

Soldering and welding are not the same.

Lightning in a Bottle

Joachim Mosch, Andreas Hoffmann, Michael Hopp



Fig. 1: Successful welding requires Argon with a purity of 99.996% or more.



The previous three installments of this series about welding in the dental laboratory make it clear that soldering and welding are different. Successful welding requires its own technological approach requiring the welder to leave most of the old solder knowledge behind. Part Three emphasizes the importance of composition and size when choosing welding wire. In addition, the correct approach to hybrid welding is explained, along with other subjects. Part Four of the series will describe some more general welding rules, explain how to solve general problems, show how to repair “accidents” and answer some of the most frequently asked questions.

Key words:
welding rules,
welding problems,
welding accidents,
welding questions,
tungsten inert
gas welding
(TIG), phaser
mx1, laser, Joker
welding assistant

GENERAL RULES

1. Choose the proper shielding gas and adjust it properly. Welding with the primotec phaser mx1 (or any laser welder) requires the use of Argon as a shielding gas (Fig.1). It is necessary to use Argon 4.6, meaning that the gas has a purity of 99.996% (in the US, this gas quality is called Argon grade 5).

Once the gas pressure regulator is installed on the gas tank and connected to the welding machine, the gas flow has to be pre-adjusted. For the phaser mx1 the correct pre-flow rate is two to four liters per minute; for laser welders generally 10 to 15 liters per minute (Fig. 2).

On the primotec phaser mx1, the Argon gas is directed through the hand piece right onto the welding area, without additional adjustments. Most laser welders have one or two Argon nozzles inside the welding chamber, which must be adjusted so

that they point to the spot on the focus plain where the laser impulse hits the object. This can be a bit time consuming but is necessary to achieve oxide-free, durable welds.

To check whether the gas-flow rate (and, for lasers, the nozzle positions) is correct, make some welds on Titanium. Titanium is highly reactive during melting. If the Argon is not properly aimed, the Titanium will either react with environmental oxygen causing blue discoloration, or nitrogen causing yellow discoloration at the welding spot. The flow rate and direction are correctly adjusted when the Titanium welding spot is a shiny, silver color (Fig. 3).

If the phaser mx1 welding spot produces blue or yellow discoloration, it usually means the flow rate is adjusted too high (+ four liters per minute). This makes the Argon “hit” the welding surface rather than gently flow onto it. The gas then splashes off



Fig. 2: The gas flow rate is adjusted with the valve on the bottom of the gas regulator. The actual flow rate is shown on the right gauge.



Fig. 3: Shiny, silver welding spot on Titanium indicates correctly adjusted Argon gas.



Fig. 4: Illustration of the worst case. Blue and yellow discoloration at the welding spots, heavy soot and micro cracks in the spots (causes and countermeasures for cracks will be discussed later).

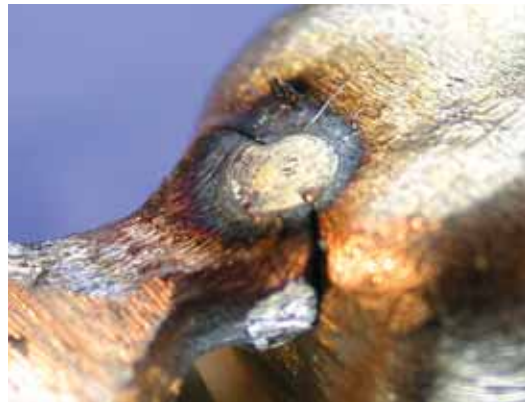


Fig. 5: Not steam cleaned after sandblasting. The remaining aluminum oxide particles in the welding spot area have burned to carbon soot.

the object; similar to the way running water from the tap hits the bottom of the kitchen sink. Furthermore, a high flow rate dilutes the Argon by causing air turbulence. When adjusting the gas flow “less is more” is the general rule.

This also applies to laser welders, however, the gas nozzles should be adjusted prior to regulating the gas flow.

2. Carefully clean the area to be welded. The second general rule is that the welded object should be clean in the welding area. In 99% of the cases, black soot comes from some kind of burned dirt that carbonized in the high heat of the plasma (phaser mx1) or laser pulse. It can be a combined effect also with improper gas or gas adjustment (Fig. 4).

To avoid black soot, (even though it only has a slight influence on the weld quality), the object

must be cleaned properly. Any organic (and even most of the inorganic) materials in the area of the welds will burn to carbon in the 3,300°C heat.

These organic/inorganic materials can be (just some examples):

A. perspiration or grease: keep the hands clean.

B. aluminum oxide: after sandblasting aluminum oxide dust remains in the surface roughness of the sandblasted object. If this dust is not removed by steam cleaning or ultrasonic cleaning before welding it will burn to carbon (Fig.5).

C. polishing compound: if, for example, an interproximal contact was lost during polishing, this area must be steam cleaned first to remove the polishing compound, which remains on the surface.

“99% of the cases, black soot comes from some kind of burned dirt that carbonized in the high heat of the plasma (phaser mx1) or laser pulse.”



Fig. 6: Inadequately soldered telescopic crowns broke off the partial. The old solder material was completely removed and the case prepared for welding.

3. Never weld over old solder. The third general rule concerns repairs. Never weld on spots that were soldered unless the old solder material is completely removed first and the case is prepared properly for welding (Figs. 6,7,8). Also never use solders as additional welding material. Solders contain low fusing components that will burn and splash metal around during welding.

4. Carefully consider the thermal conductivity of the alloys welded. Generally when setting the parameters of the phaser mx1 or laser welder, the thermal conductivity of the alloy to be welded is more important than its melting range.

For instance, because of its high thermal conductivity,

a high gold content alloy will absorb the energy applied faster and requires greater energy input (power x impulse duration) than, say, cobalt-chrome or titanium, even though the melting range of the Co-Cr alloy (and/or the melting point of titanium) is much higher than that of high gold content alloys.

GENERAL PROBLEMS

1. Micro cracks in the welding spot. This phenomenon can be observed mainly when welding Co-Cr or Pd-base alloys. In Co-Cr alloys, these cracks appear mostly when the impulse duration, (e.g., the time, in milliseconds, the plasma or laser pulse remains on the object) was set too low (for example, 3 ms). Co-Cr alloys are eutectic alloys, meaning that they have a very narrow melting range. After the weld is placed, the "cooler" alloy surrounding the spot pulls energy away before the cooling contraction is completed. This pulling force is stronger than the cooling shrinkage and creates the crack. These cracks must never be ignored! If welding continues, the case will break 'like a cookie' after the seam is completed because the cracks extend deep inside the weld (Figs. 9, 10).

It is relatively simple to overcome this problem. The first counter measure is to increase the impulse duration (even as high as 30 ms) and to decrease the power accordingly. This prevents alloy overheating since increasing the time would increase the overall energy output (energy applied to the object = power x

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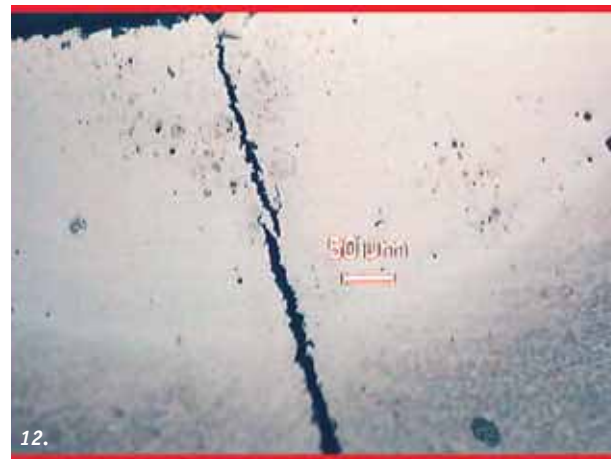
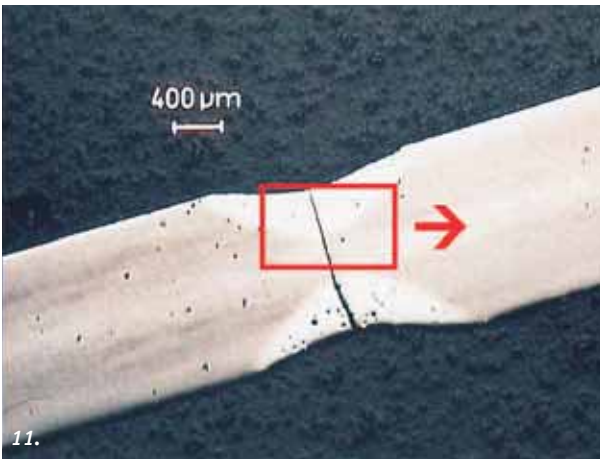
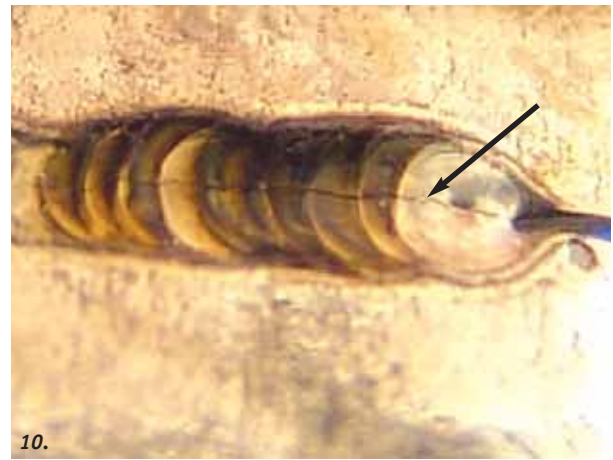
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impulse duration). It is also helpful to use machined carbon-free welding wire as additional material, especially when welding old Co-Cr partials with a relatively high percentage of carbon.

The same problem with the same reasons can be found with Pd-base alloys (Figs. 11,12).

To a certain extent the reasons, results and counter measures are the same as with Co-Cr alloys. In addition, the most important way to avoid these

cracks in Pd-base alloys is to use a very high gold content welding wire as additional material from the very first weld.

2. Distortion. This problem was previously discussed and explained in parts Two and Three of this series. The key to avoiding distortion is to guide the shrinkage direction of the weld during its cool down phase by blocking the “natural” shrinkage towards the heat center. To achieve this, a new tool was developed – the JOKER welding assistant (Fig. 13).

Figs. 7, 8: A new connecting piece was cast and welded correctly.

Figs. 9, 10: Old Co-Cr partial was cut with a disc and welded with wrong impulse duration setting (3 ms).

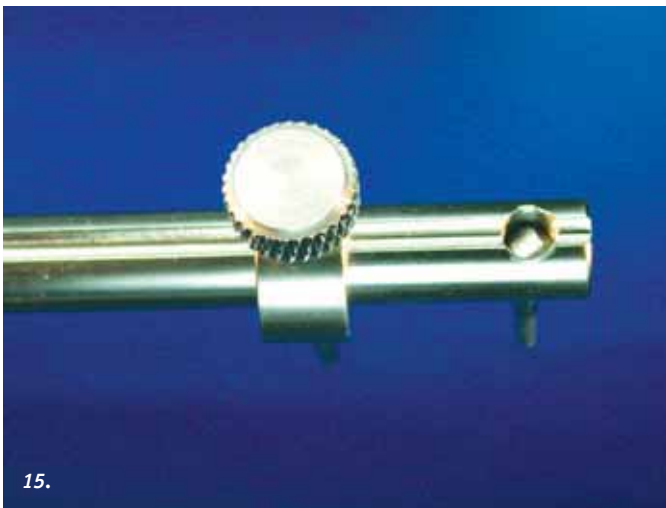
Figs. 11, 12: Palladium base alloy test welded with short impulse duration and no additional high gold content welding wire.



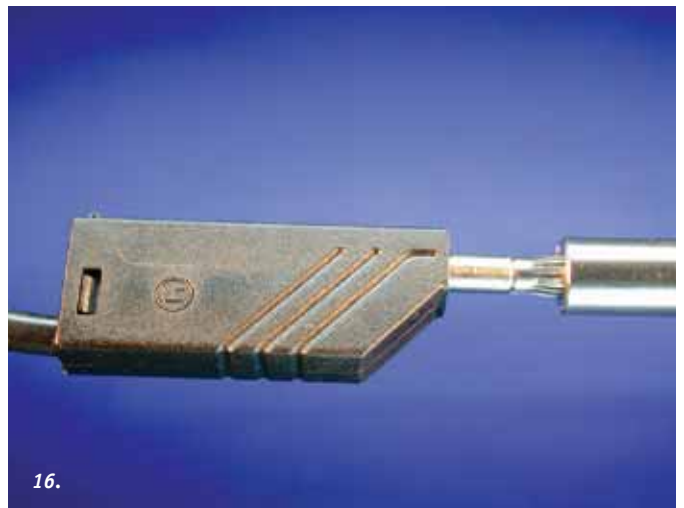
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Fig. 13: The new JOKER welding assistant prevents distortion that may be created by phaser or laser welding (available at Dentation LLC, New York).

The JOKER consists of one high quality CAD/CAM milled stainless steel bar, which can hold two exchangeable tips. One tip is fixed and the other one can slide on the bar to adjust the width depending on the case requirements (Figs. 14,15).

The first step in working with the Joker is to select the correct tips for the alloy to be welded and to tightly screw these tips into the prepared bar. Then the screw on top of the bar is loosened, to move the second tip for the desired width (Fig. 21)

Figs. 14,15: The "heart" of the JOKER - CAD/CAM milled bar. The adjustable tip is secured in position with the screw.

This welding assistant can be used for laser welding and, when welding with the phaser mx1, it can be connected directly to the machine without using the connecting clamp (Fig. 16).

Once the width is correct and the screw on top of the bar is tightened, the tips are welded to the selected area of the work piece with just one or two phaser or laser pulses and the initial fixing spots are placed on the gap that needs to be welded (Fig. 22).

Fig. 16: On the far end of the bar a socket is prepared to house the phaser mx1 connecting plug.

The Joker is equipped with two Co-Cr tips and 12 plastic tips that can be cast with alloys normally used by the laboratory. This is necessary so that only parent alloy touches the work piece when the tips are welded to the case (Figs. 17,18,19,20).

Now the case can be removed from the model and the welding can be finished "free-hand", because the Joker tips connected to the case and the two separate case pieces connected by the fixing pulses create a highly stable ring (Fig. 23).



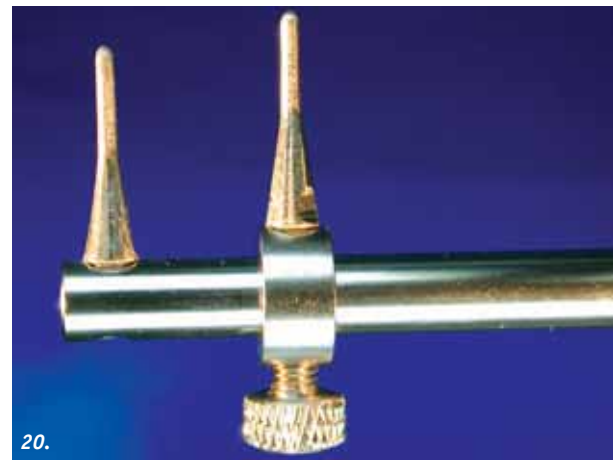
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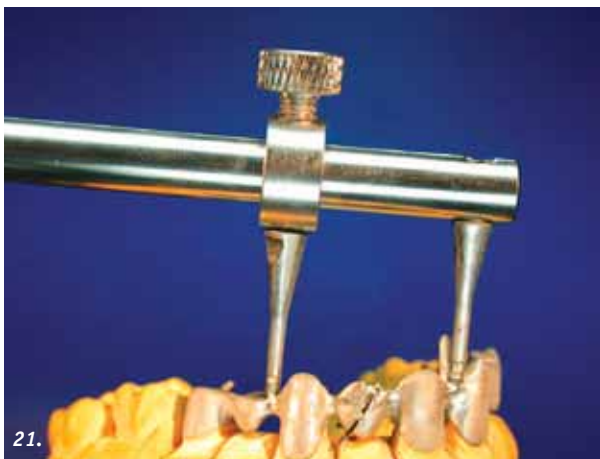
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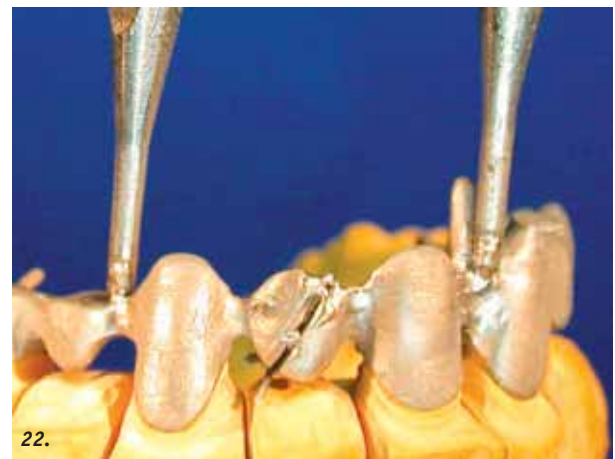
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Figs. 17, 18, 19, and 20: The enclosed plastic tips are designed to be cast in Pd-base or high gold content alloys. The plastic burns out clean.

Fig. 21: The distance between the tips can be adjusted individually depending on the case requirements.

Fig. 22: The two joker tips welded to the bridge. In combination with the first fixing spots on the pontic tightly secure the position of the case against the distortion force.

Fig. 23: A stable ring is formed so the welding can be finished "free-hand" off the model.



Figs. 24, 25, 26: Once the “ring is closed”, even cases that tend to distort easily can be welded with ease.

Figs. 27, 28: In most cases additional welding wire must be used from the beginning.

Figs. 29, 30: Closing holes or porosities in an area with normal material thickness is easy. A different approach is required when the defect is in a very thin area.

Fig. 31: Even the first pulse on a hole with thin surrounding makes the hole much larger instead of closing it.

Figs. 32, 33, 34, and 35: Step-by-step pieces of welding wire are laid over the defect and welded to the edge on both sides. This looks rather time consuming but is actually quite efficient.

This also works very well for partials (especially lingual bars), which have always been challenging for phaser or laser welding (Figs. 24, 25, 26).

When welding with the Joker it is very important to place the fixing shots correctly. If the gap between the two pieces to be joined is rather wide, additional welding wire must be used from the very beginning (Figs. 27, 28).

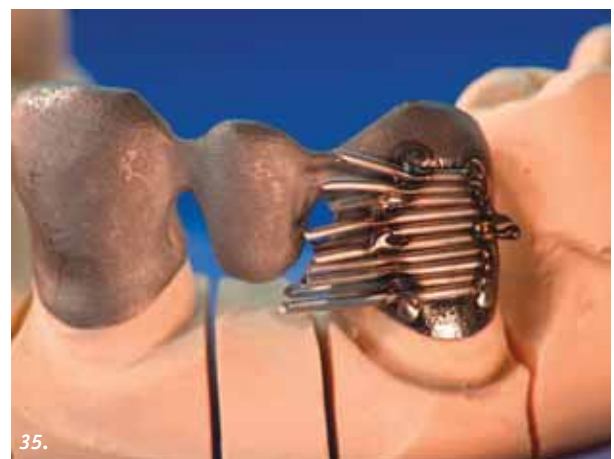
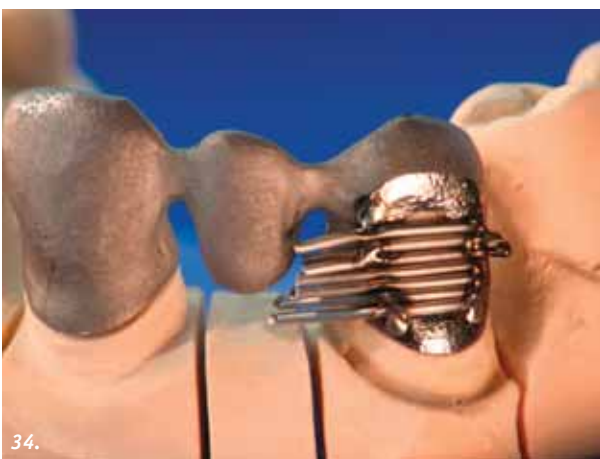
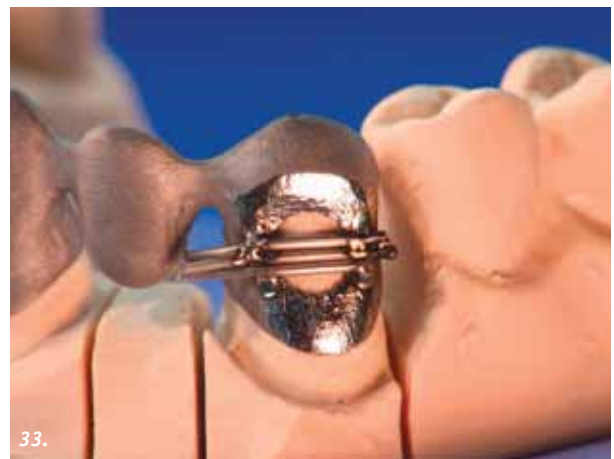
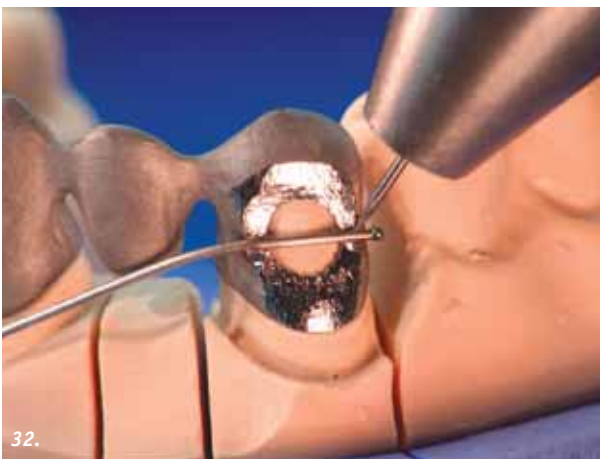
GENERAL “ACCIDENTS”

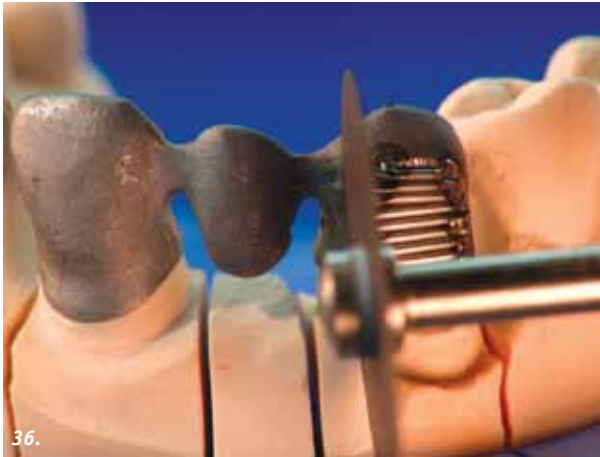
1. Porosities and holes in the casting due to investment material enclosures. This does not happen every day, but it can happen. By using the phaser mx1 or any laser welder, this problem can be solved easily with just a few well-placed welds. Place the additional welding wire over (not into) the porosity or hole, then aim at the wire (not at the tip, but the part of the wire which is over the center of the defect) and initiate the welding pulse (Figs. 29, 30)

2. Closing holes in extremely thin areas. A different procedure must be used in this challenging situation. In general, this problem occurs when either the labial surface of a crown was trimmed too much (most of the time due to not enough labial space which would, without trimming, lead to a bulky crown) or on the lingual surfaces of the upper anteriors when the bite is very tight. Now, anyone who has tried to weld such a hole has, most likely,

had the experience that the first pulse makes the hole much larger instead of closing it, especially if no additional laser wire was used (Fig. 31).

This happens because once the very thin metal becomes molten it can’t provide enough material to fill and close the hole. Instead, the liquid alloy follows its surface tension, and is pulled away from the hole making the edge a bit thicker. This behavior can be repeated until there is enough thickness on the edge. Even though this is rather shocking for the inexperienced user in the first place, it is the right way to proceed. Once the edge has sufficient material thickness, the weld can be completed in different ways. For precious alloys, a thicker welding wire can be flattened with a small hammer and anvil to create a metal sheet that will cover up the hole like a band aide. This can be welded rather easily to the thickened edge. Alternatively a “slice” of sprue from the same alloy can be used to cover the defect. If neither option is available, there is still another solution. Regular welding wire of the same alloy is laid over the defect and welded to the edge on both sides (Figs. 32, 33, 34, 35).





Figs. 36, 37, 38: Once the excess wire is cut off, the individual pieces are welded together.

Figs. 39, 40, 41: When the welding is done properly, after trimming and sandblasting the case looks like "untouched".

Now the excess is cut off with a disc and the wires lying next to each other are melted together with rather low energy pulses (Figs. 36, 37, 38).

After the outer surface of the crown is taken care of, it might be necessary to also place some welds on the inner surface. This will not necessarily improve the overall quality of the weld (if it was welded gas tight from the outside) but looks nicer and like "untouched". Finally the excess is trimmed off and the welded area is sandblasted. The whole procedure takes about 10 minutes (Figs. 39, 40, 41).

3. Margin extensions. Again, there is more than one technique to "heal" such an "accident". If the marginal defect (perhaps created by slipping with

the grinding disc during trimming) is extensive and the case is rather large, it is worth the time to completely cut off the defective margin, wax-up, cast and weld a new margin it to the remaining crown (Figs. 42, 43, 44, 45).

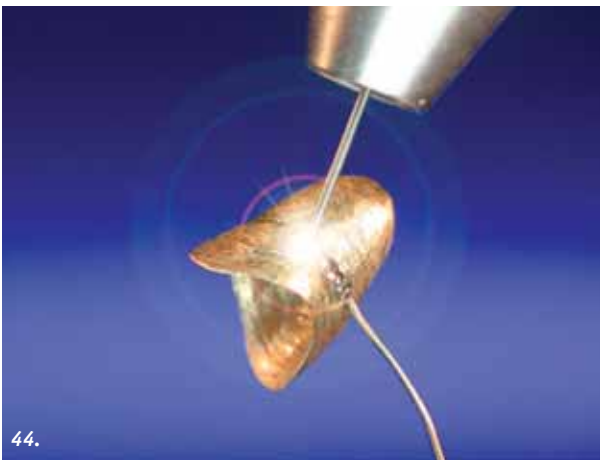
A second technique to overcome the problem is to extend the margin with a wire of the same original alloy as cast. This technique is suitable for cases that come back from the metal try-in with a small area of the margin too short. Now, if the preparation was knife-edge and the margin consequently about 0.1 mm or less on the edge, it first has to be trimmed back to an area of at least 0.2 mm thickness. Otherwise, the same "effect" appears as when placing the first impulse to the hole of a crown with very



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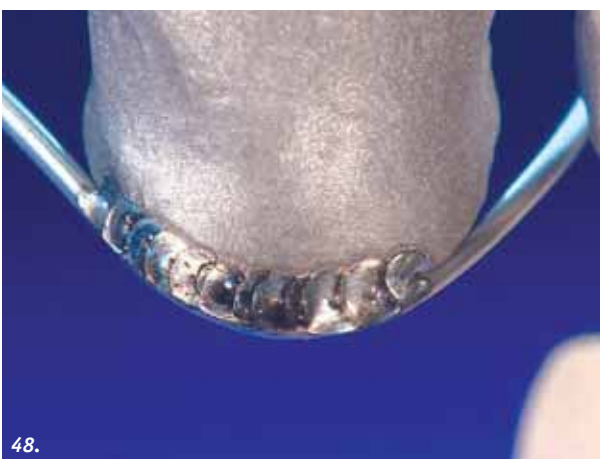
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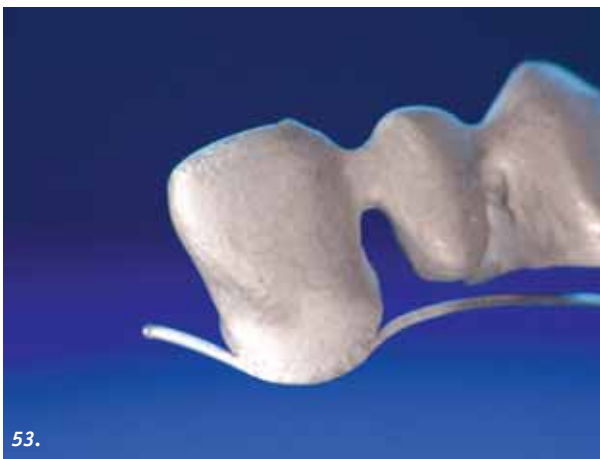
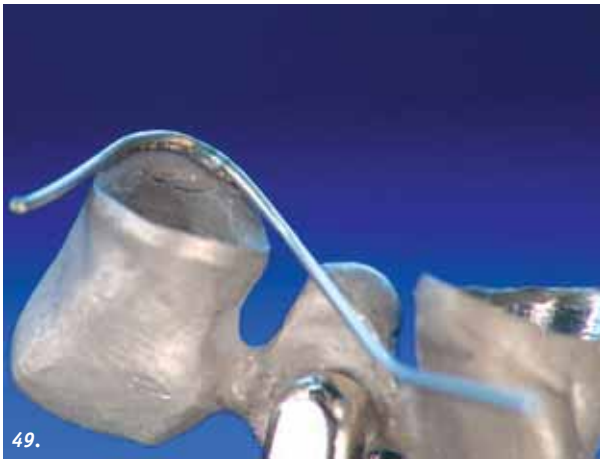
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Figs. 42, 43, 44, 45: This sample shall explain the principle, which is easier to show on a crown than on a large bridge. In general, if a single crown has a marginal defect, one would, of course, rather remake it. However, for multiple unit bridges this is the more economic way to go.

Figs. 46, 47, 48: For this kind of welding it is important to set the parameters (power and time) perfectly so that the wire does not melt completely. The wire should touch the crown margin with the phaser or laser pulse directed between margin and (touching) wire.



Figs. 49, 50, 51: After the wire has been nicely welded from the outside, it now needs to be welded "spot by spot" from the inside as well.

Figs. 52, 53, 54: Fig. 52 shows clearly that, even though the wire is completely welded to the margin, the outer edge of the wire remains untouched. This is achieved through correct parameter settings, proper aim, and steady hands.

thin surroundings (see above). Now the wire (ideally rather 0.35 mm than 0.5 mm) is placed in the desired position and welded to the margin with low power and pulse duration settings. The goal is to weld the wire to the margin without completely melting it (Figs. 46,47,48).

Once the wire has been welded to the crown margin from the outside with at least 50% overlapping spots, in this case, it is necessary to weld in the

same way from the inside (Figs. 49, 50, 51).

Finally the welded area must be sandblasted and the margin re-fitted. This technique can also work if the bridge was already veneered with acrylic or porcelain, but it requires even slower working to avoid excess heat build up in the welding zone which would unnecessarily damage the veneer material. In these cases, after the margin is corrected, the missing acrylic or porcelain must be added to the new margin. [dental dialogue](#)

FREQUENTLY ASKED QUESTIONS

Lightning in a bottle (part 4)

Which alloys and metals can be welded?

- All precious metal alloys containing gold, silver, platinum and palladium.
- Co-Cr alloys, Ni-Cr alloys, titanium and stainless steel.
- With certain limitations (depending on the alloys), aluminum, tin and most brass alloys.

Do all alloys behave the same during welding?

- No – The welding result depends on the melting range and the thermal conductivity of the alloy.
- For example, the lower an alloy's thermal conductivity, the less energy (power x impulse duration) is required to melt it.

Can welds be made next to acrylic and ceramic?

- Yes – the heat-affected zone during welding with the primotec phaser mx1 is comparable to the heat that develops during laser welding.

Can welding be accomplished without inert gas?

- No – welding without inert gas produces strong oxidation and increased soot formation at the welding site.
- The spot welds will become porous and lose their stability.

Can other inert gases besides Argon grade 5 be used?

- Theoretically, yes. However, the authors recommend Argon grade 5, because the best results have been obtained with it.

Can solder be added?

- No – Solder tends to “scorch” because of its low-fusing elements.
- That is why solder joints should not be subsequently welded.

How deep do spot welds penetrate into the material?

- The penetration depth depends on the power settings (power x impulse duration), the thermal conductivity of the material to be welded and the angle of the phaser mx1 electrode tip. That means that the higher the welding energy and the lower the thermal conductivity, the deeper the penetration of the spot welds.

How thin can the material to be welded be?

- Depending on the material, it should have a minimum layer thickness of 0.15 to 0.2mm.

Now this selection of questions and answers ends part four of the series. Further subjects discussed in the following parts will be Co-Cr partials and full plate welding and repairs, different approaches to implant bar welding and combination cases.

Note: even though all the cases shown in this article were welded with the primotec phaser mx1 (pic. 55), the same rules and procedures would apply for welding with a laser.



Fig. 55: primotec phaser mx1

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Lightning in a bottle

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Questions for: Lightning in a bottle

#1 Laser welding requires the use of which shielding gas?

- a. Oxygen at 80% purity
- b. Nitrogen at 100% purity
- c. Argon at 99.996% purity
- d. Both a and b

#2 If oxygen reacts with Titanium during welding the discoloration is...

- a. green
- b. yellow
- c. blue
- d. brown

#3 If Nitrogen reacts with Titanium during welding the discoloration is...

- a. green
- b. yellow
- c. blue
- d. brown

#4 Oxygen and Nitrogen mix with the Argon gas when...

- a. the purity levels of the Argon gas are not high enough
- b. turbulence are present over the welded surface
- c. the rate of gas flow is too high
- d. both b and c

#5 99% of the time black soot around the weld area comes from...

- a. perspiration or grease
- b. aluminum oxide
- c. polishing compound
- d. all of the above

#6 Generally speaking, what is the most important alloy characteristic to consider when laser/phaser welding?

- a. gold content
- b. melting point
- c. corrosion resistance
- d. thermal conductivity

#7 What is the most common cause of micro cracks when welding Co-Cr or Pd base alloys?

- a. impulse duration is too short
- b. the cookie effect
- c. not enough welding wire
- d. all of the above

#8 In addition to increased pulse duration, what is the most important way to avoid micro cracks in Pd alloys while welding?

- a. use a low fusing welding wire
- b. use a very high gold content welding wire
- c. use the Joker
- d. all of the above

#9 The Joker was developed to...

- a. prevent distortion
- b. guide the shrinkage direction of the weld
- c. make card games more interesting
- d. both a and b

#10 Which alloys and metals can be welded?

- a. all precious metals containing gold, silver, platinum or palladium
- b. Co-Cr alloys, Ni-Cr alloys, titanium and stainless steel
- c. To a degree, aluminum, tin, and most brass alloys
- d. All of the above

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