Comparison of the material quality of welded dental alloys

Plasma vs. Laser

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Plasma and laser welding long have been among the established joining techniques used in dental technology. In recent times microplasma welding has been developed as an alternative to laser welding. According to the advertising, this new technology offers "precise laser quality" spot welding (primotec). This assertion was the impetus for a material study to compare the quality of plasma welding using the new technology and conventional laser welding.

Key words: laser, plasma welding, grain structure, material quality, metal joint

As was done in an earlier study [1], six rectangular plates 5 x 10 x 1 millimetres were cast from a non precious high gold-content casting alloy and a reduced-gold casting alloy (Orplid EH and Cehadentor CP) and a CoCr casting alloy (Remanium GM 900) for the direct comparison. The non precious Co-Cr plates were joined in pairs with plates of one of the noble metal alloys (hybrid welding) with the new microplasma welding device (primotec phaser mx1). Two plates each of the same alloy were also joined (homogenous welding).

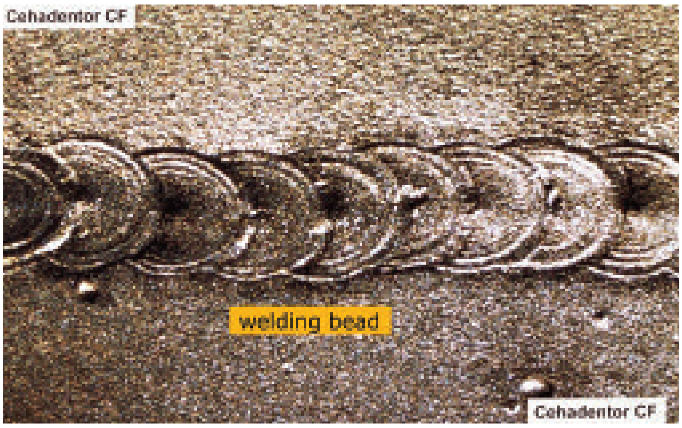

Fig. 2 Macroscopic view of the welding seam of a "homogenous" weld of a reduced gold casting alloy (Cehadentor CF).

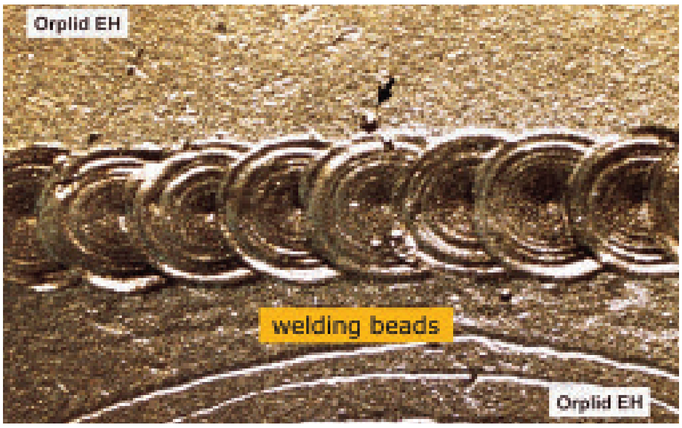

Fig. 1 Macroscopic view of the welding seam of a "homogenous" weld of a high-gold-content casting alloy (Orplid EH).

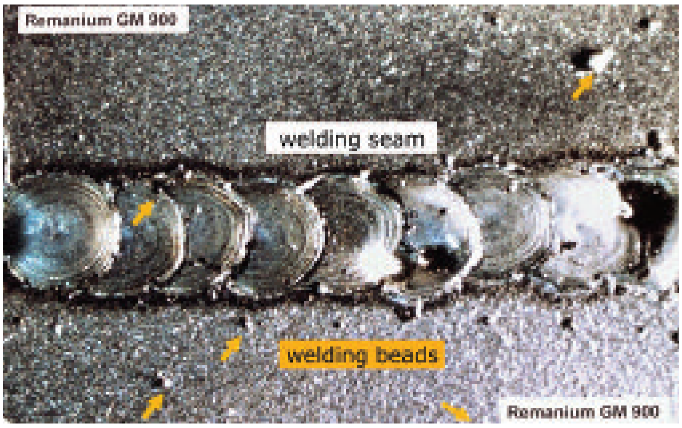

Fig. 3 Macroscopic view of the welding seam of a "homogenous" weld of a non-precious alloy (Remanium GM 900).

Study of the welded seams >>

Following the macroscopic images of the welding seams (Fig. 1 to 4), metallographic polished faces perpendicular to the welded zone were prepared. The weld on one polished half was examined under a microscope and the other half was etched in aqua regia to make the welded grain structure visible. The microscopic assessment of the non-etched polished face partially shows a fissure in the joint zone, primarily in the middle. Here the plates were not fully welded in depth (Fig. 5 to 7).

In addition to the microscopic examination, one sample each of the etched halves of the polished faces of a homogenous and a hybrid welded joint were examined under a scanning electron microscope (Fig. 8a and 8b). Both halves clearly show fissure formation, which indicates insufficient depth welding. The laser-welded samples from the earlier study showed exactly the same appearance [1] (Fig. 9).

Grain structures>>

When the polished faces etched with aqua regia were examined, two very different grain structures could be observed in the border zone between thermally unaffected CoCr alloy and the weld cone. In contrast to the large-grained casting structure (Fig. 10) of the CoCr alloy, an extremely fine-grained seam structure (microstructure) has formed as a result of the extremely fast cooling (compare Fig. 10). Such fine grain structures are characterised by certain hardness, which can cause the material to become slightly brittle in this area.

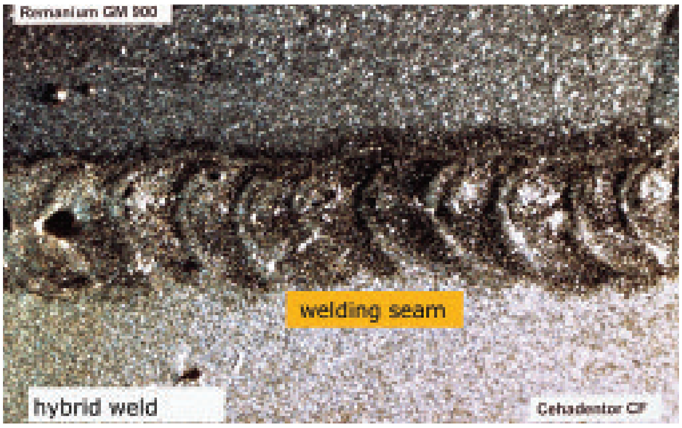

Fig. 4 Macroscopic view of the welding seam of a "hybrid weld" between a non-precious CoCr alloy (Remanium GM 900) and a precious alloy (Cehadentor CF).

Fig. 5 Microscopic view of the welding zone of a "homogenous" weld of a high-gold-content casting alloy (Orplid EH). A fissure can be clearly seen.

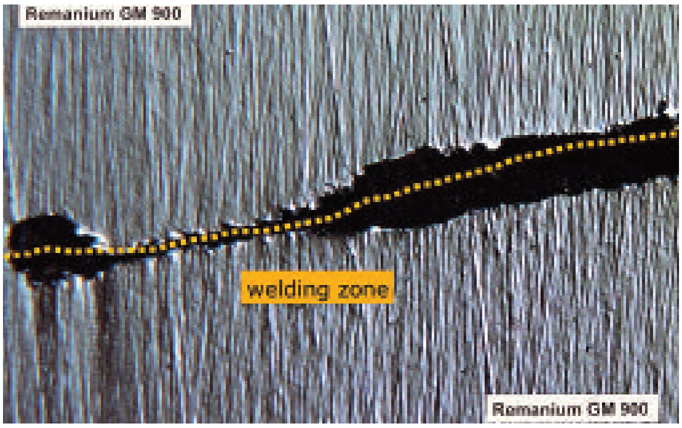

Fig. 6 Microscopic view of the joint zone of a "homogenous" weld of a non preciousCoCr alloy (Remanium GM 900).

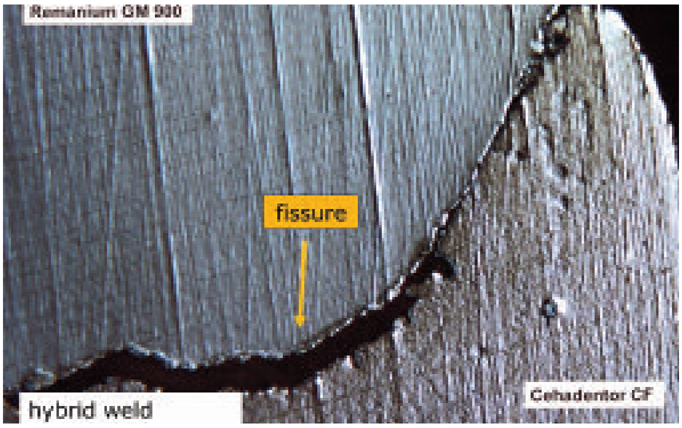

Fig. 7 Microscopic view of the joint zone of a "hybrid weld."

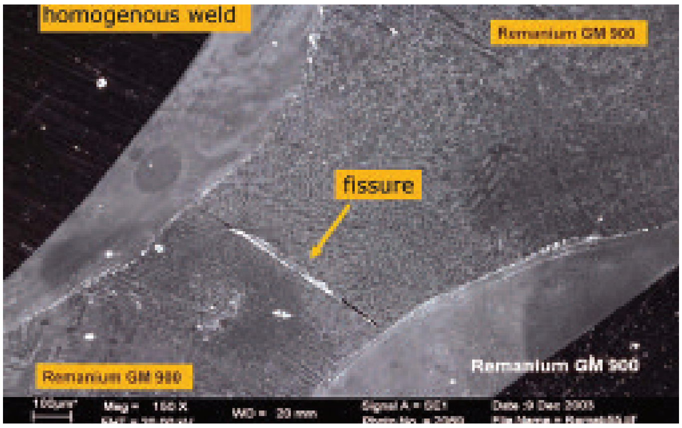

Fig. 8a Scanning electron microscope view of a "homogenous" plasma weld with fissure formation.

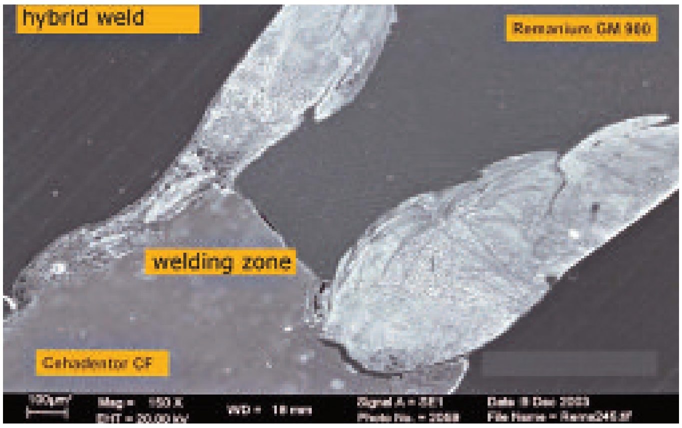

Fig. 8b Scanning electron microscope view of a "hybrid" plasma weld with fissure formation.

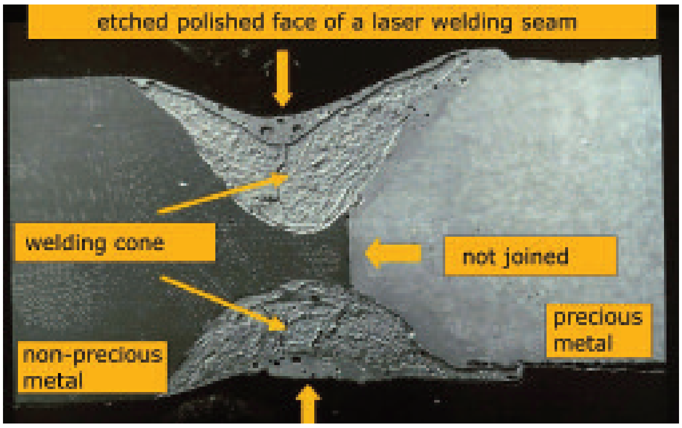

Fig. 9 Scanning electron microscope view of a "hybrid" laser weld with fissure formation.

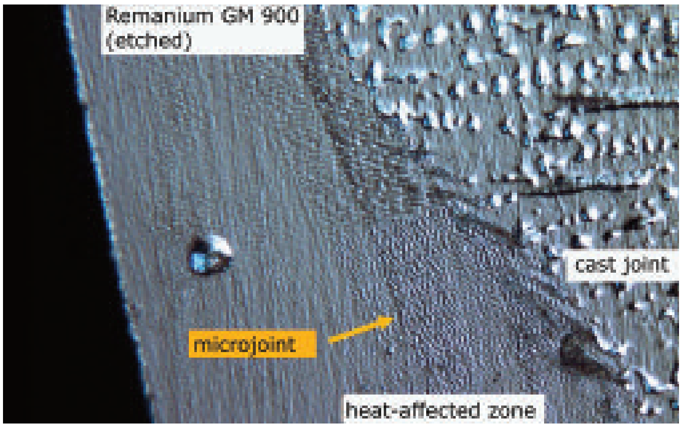

Fig. 10 Microscopic view of the transition zones between the large-grain cast structure (right) of the precious alloy and the fine-grain microstructure in the plasma welding seam (left).

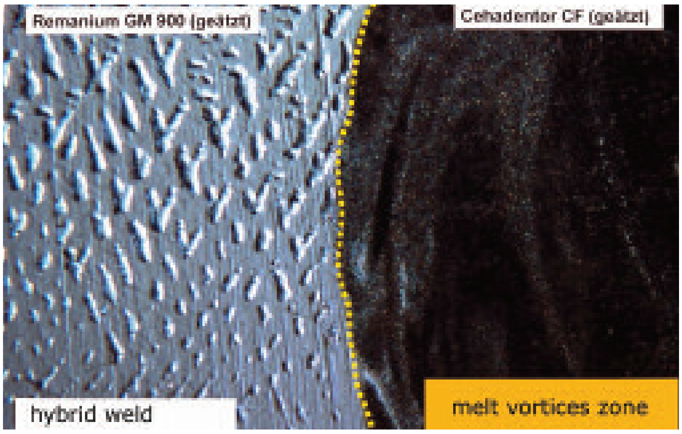

Fig. 11a Microscopic view of the melt vortex in the plasma welding seam of a hybrid weld.

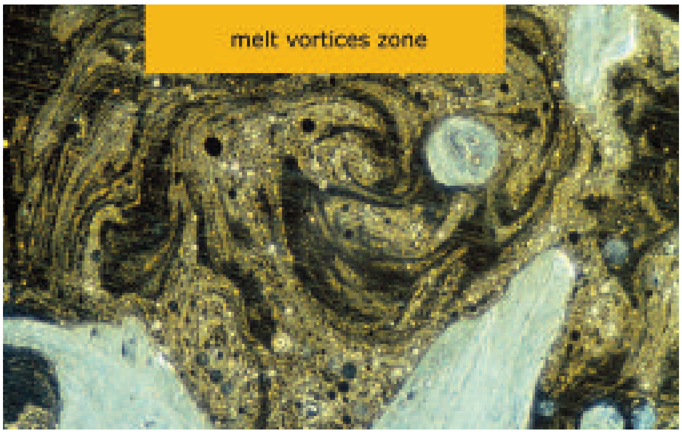

Fig. 11b Microscopic view of the melt vortex in the laser welding seam of a hybrid weld.

Melt vortices >>

In addition, a clear melt vortex can be recognised in the metallographic polished faces etched with aqua regia from the hybrid welded test series (Fig. 11a). Similar vortices were also observed in the laser-welded hybrid connections (Fig. 11b). This is caused by the high energy input required for hybrid welding, because the melting range of the CoCr alloy is much higher than that of the precious alloy.

X-ray spectra >>

The marked uniform similarity of the microstructure of the plasma and laser-welded samples must also be noted (Fig. 12a and 12b). To be able to assess whether the molten alloys have mingled in the weld zone (joint zone) during the hybrid welding, energy-dispersive x-ray spectra (EDX) were taken. The assessment of a sample element spectrum confirmed the mingling, because the major elements from both alloys could be analysed in the weld zone (Fig. 13).

The question of whether the chemical element tungsten, which could come from the tungsten electrode, could be detected in the welded connection of the plasma welding was of particular interest. X-ray spectra were recorded both outside (Fig. 14a) and inside (Fig. 14b) the welding seam. Comparison of the spectra clearly shows that tracers of tungsten can be detected in the welding seams of the welded precious alloy plates (compare Fig. 14a and 14b). This confirms that the traces of metal lost from the tungsten welding electrode during welding are found again in the welding seam. This, however, is not known to negatively influence the welding result.

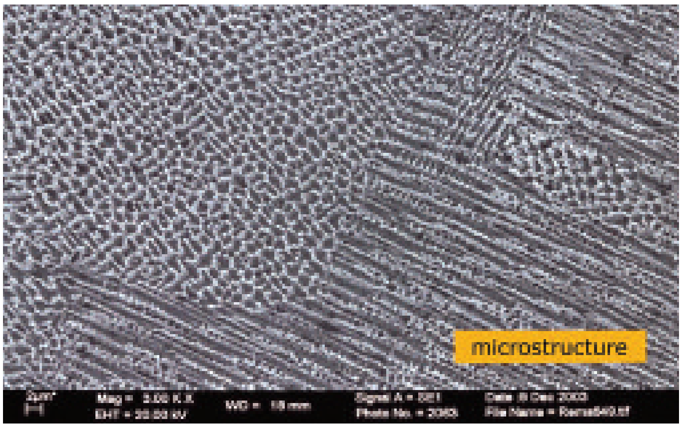

Fig. 12a Scanning electron microscope view of the microstructure in the plasma welding seam.

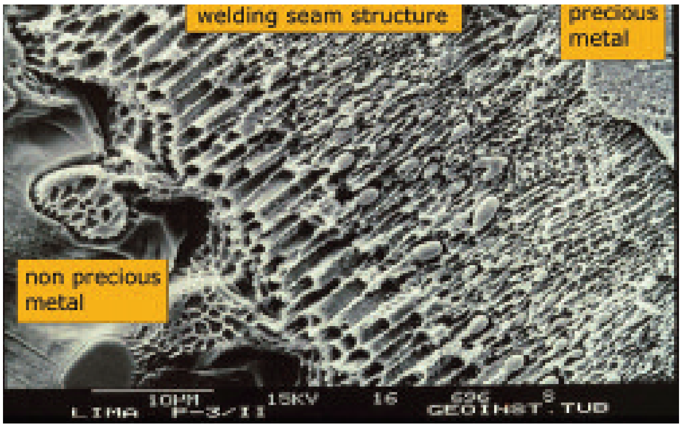

Fig. 12b Scanning electron microscope of the microstructure in the laser welding seam.

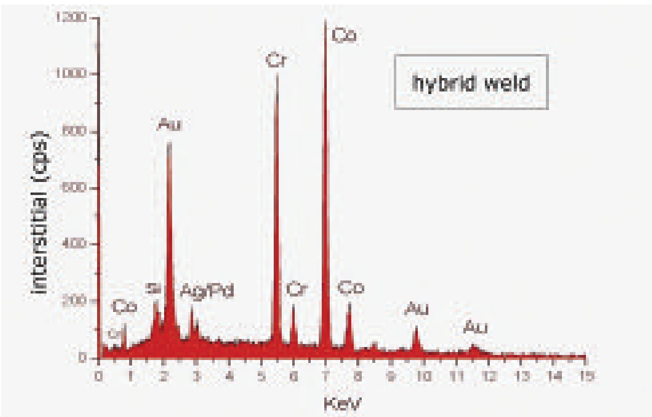

Fig. 13 Energy-dispersive x-ray spectrum of the joint zone of a hybrid weld between a non precious CoCr alloy (Remanium GM 900) and a high-gold-content casting alloy (Orplid EH). All main elements of the non-precious-metal alloy (Co, Cr) and the precious metal alloy (Au, Ag, Pd) can be detected.

Conclusion >>

The material evaluation of the two joining techniques (laser and pulsed micro plasma welding) shows that there are no significant differences in the metallographic appearance of alloy pairs joined with the two techniques. Both technologies yield exactly the same result. The facts conform exactly to the advertising slogan “precise laser quality spot welding”.

Acknowledgements >>

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Literature >>

[1] Lindemann, W., Materialkundliche Untersuchungen an Laserschweißverbindungen zwischen Edelmetall und Nichtedelmetalllegierungen

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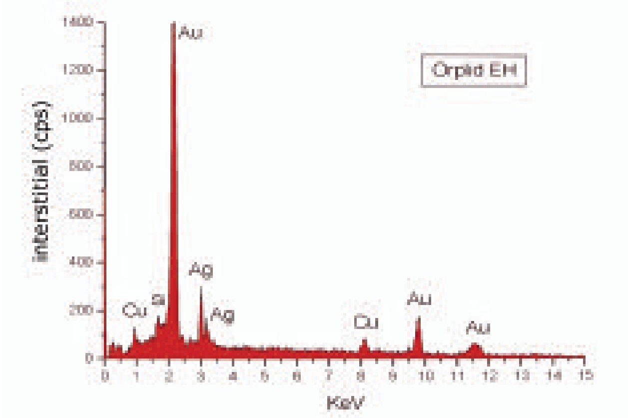

Fig. 14a Energy-dispersive x-ray spectrum (EDX) of a high-gold-content casting alloy (Orplid EH). The alloy constituents gold (Au), silver (Ag) and copper (Cu) can be detected.

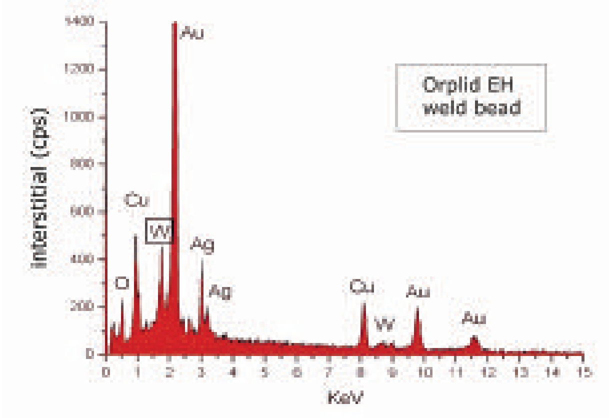

Fig. 14b Energy-dispersive x-ray spectrum of the welding seam in a high-gold-content casting alloy (Orplid EH). In addition to the alloy constituents gold (Au), silver (Ag) and copper (Cu), traces of tungsten (W) can also be detected.