

Lightening in a Bottle

*State of the art joining techniques
in dental technology*

Part 2 in a series

Joachim Mosch, Andreas Hoffmann, Michael Hopp

Introduction

It is not supposed to happen, but it happens almost every week (or sometimes even every day) in every dental laboratory worldwide: after casting, devesting and attempting to fit a bridge on the model, it rocks and/or just does not show the required precision and marginal integrity. Or perhaps, the bridge fits perfectly on the model but just does not fit in the patient's mouth at the metal try-in appointment. Now, there are many different reasons for these problems. In the first scenario maybe the wax-up was distorted; in the second one maybe the dentist's impression was questionable (but was not questioned). So, while there are many reasons why, there is basically only one solution to the problem: cut the bridge and re-join it in the correct position.

Key Words: joining, solder, brazing, plasma arc welding, tungsten inert gas welding (TIG)/ laser welding, phaser mxl, dental alloys, pure metals,

Defining the Goal >>

Once a separated bridge (no matter what caused the problem) has been rejoined in the laboratory, it should now fit perfectly, it should be as strong and biocompatible as the original material (parent alloy) and the joining method used should be as efficient as possible, since this is now an uncompensated work step.

Soldering or Welding >>

As discussed in the first article of this series, soldering generally does not meet all of the defined goals for joining. The quality of a solder joint depends on the alloy to be soldered, the soldering method and material used, the joint dimension and, finally, the technician's skills. According to Rosen, even under optimal conditions, the tensile strength of a soldered ceramic alloy bridge decreases up to 59% compared to the original strength

of the cast alloy (1). This explains the high incidence of intraoral fractures, particularly in interproximal solder joints (Fig. 1).

Biocompatibility is a greater issue than the questionable stability of soldered joints. Wirz et al (2, 3) emphasized in their soldering studies that, "In principle, only in the utmost emergency, solder should be used in dental technology", since, in general, soldered joints show a clearly reduced corrosion resistance (Fig. 2) and have a tendency to tarnish (Fig. 3).

Furthermore, the literature regularly discusses tissue reactions and irritations due to contact with soldered joints. Wirz, et al, (4) concluded in their study of non-precious-alloy soldering that the solders used are clearly less corrosion resistant than the original cast non-precious alloys.



Fig. 1 Interproximal fracture on soldered ceramic bridge

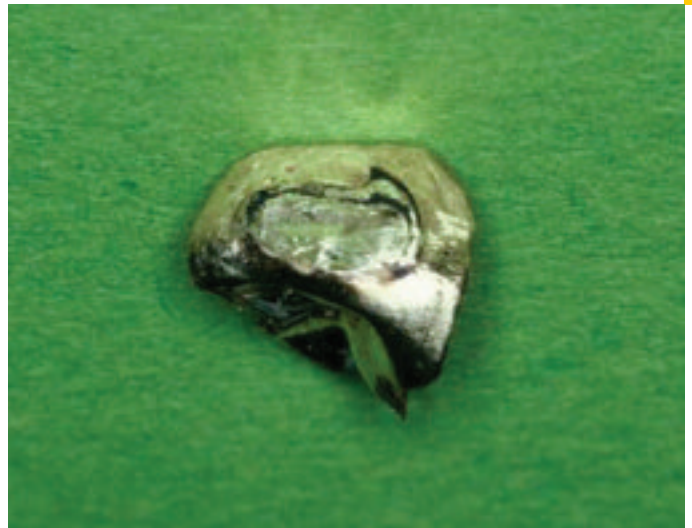


Fig. 2 Discolored and corroded soldered contact point of a gold inlay

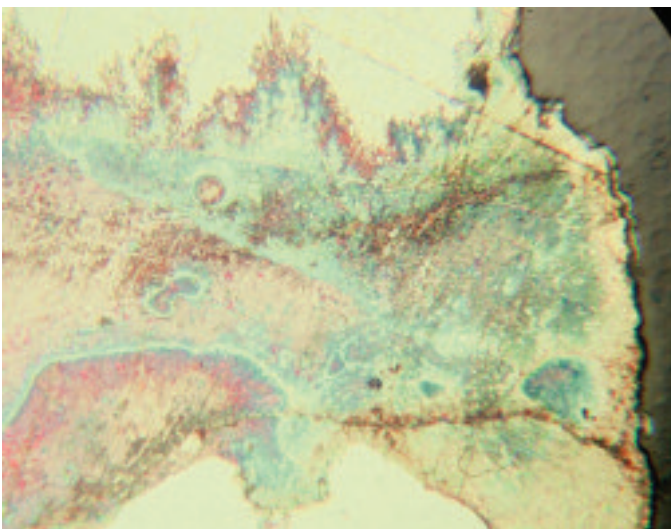


Fig. 3 Tarnished soldering^ metallographic cut, Hellfeld, 50 X magnification



Fig 4: Pulsed Tungsten Inert Gas (TIG) welder primotec phaser mxl

Based on these facts, the authors consider welding clearly preferable to soldering as a solution to the "bridge problem" described in the introduction. Note: welding in this series of articles is always defined as either TIG welding with the primotec phaser mxl (Fig. 4) or laser welding. Plasma torch welding is not considered due to the reasons stated in the first part of this series.

Soldering and (phaser / laser) welding are not the same! >>

For this discussion, it is important to understand that soldering and welding are two different methods requiring separate techniques and approaches. Welding performed with conventional solder technique (i.e., case preparation and material science) would most likely fail. The first question asked by most technicians new to

welding concerns how far the welding spot penetrates the joint. This question comes from the concept that solder must "shoot" through the gap (by capillary action) and fill it completely. If, for example, the space between pieces is 3 mm, the common assumption is that the welding spot should penetrate at least 1.5 mm to achieve a full weld. This is possible with either the phaser mxl or any laser welder, however, not recommended. The energy needed to penetrate 1.5 mm would probably overheat the alloy, evidenced by extensive alloy splashing during welding. Overheating during welding causes the same structural changes seen in overheated castings such as decreased homogeneity, increased porosity, and spongy grain structure and is, of course, not the desired result.

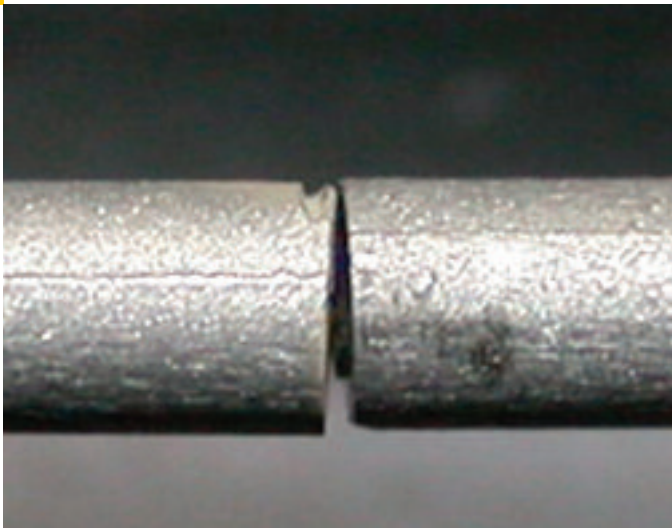


Fig. 5: Sample for standard EN 29333 strength test prepared for soldering, simulating the gap divergence resulting from a cut to relieve rocking

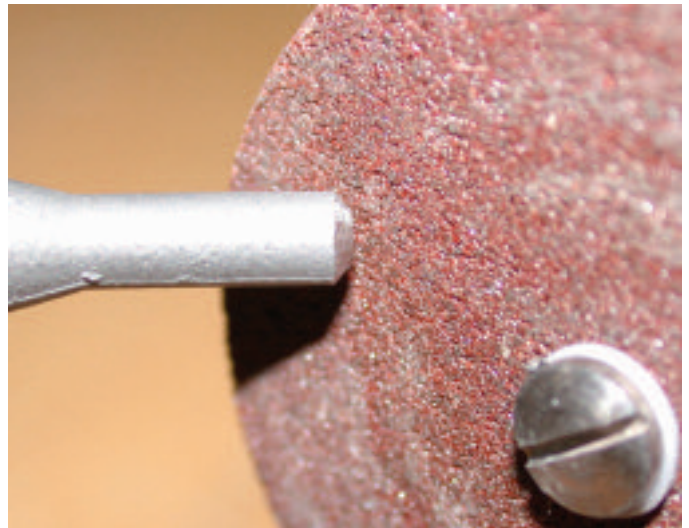


Fig. 6: The edges of the surfaces should be beveled

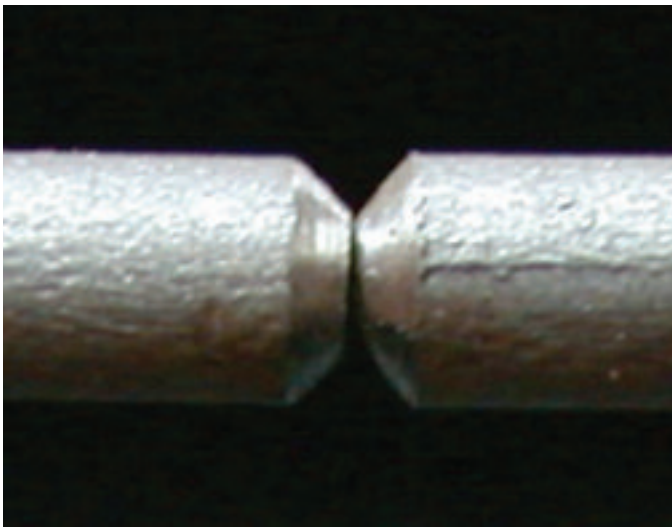


Fig.7: The beveled edges allow welding wire to completely fill the gap without applying too much energy

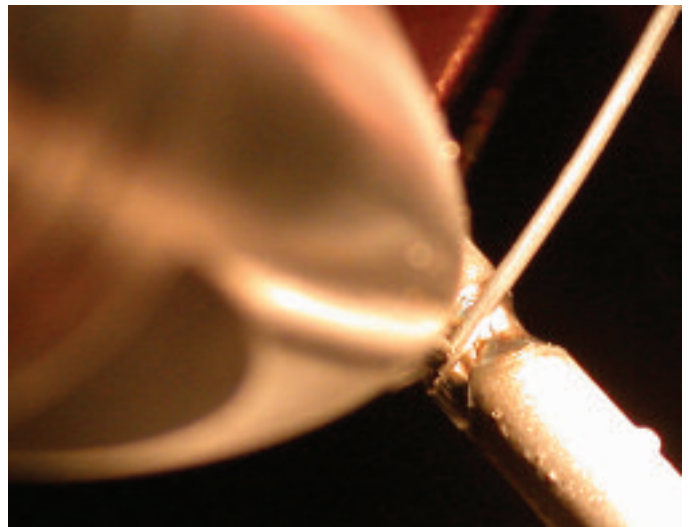


Fig 8: The beveled gap is filled with parent alloy welding wire

To overcome this problem, the old "solder rule" (i.e., interproximal cut yields two parallel surfaces 0.2mm apart (Fig. 5) must be modified for welding (which will first be explained theoretically using samples prepared for the standard EN 29333 strength test). To prepare the samples, the "left and right" edges of the interproximal cut (simulating the cut done during a metal try-in) need to be beveled (Fig 6, 7). Then welding wire of the same alloy (or alloy type) is used to fill the void (Fig. 8). When completed, welding fills the gap with wire, closing it with a full material weld having, generally, all the physical and chemical properties of the parent alloy (Fig. 9, 10)

Practically, distortion must also be considered. To avoid distortion during the welding process (in this still rather "conventional" welding procedure), place the welding spots carefully. Weld one spot from labial (but only one!), the second from the lingual. Add a third spot from the incisal, the fourth from gingival, etc. After the first two pulses the bridge can be removed from the model, however fit should be checked regularly as the welding proceeds (Fig. 11, 12).

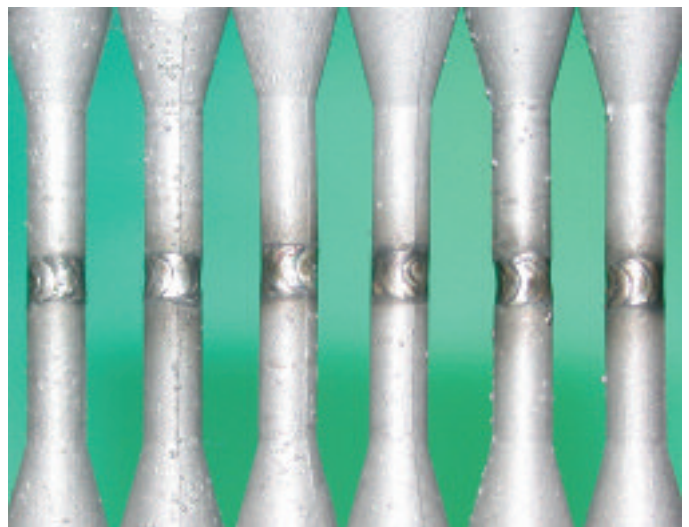


Fig. 9: specimen fully welded for standard testing

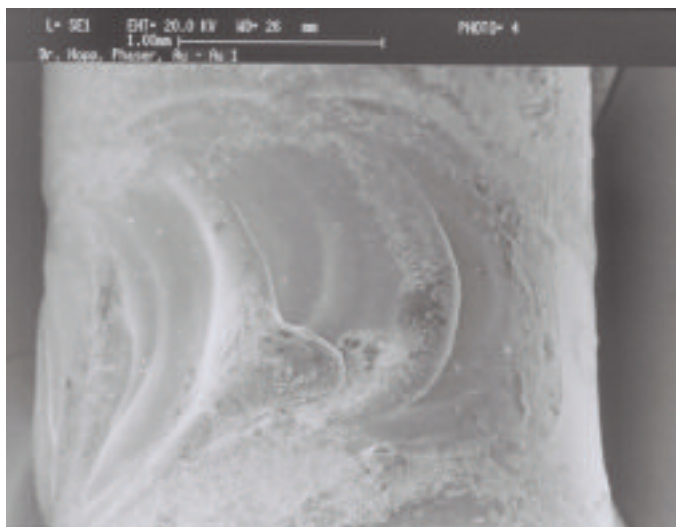


Fig. 10: SEM picture of phaser welded round profile specimen for Instron machine testing



Fig. 11: "Classic" interproximal cut, edges beveled, then phaser welded as described, with perfect passive fit



Fig. 12: Same case, lingual view. Techniques to minimize distortion will be explained later

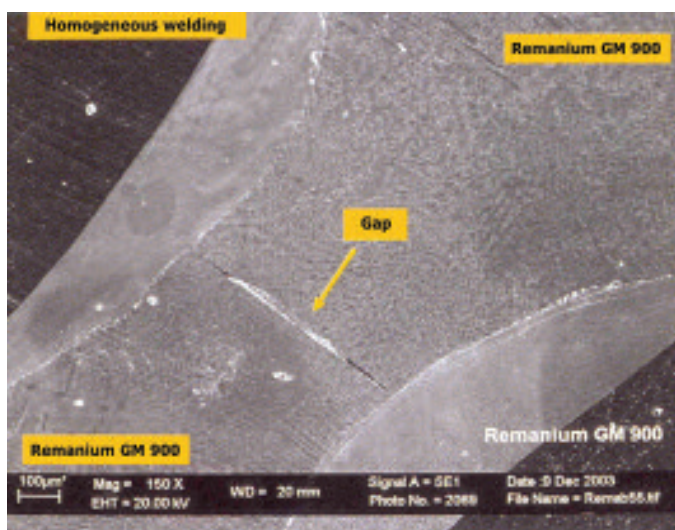


Fig 13: "Hollow seam" showing the internal gap, still as strong as a full material weld (picture courtesy of Prof. Lindemann, university of Tübingen, Germany)



Fig. 14: Primotec phaser mx1 preset programs for Gold, Cobalt-Chrome, Hybrid (Gold to Co-Cr), Titanium and orthodontics

Full material weld or "hollow seam" >>

If it is not possible to bevel the edges as shown above, maybe due to narrow interproximal space (i.e., between two lower anterior crowns) a "hollow seam" can be made. In this case, the joint is welded "all around" the perimeter leaving a void in the center (Fig. 13). The void remains since the energy needed to fully penetrate the joint would overheat the alloy (as explained above). Consequently, even though the primotec phaser mx1 could produce higher energy levels, its preset programs allow only 0.5 to 0.8 mm penetration. This generally ensures a durable weld without alloy damage (Fig. 14).

Those used to the conventional solder technique may consider leaving a void in the center of a joint very strange. However, welding is different. Realizing that the welding wire behaves like a tube structure around the joint should dispel concerns over strength, since in physics, the tube geometry is considered as strong as or even stronger in tension than the filled joint.



Fig 15: Diagonal cut through the pontic. The wide gap requires filling with welding wire. The bent bar welded on top secures the position and prevents distortion.

Another concern that technicians may have with the "hollow seam" technique is that the void might degas during porcelain firing, leading to bubbles in the porcelain. To prevent gassing, the individual spots should be overlapped by at least 50%. However, even if the welded seam is not gas tight (for example, if the operator makes a mistake) there is no danger of gassing through the porcelain because as the opaque fires, the vacuum pump evacuates the chamber and the void right away. Then, as firing continues, the opaque sinters and closes the opening in the welding seam. Besides, air never causes bubbles ("frog-eyes") in the porcelain. They are caused by contamination of any kind that gasses as it burns.

To summarize, when an interproximal cut needs welding, always bevel the edges when possible to create a full material weld from "inside out". If it is not possible to bevel, a "hollow seam" is made. If there is a large gap to weld with either technique, add welding wire of the same type as the parent alloy to fill the gap.

Furthermore, when a long welding line must or can be made, choose the hollow seam technique. In the following case study the bridge was separated diagonally through the pontic (Fig. 15 to Fig. 17).

Distortion: how to avoid it, how to use it >>

Welding performed with the laser or the primotec phaser mxl produces identical grain structures in the welded areas ⁽⁵⁾. Both machines also yield similar distortion factors.

Usually, distortion is the "natural enemy" of the technician who has to weld a bridge, but sometimes it can also be a friend. However, first we will discuss ways to defeat the "enemy" by understanding how "he" works.

Every material expands when it is heated and shrinks (contracts) when it cools. This becomes a problem because shrinkage behavior is not linear (i.e., the expansion is not necessarily identical to the contraction). When the energy hits the gap between two objects to be welded, this energy melts the alloy and creates a melting pool. This melting pool expands as long as the alloy is liquid and contracts when the alloy cools to the solid

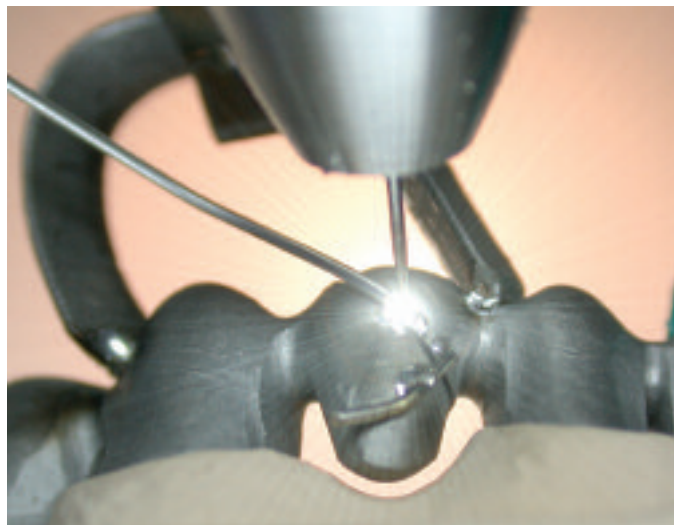


Fig. 16: Welding wire of the same alloy is used from the beginning

stage. During cooling and contraction, the shrinkage force pulls the two parts together as the melting pool naturally cools toward the heat center. This whole process happens within milliseconds but is enough to distort the object (Fig. 18).

To avoid this distortion, the shrinkage contraction needs to be guided. The most efficient way to do this is to firmly secure the position of the objects to be joined. If this is done properly, the melting pool shrinks downward "into" the object without distorting it (Fig. 19).

The power of this distorting force however must not be underestimated. Just holding the two objects in place by hand (on the model) is not sufficient to direct the shrinkage contraction.

Now that the distortion mechanisms are understood, the question becomes which countermeasures to take. The first and very reliable way to secure the objects into welding position is to connect them with a stiff cast bar. These bars can be prefabricated for the alloys most commonly used in the lab. It only requires a sublingual bar wax pattern bent into a half circle. Once cast, the bar can be used many times, however, it might be necessary to have a few bars with different widths (Fig. 20).

In addition to the bar, a piece of welding wire can be attached to bridge the gap, even though this extra security (like wearing a belt with suspenders) is very rarely needed (Fig. 21).

In those cases where it is not possible to place a stiff cast bar to secure the two parts to be welded (for example a porcelain bridge without exposed metal), place the welding spots in an alternating pattern. Weld one spot from the labial, the second from the lingual, etc. To insure the proper fit, reseal the bridge after each weld. Since a gap exists between the pieces (from the separating disk) always add additional welding wire from the beginning to fill the gap. Without additional wire, the cooling contraction will pull the two parts together and distort the case (compare Fig. 18).

The energy applied to the weld also affects distortion. The more energy (power x impulse duration time) used, the higher the distortion risk. With early laser experience,

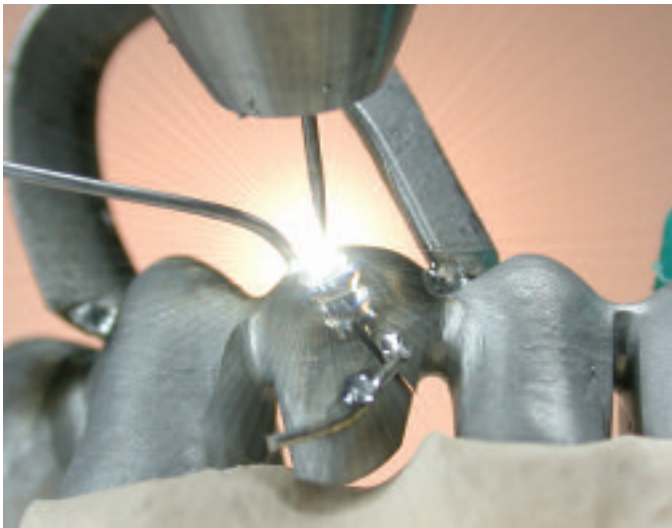


Fig. 17: Since the welding line is long the hollow seam is the most productive way to rejoin the two parts.

Welding distortion due to melting pool contraction

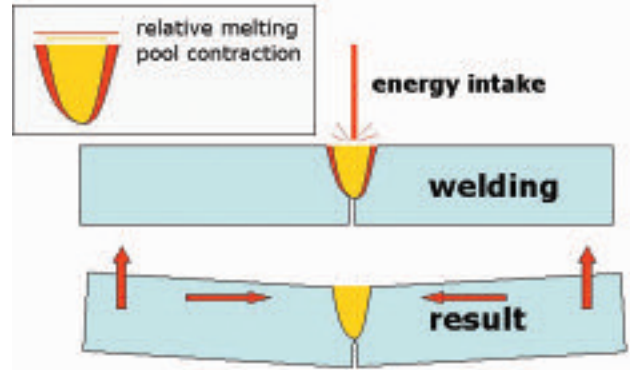


Fig 18: The yellow area shows the dimension of the welding spot in the solid stage, the red areas (left and right) show the expansion of the welding spot in the liquid stage.

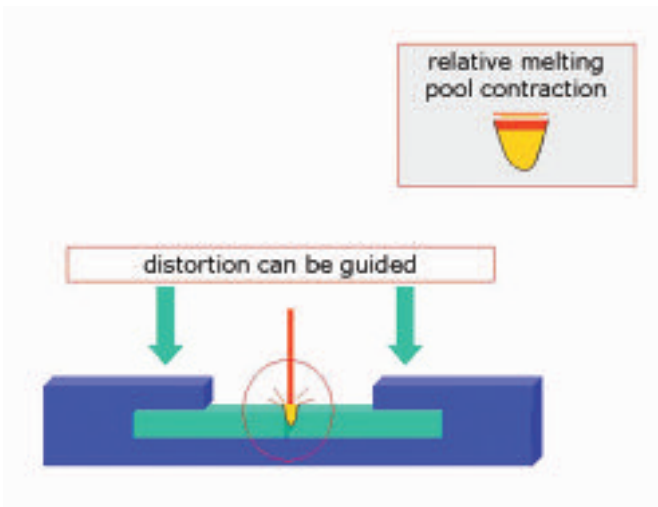


Fig. 19: The two objects are tightly secured so the melting pool cannot shrink toward the center but is "forced" to shrink downwards

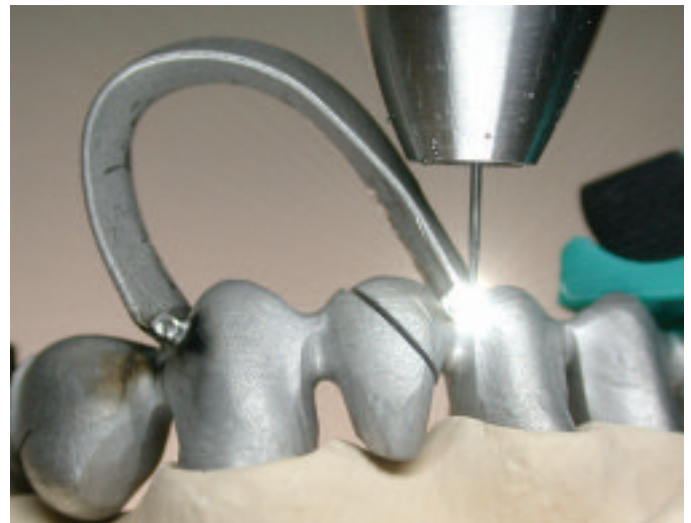


Fig. 20: The cast bar is connected with one or two pulses to each of the two parts to be joined. After welding, the bar can be easily removed by hand.

many assumed that more energy would give better results. We now know this is wrong!!! Too much energy leads to alloy overheating and distortion. From this experience, when welding an unfamiliar alloy in the laboratory, determine the power, time and spot diameter parameters by starting from a low energy level and increasing the parameters accordingly rather than beginning with a high energy level.

Finally, the separation point impacts distortion. As mentioned earlier, when the dentist cuts the bridge interproximally the lab has to live with it and perform the welding as described. If the bridge rocks after devesting, due to an error in the production process, the technician controls where to place the separating cut. It is better in this case to cut through the crown (fig. 22 a,b,c).

A cut through the relatively thin crown (usually 0.3-0.5 mm) reduces both the energy needed to melt it and the welding wire diameter, therefore, decreasing the danger of distortion (Fig 23 a - d). This cut is not possible when soldering because the solder would flow inside the crown, but becomes possible with welding since the alloy is molten only spot after spot.

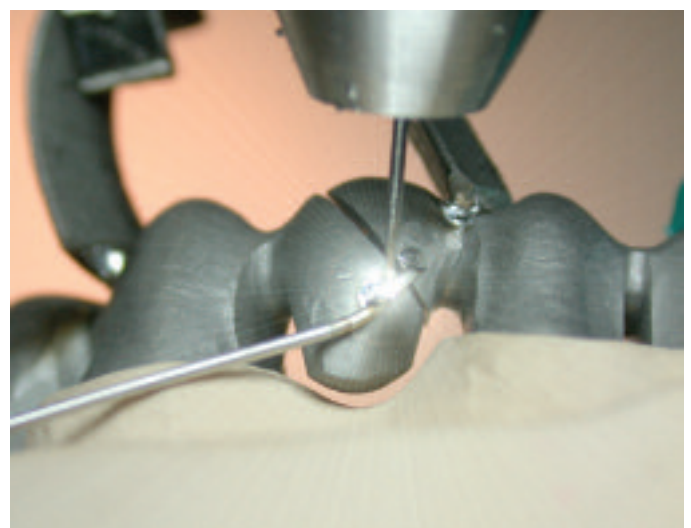


Fig. 21: Welding wire attached across the gap for security is rarely needed.

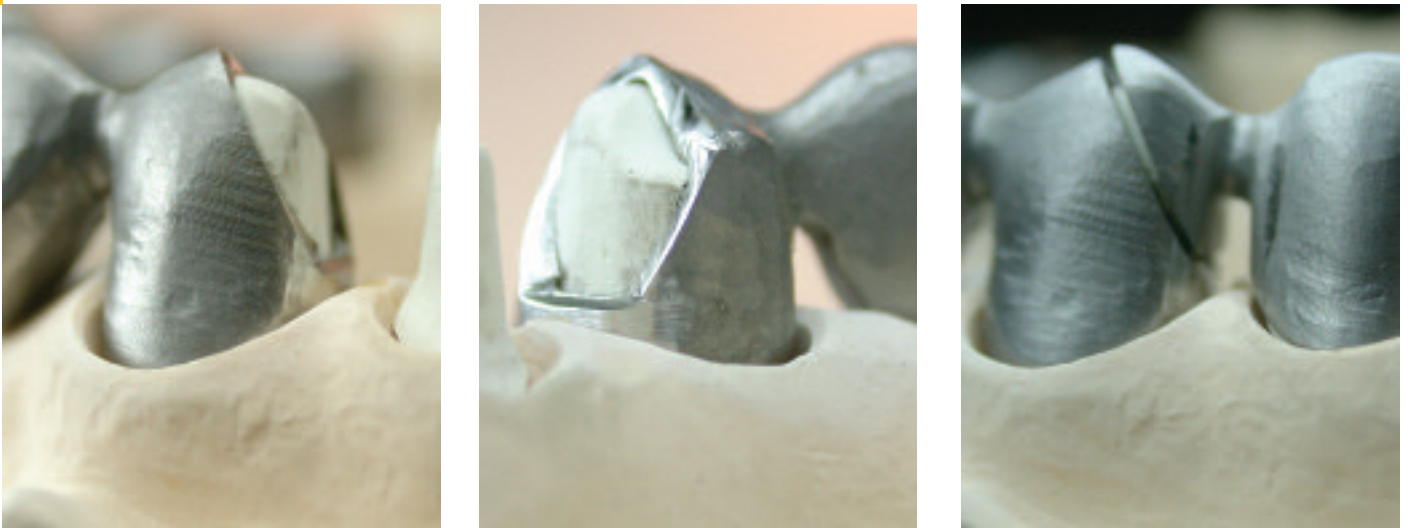


Fig 22 a,b,c: Soldering and welding are two different techniques! For soldering the cut would have to be interproximally. For welding it is recommended to place the separating cut through the crown.

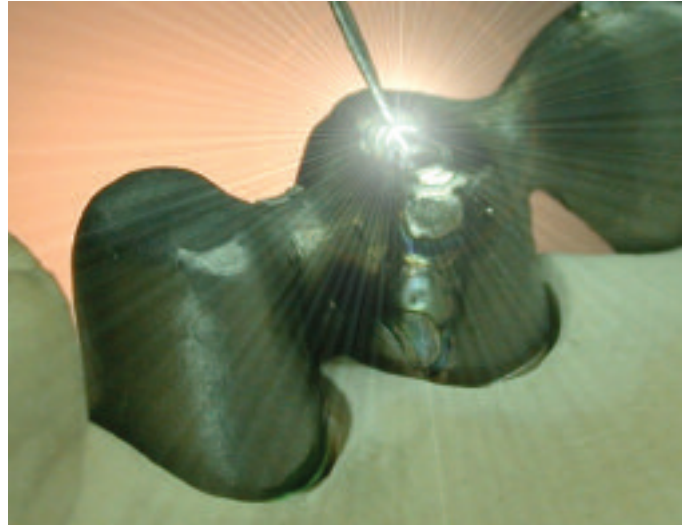
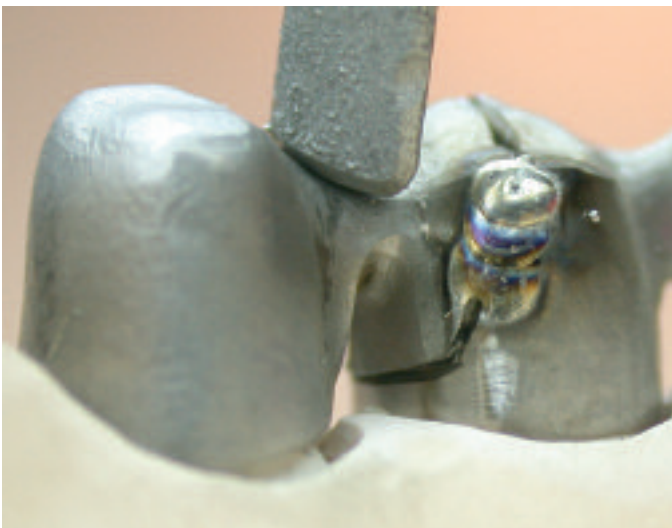
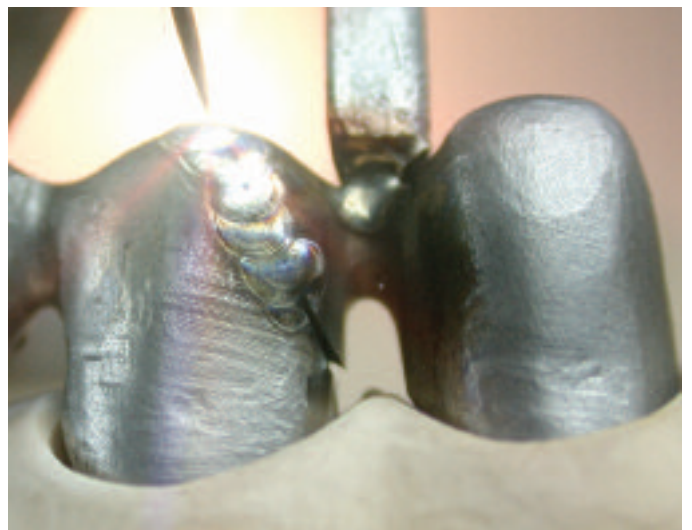


Fig 23. a - d: A foolproof way to defeat distortion: a properly placed separating cut (through the crown), less welding energy, smaller diameter welding wire and positioning with a stiff cast bar.



Fig. 24: Full cast gold crown to be connected to non-precious ceramic bonding bridge



Fig 25: Full cast gold crown with the open keyway prepared mesially

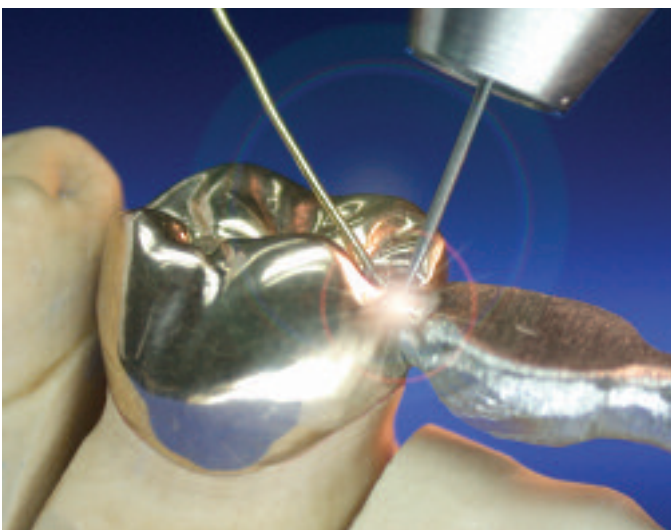
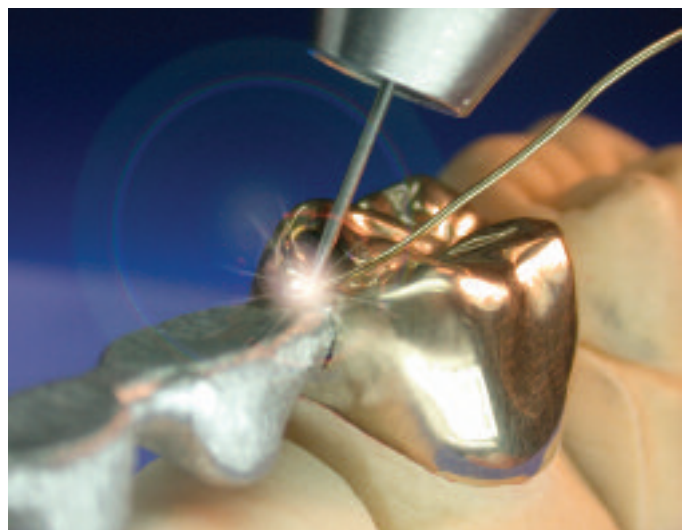


Fig 26 a,b: Depending on the space between the open keyway and key, additional welding wire may be needed to fill the gap and avoid distortion.



The distortion phenomenon has been reported in many scientific publications worldwide. Himi (6), for example, proved laser welded three unit bridges fit (depending on the fixation method) better than soldered and cast bridges. This can be easily understood since accurate casting and soldering depend heavily on technician skill. In welding, on the other hand, when prepared as described above, the human factor plays only a minor role.

Klinke et al. (7), interestingly enough, found that soldered ceramic alloy samples show less distortion than cast or laser welded control samples after the first porcelain bake. This can be explained by tension in the alloy grain structure from the casting process. During soldering, this tension is compensated automatically by the evenly applied flame heat. The study suggested that when a bridge framework fits poorly after casting, it can be helpful to anneal the bridge in the porcelain furnace (800° C, one minute, no vacuum) to release the tension and to then recheck the fit before separating.

Now we will look at how distortion can become a "friend". When a bridge rocks slightly after casting,

anneal first to determine whether tension relief in the grain structure will make the bridge fit perfectly. If not, instead of separating, direct a few strong (not overheating) welding pulses on the gingival or occlusal side of the connector (depending on the direction of rocking). The distorting force can "bend" the bridge into the right position. When applied properly, this technique may reduce the time spent separating and welding.

The "Lego block" principle >>

Welding can apply to other difficult procedures in the laboratory. For example, when it is necessary to join different alloys on one bridge (Fig 24). Instead of waxing up the two parts as usual in order to weld them interproximally, wax the gold crown with an open round keyway on the mesial (Fig 25). Once the gold crown is cast, wax the ceramic portion with a distal post key that fits into the open keyway on the gold crown. If the Metacon light cured wax system (primotec) is used, the full cast crown and the ceramic bridge part can be waxed at the same time. Once cast, the key inserts into the open keyway like a Lego block. This connection is now welded all around the outside of the joint using the alternating method (Fig. 26 a,b).

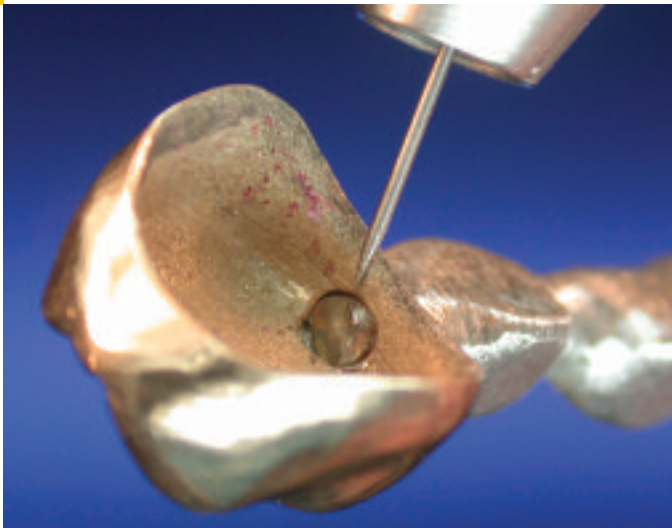


Fig 27: The key of the no precious bridge extends into the interior of the crown.

After making the initial welding spots, the bridge with crown can be removed from the model (Fig 27).

Next, the key, which extends into the interior of the crown, is welded from the inside (Fig. 28). Since the welding spots melt and become concave, additional interior finishing is not necessary.

The "Lego block principle" results in a quick, very strong non-precious joint. This general principle can be applied to various other welding tasks. Once it becomes clear that soldering and welding are different, a little ingenuity will quickly lead to great success in dental welding either with a laser or the primotec phaser mxl.



Fig. 28: Since the welding spots are in general concave, it is not necessary to refit the crown to the die after welding

The next part of this welding series will address the following subjects:

- Choosing wire materials (which wire for which alloy type)
- Alternate ways to separate and rejoin bridges
- Case study of improper fit in CAD/CAM milled Titanium superstructure
- Case study of welding a cast bridge element to Captek or Galvano copings
- Welding porcelain veneered bridges

Literature:

1. Rosen H: Ceramic/metal solder connectors; J Prosthodont 56, 671 - 676 (1986)
2. Wirz J, Jaggi D, Schmidii F: Die Qualität von Lotverbindungen - Teil 1: Lotverfahren, Prüfmethode und Zugfestigkeit; Quintessenz, 111-118 (1990)
3. Wirz J, Jaggi D, Schmidii F: Die Qualität von Lotverbindungen - Teil 2: Biegefestigkeit, Elastizitätsmodul und metallografische Gefüge; Quintessenz / 323 - 330 (1990)
4. Wirz J, Schmidii F, Jager K: Korrosionsresistenz von Lotstellen nichtedelmetallhaltiger Legierungen; Quintessenz Zahntech 17, 1140 - 1150 (1991)
5. Lindemann, Prof. Dr. Wolfgang: Plasma versus Laser; dental-labor , 793 - 799 (2004)
6. Himi A: Laser welding for precision bridge; Dentistry in Japan 37, 63 - 66 (2001)
7. Klinke Th; Mack F, Nemitz Ch. Biffar: Der Verzug von verblendeten Prüfkörpern nach Lotung und Schweißung, ZWR 109, 613 - 618 (2000)

Bio >> Joachim Mosch, CDT

Joachim Mosch was born in 1959, studied dental engineering and technology as well as international business. Mr. Mosch has been working for 18 years (for the last 11 years as general manager) at the European headquarters of an American dental company before he started his own business (primotec /primodent) in the year 2000. Mr. Mosch has published various articles on different dental subjects such as Light Cured Wax (the Metacon System), functional bite splint therapy using light cured splint materials (primosplint), welding techniques and laser, a.s.o. and gives lectures on these subjects throughout the world. Mr. Mosch is married, has two children and lives with his family in Bad Homburg/Germany.

**Bio >> Andreas Hoffman, MDT**

Andreas Hoffmann, born in 1956 achieved his German Master Dental Technician degree in 1985. As of then he was managing director and shareholder of a German dental laboratory group. He sold his shares and started his new laboratory 1. DSZ in the year 2000. At the same time he was appointed director of the "Akademie Umfassende Zahntechnik", a highly respected post graduate education program by one of the major German laboratory associations (VUZ) where he is also member of the board of directors. He received the Straumann prize in 1998 and is known in Germany and Europe for his outstanding publications, lectures and courses on Metacon (light cured wax), phaser and laser welding techniques, Cercon, Versyo.com, Cerec, Procera, and Galvano. Mr. Hoffmann is married, has two children and lives with his family in Bilshausen/Germany.

**Bio >> Dr. Michael Hopp**

Dr. Michael Hopp was born in 1962 in Binz, Isle of Rügen. He graduated from Humboldt School of Dentistry, University of Berlin in 1987 where he remained as the Assistant professor, Head of sector for Preclinical Prosthodontics. Since 1992 Dr. Hopp has worked for various groups in dentistry at the German Institute of Standardization. He is a member of several Scientific Societies and is a guest lecturer at the Dental Technician School in Berlin. Dr. Hopp is the Editor in chief of the Journal of International Dental Technology. He has given more than 300 lectures and has authored or co-authored more than 200 essays for international publications and book chapters.

