wire rather than Gold for hybrid welding. Let us assume that the floor in a room was made of Cobalt-Chrome. We take a bucket of liquid molten Gold (which would be nice to have) and pour it over the floor. What happens? The Gold cools down, solidifies and can be lifted off the Co-Cr floor in one piece without any problem. Since the melting point of the Gold is way below the melting range of the Co-Cr alloy, there is no way that the liquid Gold could melt the Co-Cr in order to mix both materials. Now, imagine if the floor was made of Gold (maybe even nicer to have) and we pour a bucket of liquid molten Cobalt-Chrome over this Gold floor, once the Co-Cr cools down and solidifies there is no way to lift it off the Gold floor. The reason is simple: the melting range of the Co-Cr is much higher than the melting point of Gold. Consequently the molten Cobalt-Chrome has enough energy reserve to melt the Gold. Molten Co-Cr and Gold will mix in this stage, cool down and stay "welded" together.

Based on this explanation, the following rule can be stated:

For hybrid welding always use adding wire of the alloy with the higher melting range.

ALLOY	BASIC COMPOSITION	WELDABILITY	ADDING MATERIAL
High Gold content (precious) alloys	AuTi AuAgCu AuPdAg AuPtAg AuAgPt (universal-alloys)	++ - +++	High gold content wires of the same alloy or alloy group and AuTi-wires (99,7 % Au)
Semi precious alloys	AuAgPd AuPdAg	++	Alloy identical welding wires
Palladium base alloys	PdAgAu PdCuGa	+	High gold content welding wires Eventually alloy identical welding wires
Silver Palladium alloys	AgPdAu	++	Alloy identical welding wires
Cobalt-Chrome alloys	CoCrMo CoNiCrMo	+++	Carbon free CoCr-welding wires
Nickel-Chrome alloys	NiCrMo	+++	Alloy identical welding wires
Titanium	Ti	+++	Machined pure Titanium wires
Galvano-Gold (99,9%)	Au 99,9%	+++	Au-wires, AuTi-wires (99,7 % Au) High gold content alloy wires

Table 1: Summary of which welding wires to use for which alloys (or metals).

ANOTHER KIND OF HYBRID WELDING: JOINING CAST BRIDGE ELEMENTS TO CAPTEK OR GALVANO COPINGS >>

Based on the previous discussion and the hybrid-welding rule, to fulfil this welding task it is necessary to always aim at the cast alloy, as the melting range of the cast alloy is always higher than the melting point of the Captek or Galvano Gold coping. The molten cast alloy will melt the gold coping, thereby causing the two components to fuse. In practical terms, when working in the transition zone between cast bridge element and Gold coping, the phaser mx1 is set to the correct parameters (power and time) for the **cast alloy** because the impulses are always aimed at the cast alloy. If the impulse would be aimed at the small gap between cast element and coping, most likely the coping would be perforated.

Since the cast bridge element usually fits accurately on the copings, most of the time it is not necessary to use additional welding wire. However, if it would be needed, choose the wire of the alloy used for the cast element.

Fig. 10: the finished coping is placed on the die and the die on the model.

Fig. 11: the cast bridge element is placed over the coping.

Fig. 12: the first tacking impulse is always directed to the area where the gap between coping and bridge element is the smallest.

Fig. 13: always aim at the cast alloy, never at the coping or the gap in between. It may take some impulses on the same spot before the cast alloy will melt the gold and both fuse together.

Fig. 14: once bridge element and coping are fused together, the seam welds are placed. If the gap between the elements turns out to be too wide in isolated areas ...

Fig. 15: ... cast alloy welding wire is used to fill the gap. In this case it is important to always aim at the wire.

Fig. 16: when this welding task has been performed properly, the cast metal has nicely fused with the Gold copings (metallurgic cut, Hellfeld, 100x magnification).

Fig. 17: relatively wide separating disc gaps between canine and first bicuspid, as well as first and second bicuspid.

Fig. 18: first a cone shaped bur is used.

Fig. 19: next, a parallel round bur of the same size as the wire to be inserted is used.

Fig. 20: as final preparation step the adequate wires are inserted.

ALTERNATIVE WAYS TO SEPARATE AND REJOIN BRIDGES >>

Up to this point a number of alternative ways to separate and weld distorted bridges have been discussed (cut the crown, the pontic, interproximal, etc.). So far it was assumed that the technician had cut the bridge in the laboratory using a thin separating disc and making a clean cut. If the improper fit, however, is detected in the dentist's office, (because the bridge fit well on the model but not in the patient's mouth) the separating cut might be much wider due to the separating disc used (Fig. 17).

In these cases, filling the large void with welding wire is not, in general, efficient or economical. One time consuming alternative is to cast and fit a fill-in piece. A more efficient approach would be to drill one or two 1.0 mm to 1.5 mm holes (depending on the size of the joint) right into the gap and to insert a wire of the same diameter and alloy ("wire-pin technique", Fig. 18 – 20)

Fig. 21: the primotec "Joker" welding assistant.

Fig. 22: the Joker firmly blocks the two pieces to be joined, forcing the cooling down melting pool to shrink downwards (see part two of this series, page 59, Fig. 19).

In part two of this series the mechanisms of distortion and the counter measures were discussed. Meanwhile primotec has developed the "Joker welding assistant" (Fig. 21) as the ultimate "fool-proof" tool to avoid distortion by phaser mx1 or laser welding. Its use will be described in detail in the next part of this series. Since this implant case is a recent work, the "Joker" is used to easily weld without any distortion worries (Fig. 22).

Once the joker is in place (welded with one spot each to either of the parts to be joined), two fixing shots with the case on the model are sufficient. After that the case can be removed from the model and the welding can be finished "free-hand" off the model (Fig. 23). Utilizing this new "Joker" tool enables even the inexperienced technician to create phaser mx1 or laser welding with perfect passive fit (Fig. 24 and 25).

Fig. 23: after the initial fixing spots, working off the model is fine.

Fig. 24 and 25: the case after welding. Perfect passive fit. Next, remove the Joker and finish the welded areas.

Fig. 26 to 28: the new master model with the cut pieces in place. Compared to a normal bridge with a joint dimension of, in general, 3 mm x 3 mm, the joint of this superstructure was approx. 7 mm wide and 5 mm high.

Fig. 29: after the cut a step of more than 1 mm was created between the two pieces.

Fig. 30: Before drilling the holes, the two pieces must be screwed to the model with the same defined torque that will be used later on in the patient's mouth.

APPLICATION OF THE SYSTEM FOR INSERTING WIRES INTO A PREPARED GAP ("WIRE-PIN TECHNIQUE") TO A CAD/CAM MILLED TITANIUM IMPLANT SUPERSTRUCTURE >>

Case history: to achieve maximum precision and passive fit it was decided that the Titanium superstructure of this upper full arch implant case should be produced with CAD/CAM milling technology. After milling, the structure was, as expected, fitting on the model perfectly. However, at the try-in, unfortunately, the case did not fit in the patient's mouth. Obviously a mistake had been made either during impression taking or while producing the original master model (it was certainly not a fault of the CAD/CAM machine). Consequently the superstructure was separated with a disk in the dentist's office, a new impression with the parts in the new position was taken and a new master model was made (Fig.26 to 28)

Fig. 31: the two wire pins in place. Since the gap was larger in width than in height the holes to house the wire pins had been drilled horizontally.

Fig. 32 and 33: one wire is welded to the lower groove of the one piece; the other wire-pin is welded to the upper groove of the other piece.

Even though the gap was wide, the joint dimension large and the shift quite big (Fig. 29), it was decided to make a full weld (no hollow seam) using the "wire-pin technique" described above. It is very important when drilling the holes to house the pins, that the two pieces are screwed down to the model with the same torque the dentist will use later on when inserting the case in the patient's mouth. (Fig. 30 and 31).

Next, the screws are loosened again, and the wire-pins are welded to one of the two pieces each (Fig. 32 and 33).

Now everything is put together for the final welding steps. Again, the screws must be tightened with the same torque the dentist will use in the mouth later on. Since in this case the two parts to be welded together are securely screwed in place, it is not necessary to utilize the "joker" welding assistant. First, two connecting shots are placed lingually (Fig. 34). This is actually the first time during the whole procedure that the two pieces are connected. Next, the wire pins extending buccally are shortened and an approximately 1-2 mm deep vertical groove is ground using an adequate bur for Titanium (Fig. 35). This groove serves as the "bevel" used in the conventional interproximal welding technique (see part two of this series, page 56). Now the case is welded on the buccal half from inside out using some regular Titanium welding wire (Fig. 36). Again, since the pieces are securely screwed down to the model, distortion by welding is not to be expected. Finally the same procedure is done for the lingual half to finish this welding case (Fig. 37). The result is an efficient, economical and secure full welding for a rather unusual case.

Note: even though all the cases shown in this article were welded with the primotec phaser mx1 (Fig. 38), the same rules and procedures would apply for welding with a laser.

Fig. 34: it is sufficient to place to connecting pulses lingually (between each wire pin and the other side) to further stabilize the correct position.

Fig. 35: to achieve a full weld, an approximately 1-2 mm deep vertical groove is ground buccally.

Fig. 36: the case is welded on the buccal half from "inside out".

Fig. 37: once the lingual half is welded the same way as the buccal side the case is finished.

Fig. 38: primotec phaser mx1

Literature >>

(1) DIN 13972-2: Qualitätssichernde Maßnahmen beim Laserschweißen: Teil 1: Laserschweißen im Dentallabor (Part 1 – Laser welding in dental laboratories); Beuth-Verlag Berlin 2001

(2) DIN 13972-2: Qualitätssichernde Maßnahmen beim Laserschweißen: Teil 2: Laserschweißeignung von identischen und artgleichen metallischen Werkstoffen (Quality assurance during laser welding – Part 2: Suitability of identical and similar metallic dental materials for laser welding); Beuth-Verlag Berlin 2001

(3) Chai T, Chou CK: Mechanical properties of laser-welded cast titanium joints under different conditions; J Prosthet Dent 79, 477 – 483 (1998)

(4) Sjögren G, Andersson M, Bergman M: Laser welding of titanium in dentistry; Acta Odontol Scand 46, 247 – 253 (1988)

(5) Yilmaz H, Demirel E, Dincer C, Päßler K, Bek B: Vergleichende Untersuchung an Fügetechniken von gegossenem Titan und zwei Edelmetallfreien Dentallegierungen; Quintessenz