EXPERIMENTAL STUDIES ON MICROPLASMA WELDING IN DENTAL LABORATORY

Liliana Sandu[1], Florin Topala[2], Cristina Bortun[1], Sorin Porojan[1], Daniela Pop[1]

REZUMAT

Introducere: Sudarea cu microplasmă în mediu de gaz protector a adus îmbunătăţiri substanţiale metodelor tradiţionale de îmbinare utilizate în tehnologia protezelor dentare. **Scop:** Studiul a investigat efectul parametrilor de sudare asupra calităţii sudurii pentru diferite tipuri de aliaje dentare nenobile. **Material şi metodă:** Pentru testele experimentale de sudură au fost turnate plăcuţe de Co-Cr-Mo, utilizând tehnologiile clasice. Plăcuţele au fost sudate cu microplasmă, în configuraţia cap la cap, fără material de adaos, cu o suprapunere a petelor focale de peste 50%. Eşantionele sudate au fost analizate macroscopic, radiografic, microstructural şi s-au determinat microdurităţile în materialul de bază (MB), zona de sudură (SUD) şi zona de influenţă termică (ZIT). **Rezultate:** Analizele metalografice şi testele de microduritate au arătat modificări microstructurale în special în ZIT, cu precipitarea anumitor componente, care durifică zona respectivă (valorile microdurităţilor au crescut cu valori între 15.38% and 43.90% pentru aliajele testate). Asociate cu defecte de turnare, ca goluri sau fisuri, zonele fragile pot duce la o degradare precoce a structurilor sudate. **Concluzii:** În vederea obţinerii unor suduri de maximă precizie şi calitate superioară, care să satisfacă necesităţile actuale, trebuie aleasă o combinaţie adecvată a parametrilor de sudare şi particularizată, pentru a putea fi reprodusă şi implementată în practică.

Cuvinte cheie: sudare cu microplasmă, aliaj de Co-Cr-Mo, parametrii de sudare, analize metalografice, microduritate

ABSTRACT

Introduction: Microplasma welding in inert gas environment have led to substantial improvements to the traditional joining procedures used in denture technology.Purpose: The study investigated the effect of the welding parameters on the weld quality for different base metal dental alloys. **Material and method:** For experimental welding tests Co-Cr-Mo alloys plates were cast using classical technologies. The plates were microplasma welded in a butt joint configuration, without filling material, with a spot overlapping of more than 50%. Welded specimens were analyzed macroscopically, radiographically, microstructurally and the microhardness was determined in the base metal (BM), weld metal (WM) and heat affected zone (HAZ). Results: Metallographic analyses and microhardness tests showed structural changes particularly in the HAZ, with precipitates of some compounds, which harden the respective area (the microhardness values increased between 15.38% and 43.90% for the tested alloys). Associated with welding defects, like voids and cracks, the fragile areas can lead to an early degradation of the welded structures. **Conclusions:** In order to obtain maximum precision and high quality weldings, which would fulfill current requirements, an adequate combination of the welding parameters have to be chosen and particularized, to can be reproduced and implemented in practical use.

Key Words: microplasma welding, Co-Cr-Mo alloy, welding parameters, metallographic analyses, microhardness

INTRODUCTION

Modern welding procedures of dental alloys, namely with laser and microplasma, in an inert gas environment, have led to substantial improvements to the traditional joining procedures used in denture technology. They allow welding of different prostheses compounds, framework optimizations, that in classic laboratory conditions would need the resumption of all technical stages.[1-7]

Literature data regarding welding in dental technique have existed for more than ten years, but this subject is in the top now.[8,9] There are a lot of devices produced specially for this, like Laser Star PW, T (Bego, Bremen, Germany), Connexion II Ergo (DeguDent GmbH, Hanau-Wolfgang, Germany), Desktop Power Laser (Dentaurum, Ispringen, Germany), Neolaser L, P (Girrbach, Calw-Wimberg, Germany), Vision-Laser (Vision GmbH, Göxe, Germany), Hercules (Interdent, El Segundo, CA, USA), Jewellaser (Manfredi, Torino, Italy), Welder (Schütz-Dental, Rosbach, Germany) and Phaser (Primotec, Baltimore, MD, USA).

Microplasma welding is a lower costing alternative to laser welding is. Using of microplasma for frameworks repairs is characterized by: low thermal

---

[1] Department of Dental Technology, [2] Department of Prosthetic Dentistry, Faculty of Dental Medicine, Victor Babes University of Medicine and Pharmacy, Timisoara

Correspondence to:
Assoc. Prof. Liliana Sandu, 6 Socrate Street, 300552 Timisoara, Tel. +40-722-310299
Email: lilianasandu@gmail.com

Received for publication: Jul. 10, 2007. Revised: Feb. 05, 2008.

energy, fine layers with high reproducing degree, strength joints, high accessibility, time saving, corrosion absence because there is no material with other composition used, mechanical strength; low thermal influence with limited deformations. This means that it can be welded directly on the cast; it can be worked near resins or ceramics, without damaging them.

Because the success of welding depends on the control of several parameters, and the welding interactions are extremely complex, there are studies that have assessed the welding quality determining factors, namely operator dexterity and the selection of welding parameters (power, pulse duration).[8-11] Regarding the inert gas atmosphere (Argon) some studies state that it is not absolutely necessary in the case of Co-Cr alloy welding.[12] Some studies demonstrated that minimum changes to the composition of Ni-Cr alloys greatly influence the quality of joints by welding.[11] As a result, attention should be paid to the differences of chemical composition between the welded area and the basic alloy. High C and B levels are responsible for low weldability. Co-Cr alloys generally present good weldability properties, but microstructure changes are accompanied by an increase in microhardness. The mechanical properties of joining areas depend on microstructure changes.[13] The effect of welding conditions on the penetration depth in different alloys was analyzed, and it was showed that by increasing the energy and decreasing the focal spot, an increase of the penetration depth is achieved.[14,15] Also for the assessment of welding quality, in order to compare Nd:YAG laser and TIG (tungsten inert gas), flexion resistance tests were run.[16] Significant differences were recorded between the two welding types, as well as between the welding procedures with and without material supplementation.

The purpose of the research was to assess the weldability of Co-Cr-Mo base metal alloys used in dental prosthodontics, depending on their chemical composition, as well as on material morphology, structure and quality. Non-destructive and destructive analyses served the purpose of assessing the welding quality.

MATERIAL AND METHODS

For experimental welding tests 30 plates of three different Co-Cr-Mo alloys: Wironit (Bego, Bremen, Germany), Heraenium CE (Heraeus Kulzer GmbH, Hanau, Germany), C (Vaskut Kohászati KFT, Budapest, Hungary) were cast using classical technologies. (Fig. 1-3)

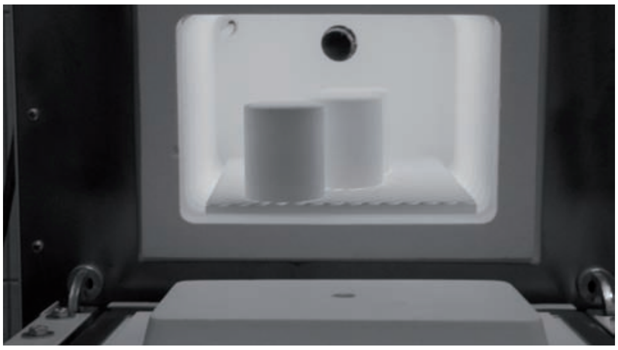


Figure 1. Ring positioned for wax burnout.

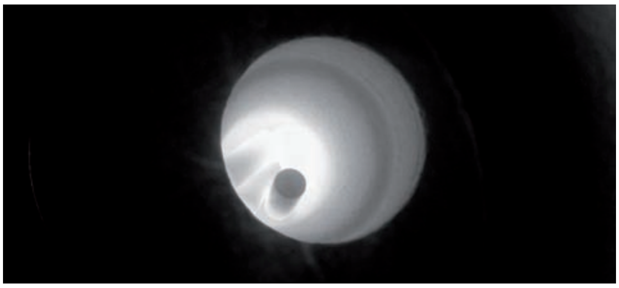


Figure 2. Melting of the alloy in the crucible.

Figure 3. Casting of the Co-Cr alloy.

Figure 4. Cast plates after investing removal.

Figure 5. Casted plates after sandblasting and finishing.

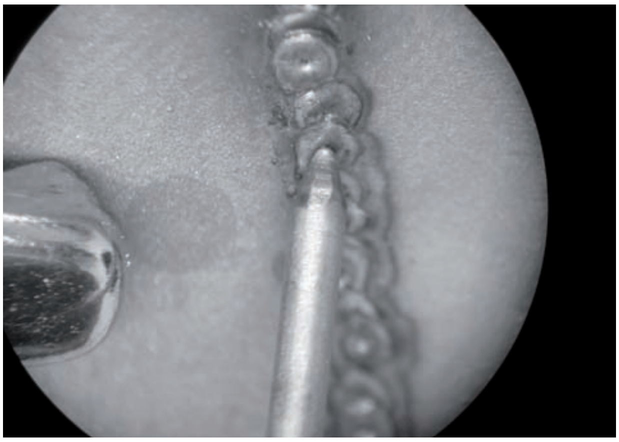


Figure 6. Microplasma welding of the plates.

After preparing the surfaces to be welded by sandblasting with Al_2O_3 (250 µm) and grinding the plates were matched for butt joint welding. Then they were polished using silicon carbide abrasive rotator instruments and welded using microplasma Welder (Schütz-Dental, Rosbach, Germany). (Fig. 4-6) Each specimen was bilaterally welded in a butt joint configuration, with a spot overlapping of more than 50%, using 1 mm in diameter wolfram electrode. Plates were welded by twos, varying the parameters of the device: power step (2, 3, 4) and pulse delay (20, 30, 40 ms). The argon quantity was maintained at 5-6 l/min in all cases. 15 samples resulted, 5 for each tested alloy. (Table 1) Welded specimens were analyzed macroscopically, radiographic, microstructural and the microhardness was determined in the base metal (BM), weld metal (WM) and heat affected zone (HAZ).

Table 1. Parameters used for the experiment: samples 1-5 for Wironit, samples 6-10 for C alloy, samples 11-15 for Heraenium CE.

Sample	Parameters	
	Power step	**Pulse delay**
1, 6, 11	3	30 ms
2, 7, 12	2	40 ms
3, 8, 13	4	20 ms
4, 9, 14	3	20 ms
5, 10, 15	3	40 ms

Microscopic observations were made using an inverted metallographic microscope Reichert MeF2 (Reichert, NY, USA). (Fig. 7) Therefore, the samples were incorporated into an acrylic resin, cut perpendicularly to the weld axis, grinded using silicon carbide abrasive paper and polished with a series of abrasives culminating in rouge. The surfaces to be analyzed were chemically attacked using acid solution of ferric chloride for 2-3 seconds at room temperature.

Microhardness (HV) was measured on the polished surface of the samples at room temperature using a Zwick 3212 (Zwick, Ulm, Germany) microhardness device. At least three individual tests with a peak load of 9.8 N and a loading time of 20 seconds were performed for each determination. (Fig. 8)

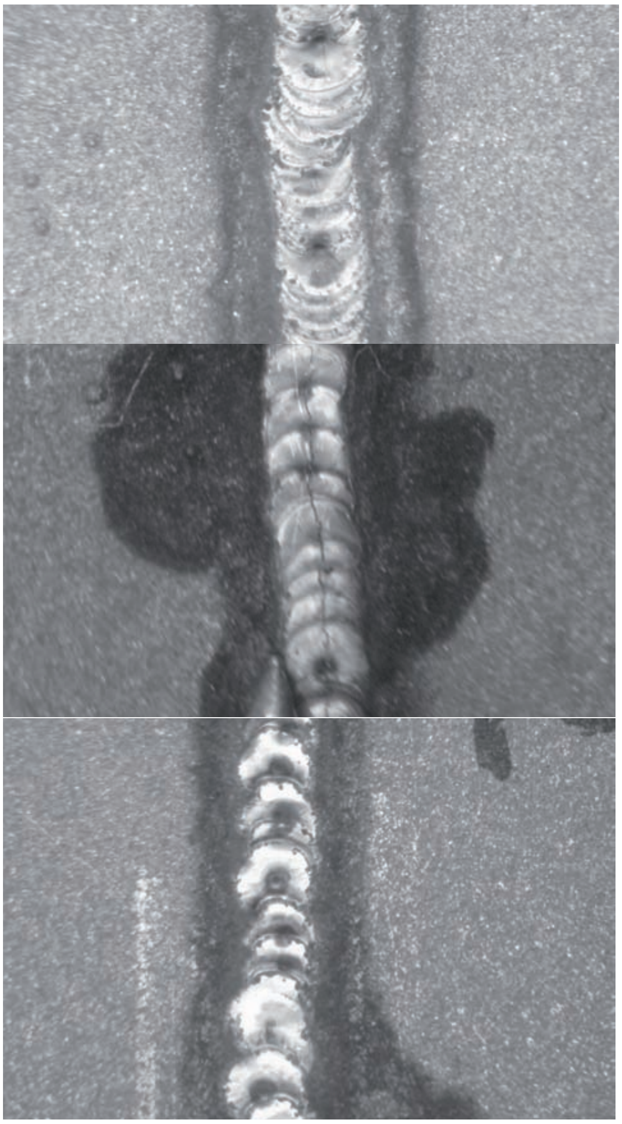


Figure 7. Inverted metallographic microscope Reichert MeF2.

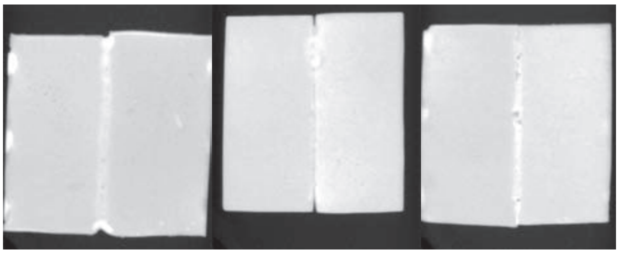


Figure 8. Microhardness measuring device Zwick 3212.

RESULTS

The welding imperfections, like an nonuniform width of the welding rib, craters on the welding surface, associated with radial cracks, lack of melting between the components have to be detected, explained an eliminated.

Macroscopic analyses of the joints regarding rib width, welding continuity and welding defects were made. (Tables 2-4) Radiographic analyses confirmed these aspects. (Fig. 9, 10)

Table 2. Macroscopic examination of Wironit welded samples.

Sample	Macroscopic examination
1	Uniform width, welding craters on ~ 20% from WM, 15% continuous welding
2	Relative uniform width, welding craters on ~ 25% from WM, 30% continuous welding
3	Uniform width, welding craters on ~ 10% from WM, 50% continuous welding
4	Relative uniform width, welding craters on ~ 30% from WM, 25% continuous welding
5	Uniform width, welding craters on ~ 10% from WM, 60% continuous welding

Table 3. Macroscopic examination of C alloy welded samples.

Sample	Macroscopic examination
6	Relative uniform width, welding craters on ~ 35% from WM, 20% continuous welding
7	Uniform width, welding craters on ~ 30% from WM, 30% continuous welding
8	Uniform width, welding craters on ~ 25% from WM, 20% continuous welding
9	Nonuniform width, welding craters on ~ 10% from WM, 80% continuous welding
10	Relative uniform width, welding craters on ~ 35% from WM, 15% continuous welding

Table 4. Macroscopic examination of Heraenium CE welded samples.

Sample	Macroscopic examination
11	Nonuniform width, welding craters on ~ 40% from WM, 15% continuous welding
12	Relative uniform width, welding craters on ~ 35% from WM, 10% continuous welding
13	Relative uniform width, welding craters on ~ 25% from WM, 45% continuous welding
14	Nonuniform width, welding craters on ~ 25% from WM, 40% continuous welding
15	Nonuniform width, welding craters on ~ 25% from WM, 25% melting lack, 20% continuous welding

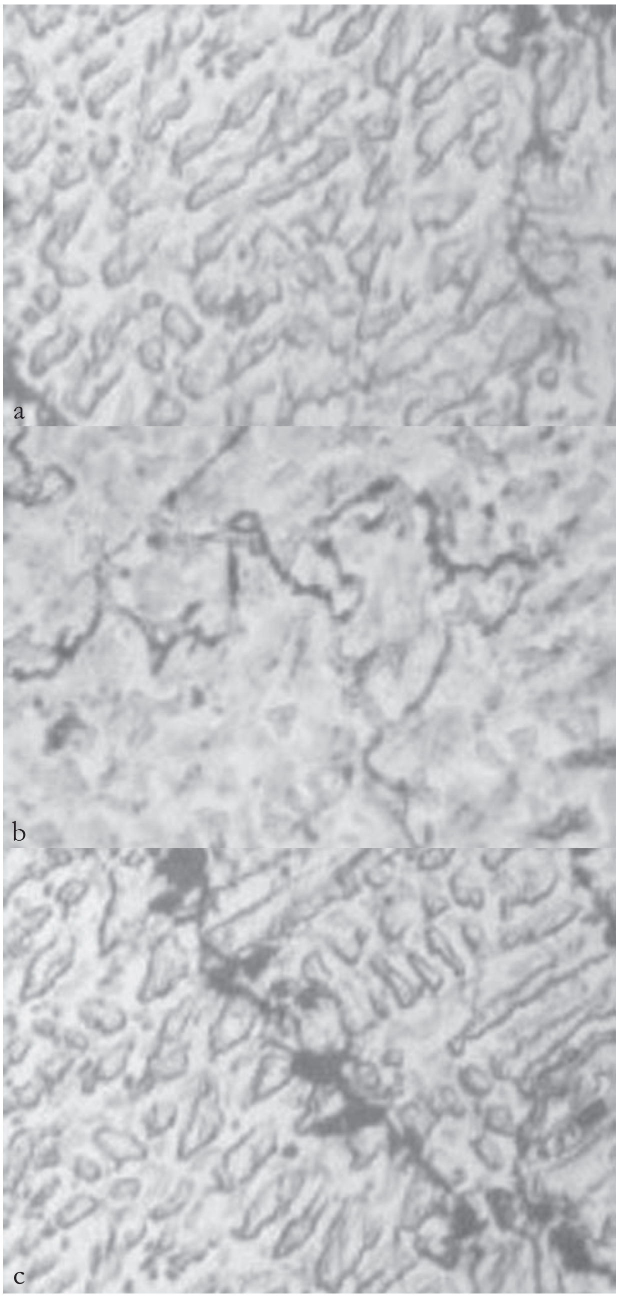


Figure 9. Welded plates: a. Wironit - sample 5, b. C alloy - sample 9, c. Heraenium CE - sample 13.

After that micrographic observations perpendicular to the weld axis were conducted in order to analyze the quality of the microstructure. (Fig. 11)

Additionally, the microhardness was measured both in the welded and the heat affected zones and then compared to the non welded cast alloys. (Tables 5-7) The microhardness values increased between 15.38% and 43.90% in the HAZ for the tested alloys.

The areas with increased microhardness values, located in the heat affected zone are fragile structures. Associated with welding defects, like voids and cracks, these can lead to an early degradation of the welded structure.

Table 5. Microhardness values of the tested samples for Wironit.

Tested zone	Vickers microhardness HV 10				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
BM_1	380	373	390	351	380
HAZ_1	401	425	421	357	401
WM	421	360	450	405	429
HAZ_2	383	417	370	327	405
BM_2	370	363	380	333	370

Table 6. Microhardness values of the tested samples for C alloy.

Tested zone	Vickers microhardness HV 10				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
BM_1	336	325	322	370	376
HAZ_1	405	357	351	383	342
WM	417	376	383	401	357
HAZ_2	401	345	390	405	348
BM_2	351	351	370	390	333

Table 7. Microhardness values of the tested samples for Heraenium CE.

Tested zone	Vickers microhardness HV 10				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
BM_1	312	319	302	287	314
HAZ_1	327	357	354	357	306
WM	370	421	413	413	363
HAZ_2	327	360	366	360	327
BM_2	312	306	317	317	294

DISCUSSIONS

The main advantage of using microplasma welding process is the fact that the repair by welding can be done directly on the working cast and close to resins and ceramics with minimal or no impact on them. It is also time saving, induces a low thermal influence, and involves minimal deformations of the metallic framework.

These microstructural changes, due to the very rapid heating and solidification process after laser welding could not be avoided and can be a real problem and affect the quality of the joint. The precipitates increase the hardness of the welded metal, which leads to fragile areas, which could crack during high functional loads.

Adequate combination of the welding parameters appears to improve the success of the welding procedure. Operator skill is determinant for the weld quality. Experimental studies allow to asses optimal parameters for each alloy type and working step. This study established optimal combination of parameters for some Co-Cr-Mo alloys frequently used in practice.

Microplasma welding without filler material is very demanding, in respect to surfaces processing, but can be applied for small defects dental frameworks repairing in practical use.

CONCLUSIONS

In order to obtain maximum precision and high quality weldings, which would fulfill current requirements; it is a must that modern analysis concepts be used for each particular case.

Following the research, it is wanted that the new welding procedures be optimized, particularized, reproduced and implemented in practical use.

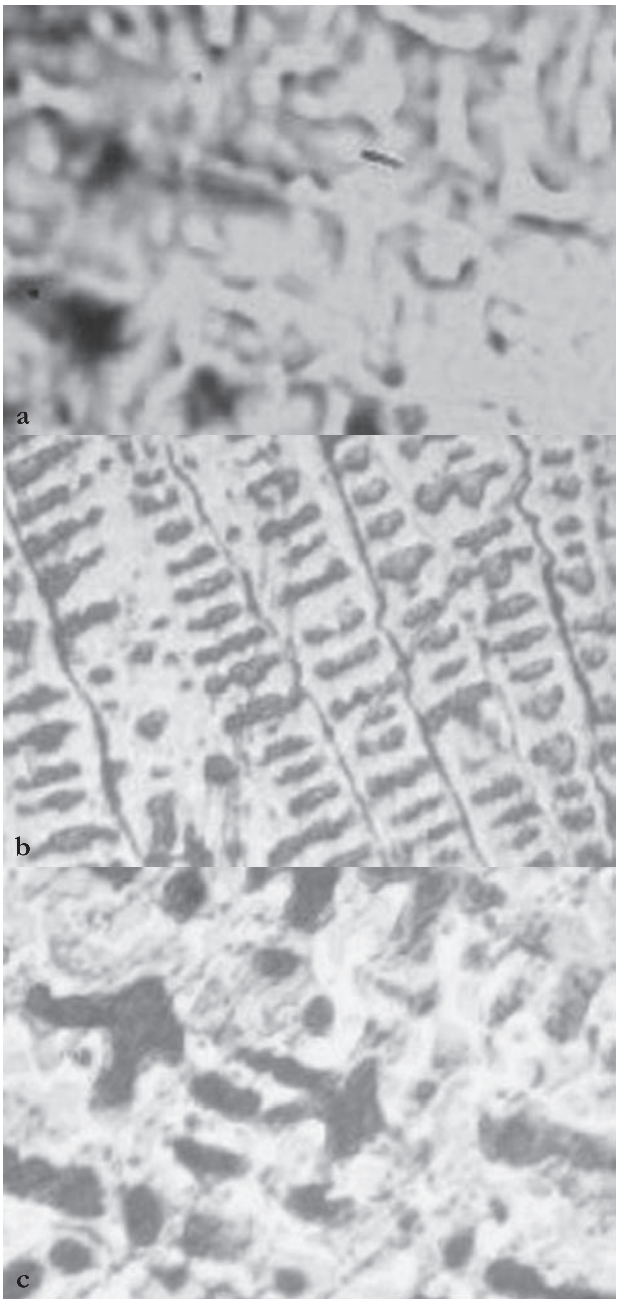
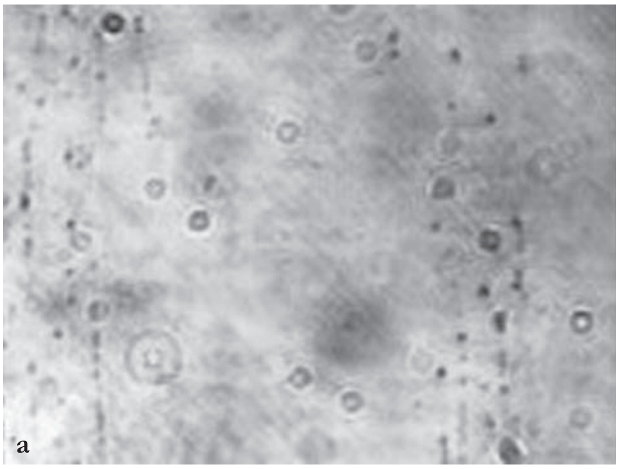


Figure 10. Radiographic images of the welded plates: a. Wironit - sample 5, b. C alloy - sample 9, c. Heraenium CE - sample 13.



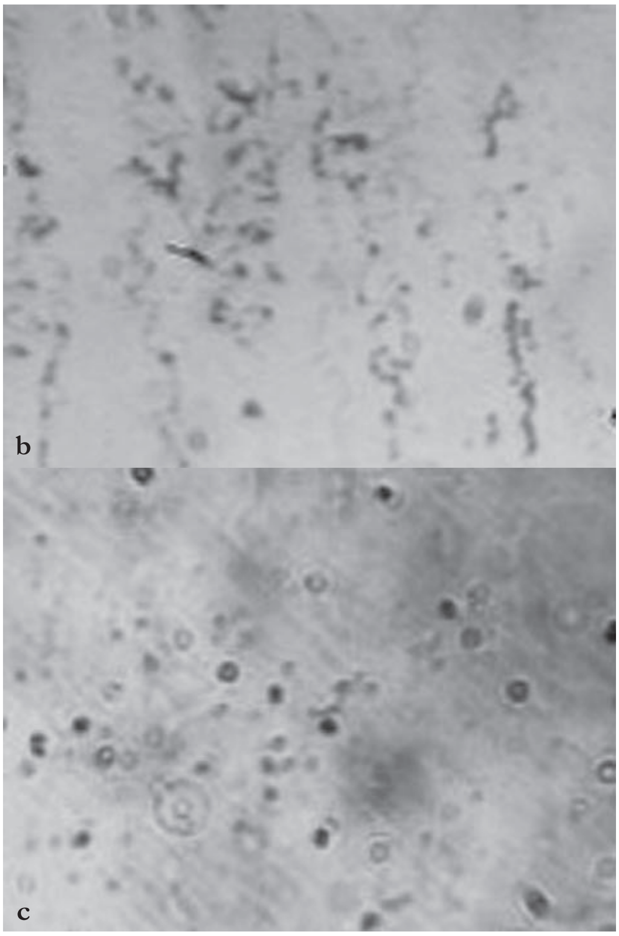


Figure 11. Microstructure of Wironit: a. cast alloy, b. weld area, c. heat affected zone.

Framework repairs using microplasma welding need preliminarily experimental studies in order to determine adequate parameters for the alloy type and defect size.

REFERENCES

1. Carr AB, Mc Givney GP, Brown DT. Mc Cracken's removable partial prosthodontics. 11th Edition, St. Louis: Mosby, 2005.
2. Phoenix RD, Cagna DR, De Freest CF. Stewart's clinical removable partial prosthodontics. 3rd Edition, St. Louis: Mosby, 2003.
3. Rosenstiel S, Land M, Fujimoto J. Contemporary fixed prosthodontics, 3rd Edition, St. Louis: Mosby, 2001.
4. Schneiderbanger T. Der einsatz des Lasers am beispiel eines klammerbruchs. Dent Lab 2000;2:207-9.
5. Hassan L, Juszczyk AS, Clark RKF. Immediate replacement removable partial dentures with cobalt-chromium frameworks: rationale, technology and a case report. J Oral Rehabil 2005;32:772-5.
6. Sandu L, Bîrdeanu V, Borţun C, Matekovits G. A fémvázas részleges fogsorok ötvözeteinek hegesytése puzáló lézernyalábbal. Dent Lab 2006;1:42-4.
7. Dharmar S, Rathnasamy RJ, Swaminathan TN. Radiographic and metallographic evaluation of porosity defects and grain structure of cast chromium cobalt removable partial dentures. J Prosthet Dent 1993;69:369-73.
8. Bertrand C, Le Petitcorps Y, Albingre L, et al. The laser welding technique applied to non precious dental alloys procedure and results. British Dental Journal 2001;190(5):255-7.

9. Bertrand C, Le Petitcorps Y, Albingre L, et al. Optimization of operator and physical parameters for laser welding of dental materials. Br Dent J 2004;196(7):413-8.

10. Lindemann W. Materialkundliche untersuchungen an laserschweißverbindungen zwischen edelmetall- und nichtedelmetall-legierungen, Dent Lab 2000;XLVIII(H2):199-202.

11. Päßler K, Hottinger B. Werkstoffkundliche Untersuchungen mit dem Dentallaser DL 2002. Quintessenz Zahntech 1997;23(7):909-19.

12. Watanabe I., Topham S. Laser welding of cast titanium and dental alloys using argon shielding. J Prosthodont 2006;15:102-7.

13. Srimaneepong V, Yoneyama T, Kobayashi Equo, et al. Mechanical strength and microstructure of laser-welded Ti-6Al-7Nb alloy castings. Dent Mater J 2005;24(4):541-9.

14. Baba N, Watanabe I,. Liu J, et al. Mechanical strength of laser-welded cobalt-chromium alloy. J Biomed Mater Res B Appl Biomater 2004;69(2):121-4.

15. Baba N, Watanabe I. Penetration depth into dental casting alloys by Nd:YAG laser. J Biomed Mater Res B Appl Biomater, 2005;72(1):64-8.

16. Roha R, Pinheiro ALB, Villaverde AB. Flexural Strength of pure Ti, Ni-Cr and Co-Cr alloys submitted to Nd:YAG laser or TIG welding. Braz Dent J 2006;17(1):20-3.