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Corrosion resistance measurements of dental alloys

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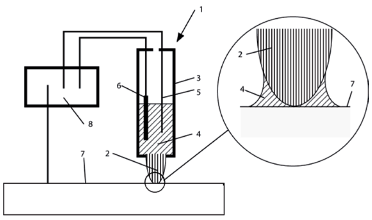
INTRODUCTION

Metals and metallic alloys still belong to the vital materials in dentistry, as they provide the necessary mechanical stability and elasticity to fabricate designated delicate constructs. Several patients, however, complain of incompatibility owing to corrosion of the applied metals. Consequently, the metallic parts are in vitro tested electrochemically to determine their resistance to corrosion. The better approach, however, are in vivo measurements. In vivo studies require the specific set-up accounting for the limited space, accessibility and restricted treatment period. Hence, the ec-pen1 has recently been developed and applied by dentists for direct measurements at the patient. These direct measurements help the patients to determine the reasons of inflammatory reactions as shown on the right around tooth 12 even if the hygiene is perfect.

EC-PEN

The field study is based on the ec-pen that consists of two electrodes located in the electrolyte reservoir. Pushing the tip towards the metal part of interest, electrolyte is released to wet the surface. This rather simple and fast procedure allows for electrochemical measurements, as in the present study performed with six dental alloys. The selected alloys are the Ni-based alloy Remanium CS (Dentaurium, Germany), the Co-based alloys Remanium 2000 (Dentaurum, Germany) and Bärlight (Ahlden GmbH, Germany), the Pd-Ag alloy Est. Actual as well as the Au alloys with higher and reduced concentration Est. Royal and Est. Plus (Cendres&Métaux SA, Switzerland) (Table I).



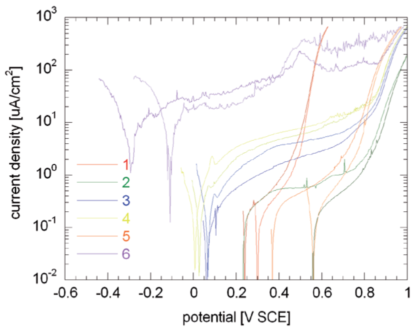
Tab. I Composition of dental metallic alloys used

No.	Exchange current density [μA/cm²]	Corrosion potential [mV SCE]
#1a	0.115	333
#1b	0.108	383
#2a	0.115	327
#2b	0.120	656
#3a	0.150	116
#3b	0.071	151
#4a	0.210	45
#4b	0.166	94
#5a	0.075	466
#5b	0.095	627
#6a	8.40	-338
#6b	10.4	-177

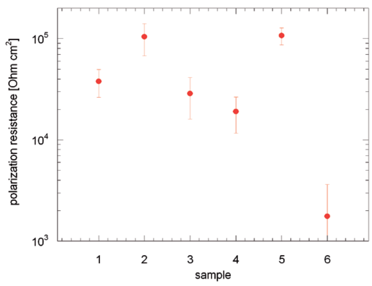
RESULTS

Tab. II measured with ec-pen a and b characterize different samples of the same alloy

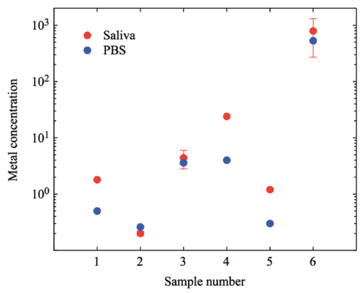
No.	Alloy	Au	Pd	Ag	Pt	Sn	In
#1	Pd-Ag		54	38		8	
#2	Au-high	81	2	3	12		1,7
		Co	Cr	Mo	Si	Ni	Ga
#3	Co-base	65	28	4.5	*		
#4	Ni-base	*	26	11	1.5	59	
		Au	Pd	Ag	Cu	Ga	In
#5	Au-reduced	44.6	39.5	5	*	1.4	8.6
		Co	Cr	Mo	Ni	Ga	In
#6	Co-base (Ga)	52	25	4.5		6	5



Classical potentalcurve of electrochemical measurement in corrosion testing: No.6 lowest resistence, No.2 highest resistence



Impedance-measurement with ec-pen 0,1 Hz and 5 sec



Corrosion study with standard Test Methode for pitting and crevice resistance (ASTM-Test modified) in ringer-solution (PBS) and artificial saliva. Sum of elementcon-centration in microgram, analysed with AAS-HGA-method.

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The corrosion resistance of the samples was investigated by means of polarisation scans . Based on the determined exchange current densities and the corrosion potential a classification of the electrochemical behavior is possible. However, the characterization time of several minutes is too long for in vivo application. Hence impedance measurements were performed at a single frequency and the polarization resistance was calculated. The higher the polarization resistance, the lower the corrosion rate of the dental metallic (Table II).

Tab. III summarized results of modified ASTM-test and impedance resistance with ec-pen

No.	Crevice corrosion [μg]	Impedance resistance [Ωcm⁻² 10⁴]
#1	1.8 ± 0.3	3.9 ± 1.2
#2	0.21 ± 0.10	10.5 ± 3.5
#3	4.4 ± 2.0	3.5 ± 2.5
#4	24 ± 16	2.1 ± 2.2
#5	1.20 ± 0.08	9.9 ± 2.2
#6	791 ± 30	0.15 ± 0.30

The ec-pen permits impedance measurements to determine the corrosion potential and the polarization resistances. Table III summarizes the results. As expected, Co- and Ni-based alloys exhibit low corrosion resistance, while the noble metals show much better values both in buffered saline and artificial saliva. Corrosion and polarization resistance data correlates well with the results of crevice corrosion (cp. Table III, Fig. 5 and 6).

DISCUSSION

Based on the present results a good reproducibility of the electrochemical measurements by means of the ec-pen was obtained. The technique allows for reliable differen-tiation of the corrosion resistance of dental metals. Moreover, the use of an impedance measurements that lasts only 10 seconds is a promising tool for in-situ characterization of dental alloys. The ec-pen is in this size and form inpracticable for use in the mouth. The ec-pen should have the same shape like a dental bur handtool.

CONCLUSION AND ACKNOWLEDGEMENT

The electro-chemical measurements using the ec-pen are reproducible and allow differentiating between different dental alloys with respect to their corrosion resistance. The obtained data correspond to the ASTM standard test methods for pitting and crevice corrosion resistance2. Consequently, the relatively simple and small ec-pen is a promising tool for patientrelevant impedance measurements to reveal the metal compatibility in vivo. The authors thank the suppliers of the dental alloys for providing the materials for free.

REFERENCES: 1 M. Büchler (2004) GWA. Gas, Wasser, Abwasser 84:575-80. 2 ASTM Standard Test Methods for Pitting and Crevice Corrosion Resistance. Designation: G48-76 in: Annual book of ASTM standards, vol. 03.02. Philadelphia, PA, USA: American Society for Testing and Materials, 1995.