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Surface structure and corrosive behaviour of dental alloys treated by Micro-Finishing

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Introduction

Surface conditions of castings are influenced by interface reactions between metal and the investment material. There are the sinterfusing and uptake of elements from the investment material. The surface near layer is also characterised by microstructural defects.
The usual surface treatment is sandblasting with corundum 250µm. It is characterised by strong surface roughening (microroughness of 10-20µm) and impaction of blasting grains. That is why a new technique of surface treatment has been developed using micro-particles and high jet pressure (Micro-Finishing).
The Micro-Finishing operates with a "sand-blast-blower" using two blasting media: The medium 1 (M1) is an abrasive medium with fine grain abrasives (grain size 30-80µm). It exists of corundum and carborundum.
The medium 2 (M2) is a spherical medium which consists of blasting balls made of zirconia (grain size 40-65µm).

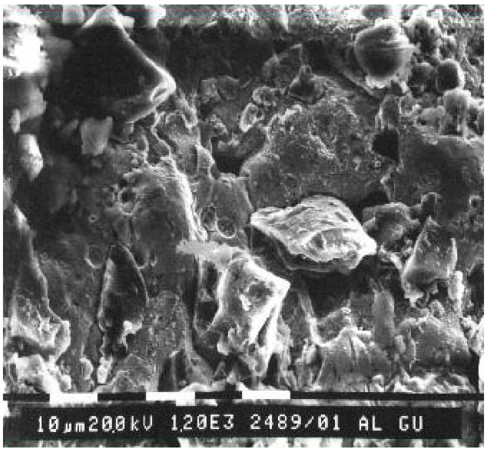


Fig. 1: high gold alloy, cast condition, SEM

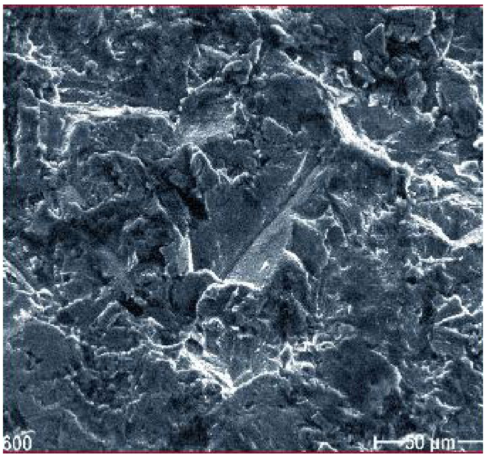


Fig. 2: Titanium, sandblasted (corundum 250µm), SEM


Fig. 3: special sand-blast-blower "Multipoint 2000"

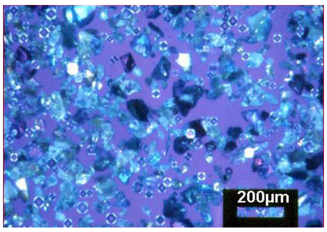


Fig. 4: micro-blasting medium (M1)

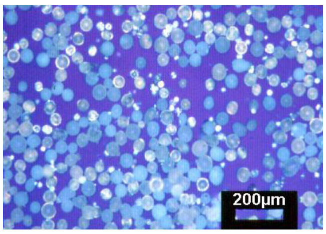


Fig. 5: micro-peening medium (M2)

Aim of Studies

The aim was to verify the improving effect of this blasting technique on different dental alloys and to investigate the corrosive behaviour of these materials after using Micro-Finishing.

Material/Method

- The following **materials** were tested:

    - a high gold alloy (AuPtPd-alloy)
    - a cobalt-based alloy (CoCrMo-alloy)
    - Titanium (grade 1)
- Samples were cast and cleaned in an ultrasonic bath.
- The samples were finished by using the abrasive and spherical medium, separate and in combination.

cast sample of:	Micro- Blasting	Micro-Peening	Micro-Blasting and -Peening
high gold alloy	3 bar 20 sec	3,5 bar 30 sec	3 bar + 3 bar 20 + 20 sec
co-based alloy	4 bar 20 sec	4 bar 30 sec	4 bar + 4 bar 20 +20 sec
Titanium	4 bar 20 sec	5 bar 30 sec	5 bar + 5 bar 20 + 20 sec

Table 1: parameters of surface treatment

- The samples were **characterised** by using:
    - light- and scanning electron microscopy (SEM)
    - metallography
    - microhardness tests on cross sections
    - analysis of the profile graph (RZD)
    - investigation of the corrosive behaviour in a 0,9% sodium chloride
      => solution recording of the current-density-potential curves

Measuring Arrangement	computer-controlled potentiostat reference electrode: satured calomel electrode
Conditions of Environment	0,9% NaCl-solution with PH value of 7,4 temperature T=37 °C, high N_2-level
Sample Preparation	- wet grinding with 1200 SiC paper (~15µm) - micro-peening with M2 in addition to SiC1200
Electro-Chemical Measurement	rest potential about 1 hour anodic polarization; from rest potential to E_{max}=1500 mV or i=0,1 mA/cm^2 polarization speed: 0,2 mV/s

Table 2: parameters of measurement (corrosive behaviour)

Results

1. Light- and scanning electron microscopy (SEM)

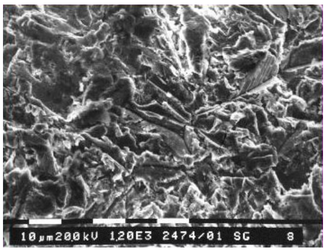


Fig. 6a

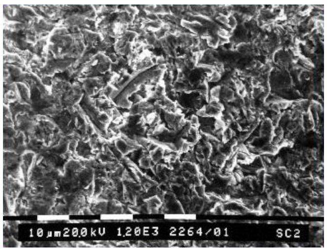


Fig. 6b

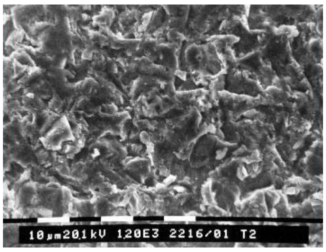


Fig. 6c

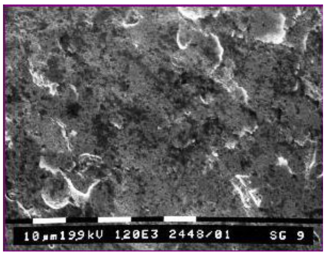


Fig. 7

- effect of the abrasive blasting on surface (Fig. 6a-c):
    - clear cutting tracks
    - regular roughness of the surface
    - different effects on each kind of tested material:
        - high gold alloy - deep and long cuts (6a)
        - co-based alloy - short and low cuts (6b)
        - Titanium - blurred cuts (6c)
- effect of the spherical blasting on surface (Fig. 7):
    - the treated surfaces of each tested material are similar
    - surface levelling by plastic deformation (blasting balls forge the surface)

- peaks of the profile seems to be folded down
- occasional impactions of blasting balls
- the effect of the abrasive grains is not to be seen

2. Metallography

high gold alloy | **casted** co-based alloy

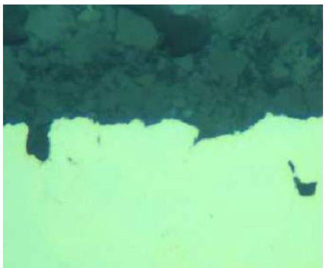


Fig. 8: strong deeply cleaved surface is to be seen

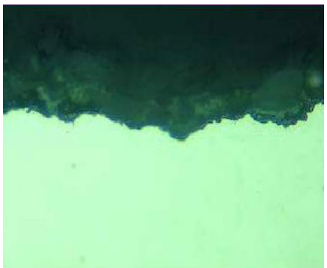


Fig. 9: regular surface with strong surface roughness

micro-blasting

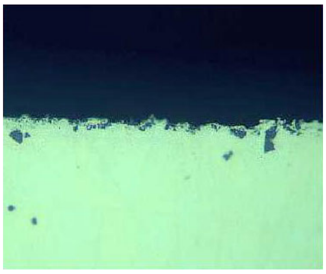


Fig. 10: surface is more smoothed with a less rugged profile there are impactions of blasting grains

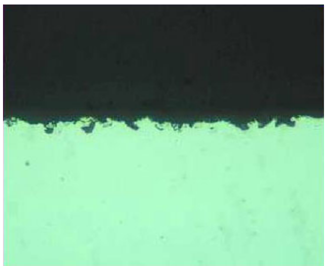


Fig. 11: deep fissured profile with impactions of blasting grains

micro-blasting and -peening

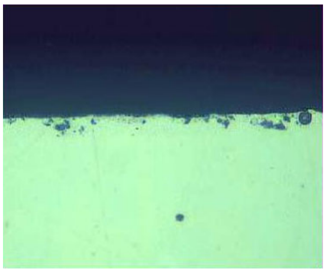


Fig. 12: the surface roughening is levelled by micro-peening

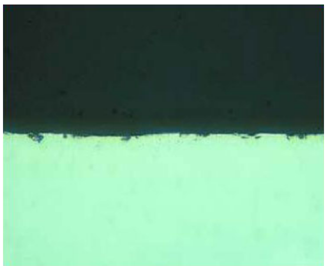


Fig. 13: homogeneous, less polluted and smoothed surface

micro-peening

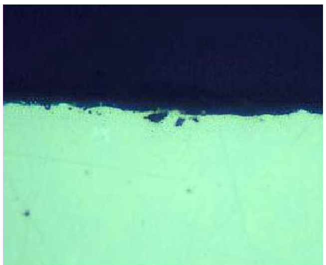


Fig. 14: surface roughness is levelled off there are less impactions of blasting grains

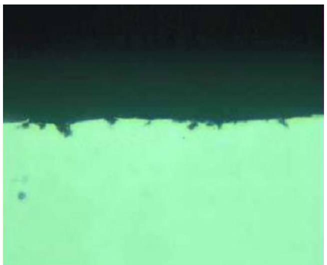
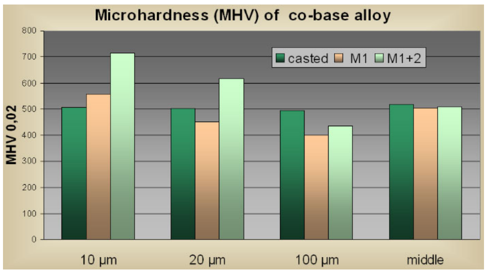


Fig. 15: surface is rougher and irregular effect is lower than by treatment of high gold alloy

Titanium reacts like co-based alloy.

3. Microhardness tests



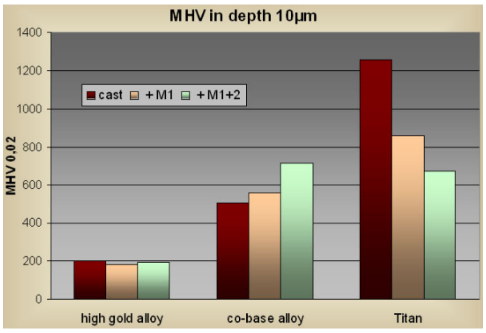


Fig. 16

Fig. 17

- deep action of the blasting media (Fig. 16):
  - microhardness in cast condition is the same on the surface and in the middle of the material
  - no significant differences of microhardness after using the abrasive medium
  - the microhardness of the surface near layer increases after using micro-peening
  - the effect is provable up to 20µm depth
- comparison of the materials (Fig.17):
  - the *high gold alloy* shows no increase of the microhardness
  - the *co-based alloy* shows a clear increase of microhardness after micro-peening
  - *Titanium*: reduction of the surface near layer by abrasive micro-blasting
    => therefore it seems to be a decrease of the microhardness

4. Analysis of the profile graphs

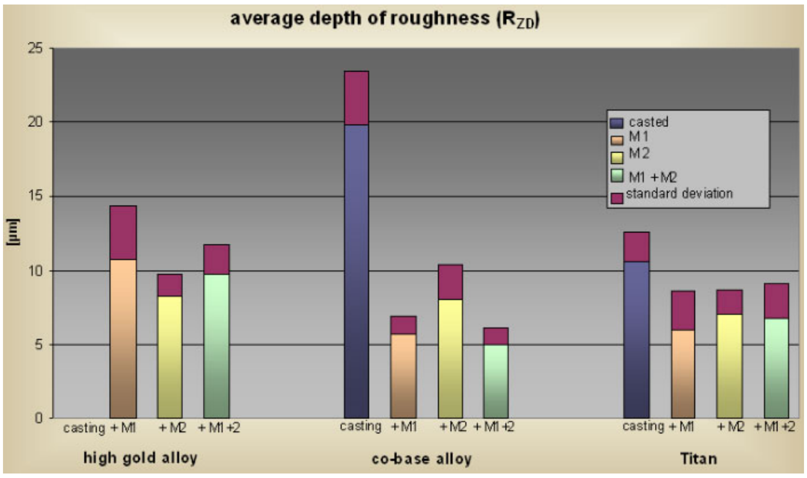


Fig. 18: Analysis of the profile graphs

- high gold alloy
  - decrease of average depth of roughness by each treatment
  - strongest decrease of RZD after using micro-peening (founded in a less degree of hardness)
  - average depth of roughness after using M 1 and M1+2 does not reach the levelling by using M 2 alone, but it is acceptable
- co-based alloy
  - shows the greatest reduction of average depth of roughness concerning the cast condition: average depth of roughness is reduced to a quarter after using M 1
  - micro-blasting and -peening effect a further reduction of RZD
  - micro-peening does not reach the levelling effect of micro-blasting and the combination of blasting and peening
- Titanium
  - clear decrease of average depth of roughness by micro-blasting
  - reduction of roughness depths of micro-peening does not reach levelling of micro-blasting
  - average depth of roughness of micro-peening is similar to using micro-blasting and micro-peening

5. corrosive behaviour

Micro-peening might have beneficial effects on corrosive behaviour. Therefore surface in pre-polished condition (wet-grinding on SiC-paper 1200) and the combination of wet-grinding and micro-peening were compared. (Fig. 19-21)

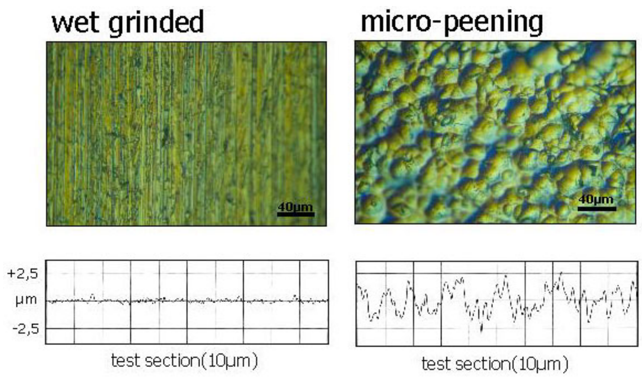


Fig. 19: high gold alloy

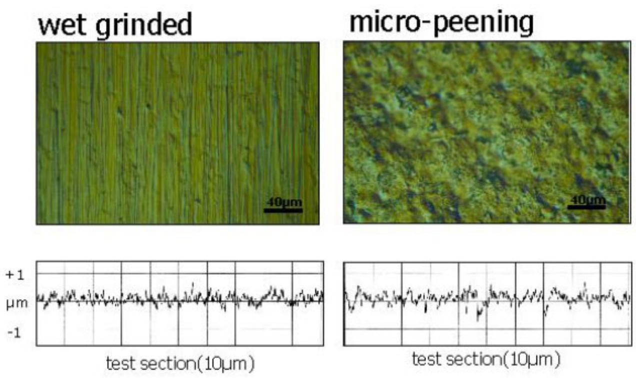


Fig. 20: co-based alloy

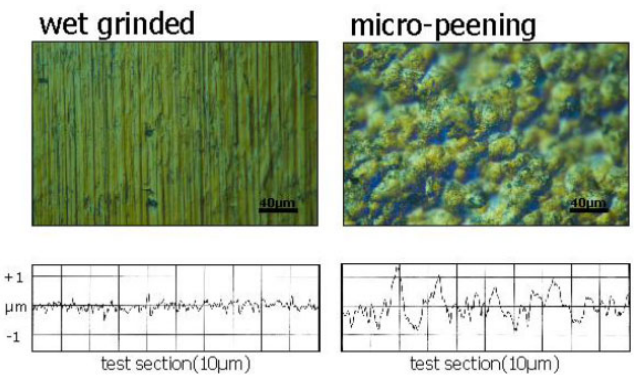


Fig. 21: Titanium

In comparison to the fine ground surface the micro-peening produces a spherical surface structure with higher roughness. As a result of this the real surface increases and might influence the corrosive behaviour, as to be seen in the following current-density-potential curves (Fig. 22-24):

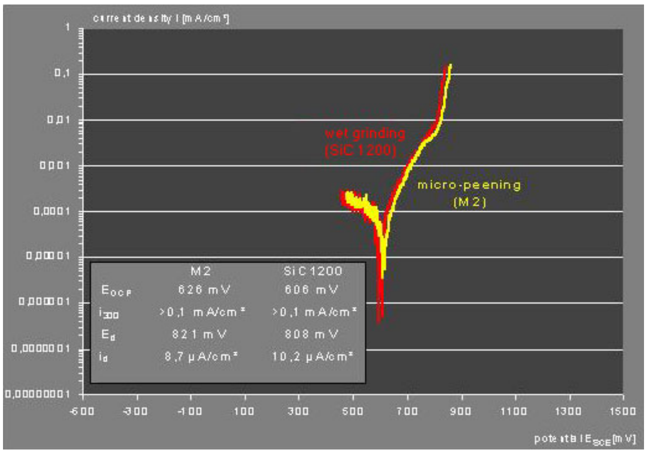


Fig. 22: *high gold alloy*: an influence of micro-peening on the corrosive behaviour is not to be seen.

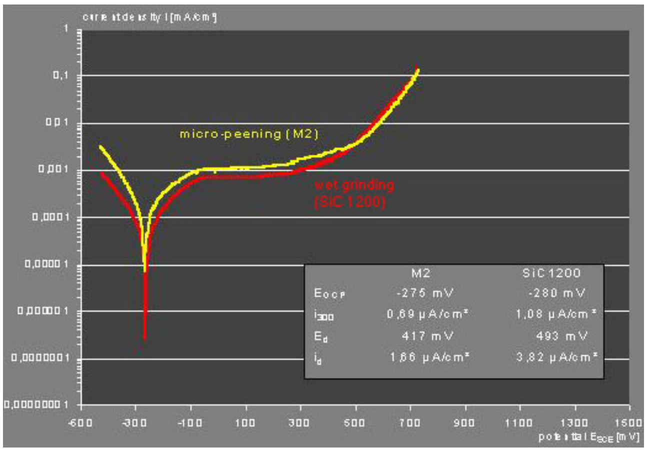


Fig. 23: *cobalt-based alloy*: it shows similar polarisation curves in both surface conditions; the current density in passive range is slightly increased

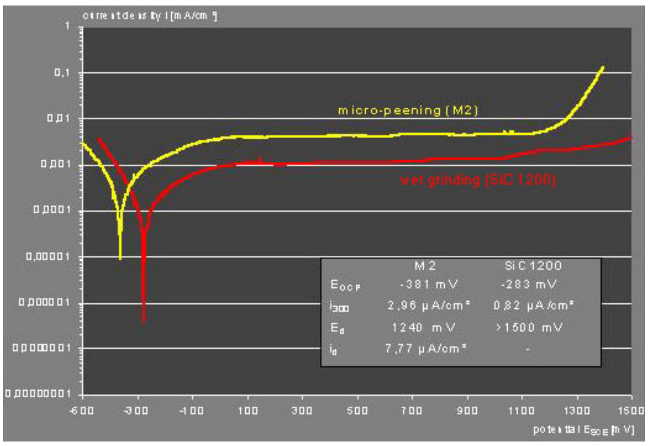


Fig. 24: *Titanium*: shows less passivation after micro-peening than in finely ground condition; current density i_{300} is increased

Conclusions

The following conclusions can be drawn from the results:

1. In comparison to traditional sandblasting the abrasive **micro-blasting** effects a profound cleaning of castings and a smaller surface roughness
2. **micro-peening** effects a slight levelling, plastic deformation and a compaction of the surface
3. Selection or combination of blasting media depends on the used material:
    - **High-gold alloys:** micro-peening is recommended; it results in a clear decrease of roughness with less impaction of blasting particles, the surface hardness is not increased.
    - For the treatment of cobalt-based alloy and Titanium-castings it is necessary to use the combination of micro-blasting and micro-peening.
    - **Cobalt-based alloys**: the Micro-Finishing effects a clear increase of surface roughness through micro-blasting and a higher degree of hardness by micro-peening.
    - **Titanium-castings**: the O_2-reach surface layer is reduced to a minimum by abrasive blasting; the surface is levelled and compressed; the surface hardness seems to be reduced (through removing of the reaction-zone).
4. The investigated dental materials have a **high corrosion-resistance**. In comparison to the fine ground surface condition the corrosive behaviour is not much influenced by micro-peening. Increased current density is caused by the higher real surfaces as a result of micro-peening.

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Abbreviations

RZD - average depth of roughness
M1 - abrasive blasting medium 1
M2 - spherical blasting medium 2

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