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Influence of organic electrolyte components on corrosion behaviour of dental alloys

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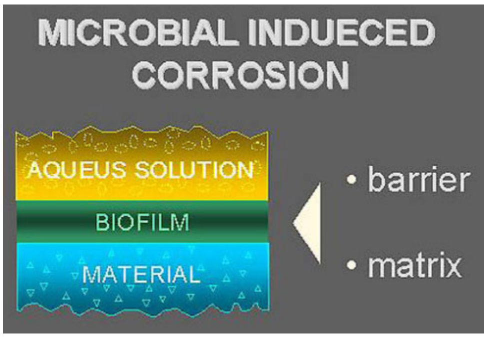
Introduction

Metallic biomaterials are integrated in the oral cavity as crown restorations and prosthesis for a long time. There they interact with the oral environment and oral tissues. Among the organic components of saliva the proteins prevail. They influence the biofilm formation such as the pellicle formation, the plaque formation and the plaque metabolism. As a consequence biochemical and microbial active depositions and electrochemical dissolution processes may occur. Dental alloys can cause incompatibility reactions in the oral environment, caused by corrosion processes. Incompatibility reactions of metallic biomaterials suggest the introduction of biological test regulations which currently do not exist in a satisfactory manner. In vitro tests under simulated biological conditions in a laboratory bioreactor are quite suitable to evaluate metallic dental materials and to estimate the biocompatibility.



Aim of the Study

The purpose of the current study is to investigate corrosion processes and superficial reactions of clinical relevant dental casting alloys in dependence of organic electrolyte components. For this reason potentiodynamic and galvanostatic polarization measurements should be carried out in a laboratory bioreactor.

Material and Methods

Fig. 1: Test system with bioreactor and potentiostat; electrochemical measuring rod is shown in enlargment

Measuring Arrangement

reaction vessel:	bioreactor
working electrode:	test material

counter-electrode: Pt-foil

reference electrode: Ag/AgCl-electrode
current and potential measurement: computerized potentiostat

Conditions of Environment:
temperature T=37 °C
high N_2-level
stirring speed 600 U/min

	Au	**Pt**	**Pd**	**Ag**	**Cu**	**Ga**	**In**	**Sn**	**Ir**	**Zn**	**other**
Degudent H	84,8	8,0	5,0	-	-	-	2,5	-	-	-	Ta
Biorplid Ker. K99	92,5	2,9	3,5	-	-	-	-	1,0	-	-	Re
Cehadentor Ker. SF3	51,5	-	38,4	-	-	1,6	8,5	-	-	-	-
Depalor	17,0	1,5	69,4	-	-	6,0	2,0	4,0	-	-	Ru
Pangold Ker. SF2	1,5	-	78,5	-	11,5	8,5	-	-	x	-	-
	Ni	**Co**	**Fe**	**Cr**	**Mo**	**Nb**	**Ti**	**W**	**Ga**	**Si**	**other**
Remanium 2000	-	61,5	-	25,0	7,0	-	-	5,0	-	1,5	-
Remanium CS	59,0	0,5	1,2	26,0	11,0	-	-	-	-	1,5	C,B,Ce,Al
Titanium	-	-	0,2	-	-	-	99,6	-	-	-	O

Sample Preparation
from 100 % new material of alloy discs with a diameter of 12 mm were cast
* 0.1 mm of the specimen was removed all-round by wet polishing (SiC paper).
* 1 hour before each measurement wet polishing with 1200 SiC paper

POTENTIODYNAMIC POLARIZATION

Potentiodynamic polarization is an electrochemical measuring method recording electrochemical current densities in dependence of the dynamic potential at the surface of the working electrode. The polarization speed is one of the most important parameters. From current density-potential-functions characteristic values e.g. zero current potential (E_Z) or pitting corrosion potential (E_D) respectively corresponding current densities could be determined.

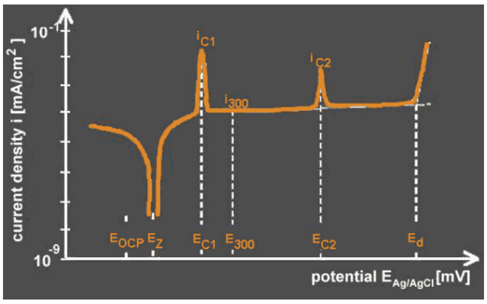


Fig. 2: Flow chart of current density-potential-curve with parameters

Electrolytes

1. 0.9% NaCl solution with a pH value of 7.4 (0.9% NaCl, pH=7.4)
2. Dextrose food solution, pH value 7.4 (DNB)
3. Dextrose food solution, pH value 7.4
   with Streptococcus mutans OMZ 176 (Strep. mut.)

Electrochemical Measurement

1. rest potential: 1 hour after measuring start
2. cathodic polarization: 150 mV from rest potential
3. anodic polarization: from previous potential to E=1500 mV
   or i=0.1 mA/cm^2

polarization speed: cathodic and anodic 0.2 mV/s

Long-term Behaviour

Measurements of rest potential and polarization was carried out in DNB after different times (0, 6, 12, 24, 48, 72 h). From current density-potential-functions current density values at a potential of 300 mV were determined.

GALVANOSTATIC POLARIZATION

Galvanostatic polarization is an electrochemical measuring method recording electrochemical potentials in dependence of measuring time at given current density values. The stationary value of the measured potential is designated as the so-called galvanostatic pitting corrosion potential (E_D). The relative corrosion resistance Delta-E is defined by the difference between rest potential and pitting corrosion potential. An analytical determination (AAS) of released ions of electrolyte is strongly suggested.

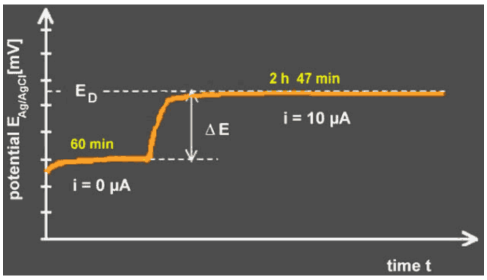


Fig. 3: Flow chart of potential-time-curve with parameters

Electrolytes

1. 0.9% NaCl solution with a pH value of 7.4 (0.9% NaCl, pH=7.4)
2. synthetic saliva according EN 30993, pH value 7.4 (CEN-saliva)
3. synthetic saliva according EN 30993, pH value 7.4
   with 1 % bovine serum albumin (CEN-saliva + BSA)

Electrochemical Measurement

1. rest potential: 1 hour after measuring start
2. polarization: record the galvanostatic potential at a current density of 10 µA/cm^2 about 2 h 47 min

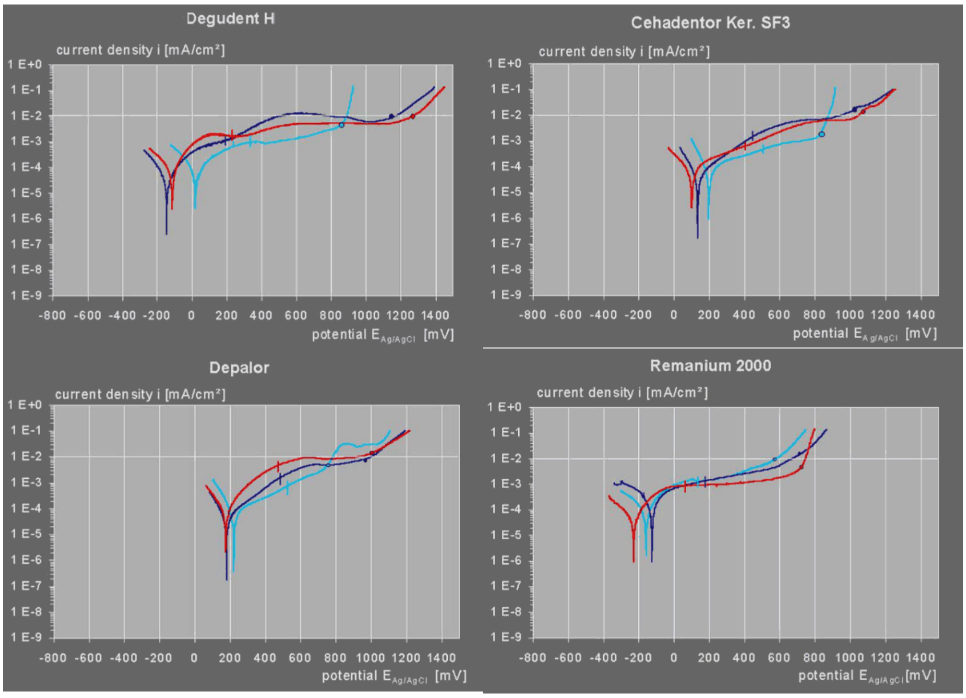
Chemical Analysis

Atomic absorption spectroscopy (AAS) of electrolytes to ion release determination

Results

1. POTENTIODYNAMIC MEASUREMENT

Potentiodynamic determination describes the corrosion behaviour about complete potential area. **Precious alloys** showed low passive current densities in NaCl solution. A change of electrolyte (dextrose food solution with and without Strep. mut.) caused an increase of passive current density like also a displacement of the breakdown potential to higher values. Similar results were found for **cobalt base alloy. Nickel base alloy** showed lowest corrosion resistance in all electrolytes. Among the alloys examined **titanium** possessed the smallest tendency of electrochemical dissolution.



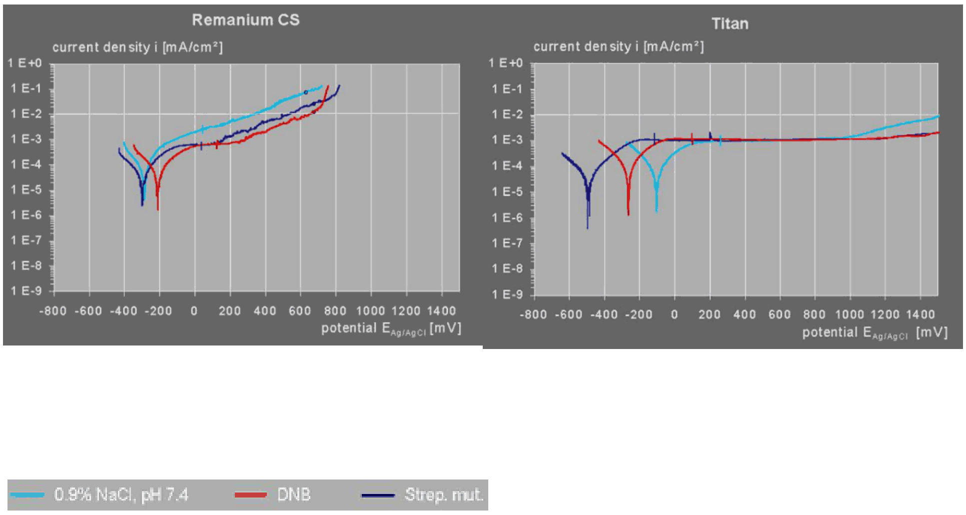


Fig. 4: Current density-potential-curves of test materials in different electrolytes

Long-term behaviour in dextrose food solution

Long-term measurements were carried out to investigate the influence of biofilms on polarization behaviour. First measurement was characterised by high passive current densities (i_{300} ~ 2µA/cm^2) and breakdown potentials between 1180 and 980 mV. Subsequent measurements showed decreasing passive current densities whereas breakdown potentials were not modified.

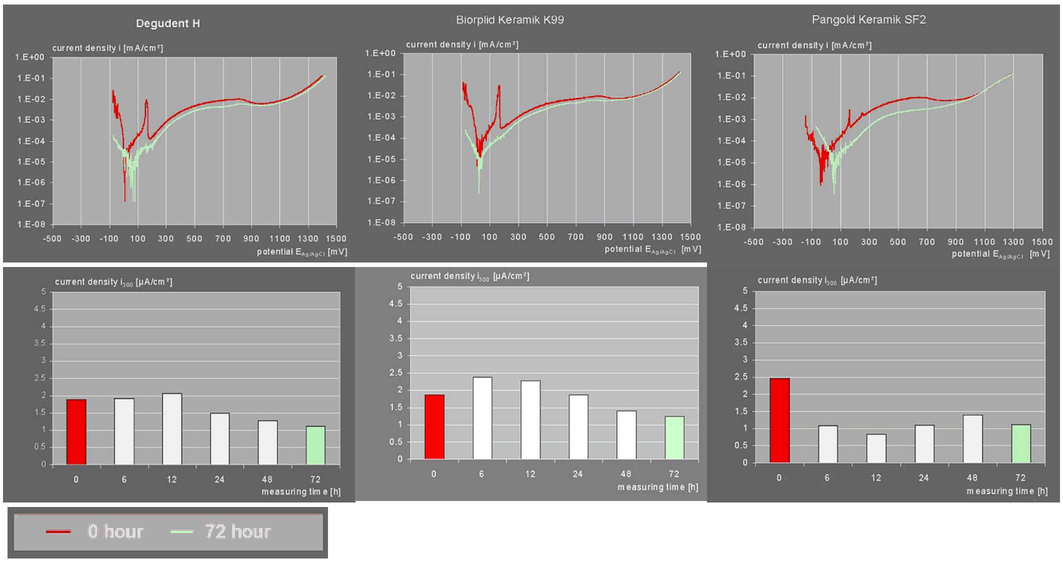


Fig. 5: Long-term behaviour of test materials in dextrose food solution after different times

a) current densities-potential-curves
b) current densities i_{300} (at a potential of 300 mV)

2. GALVANOSTATIC MEASUREMENT

The galvanostatic measuring method guarantees the determination of the lowest pitting potential. Below this potential no activation of pitting corrosion occur. By means of relative corrosion resistance Delta-E a similar ranking of alloys were found in NaCl solution like potentiodynamic method. An addition of albumin affected a minor decrease of relative corrosion resistance particularly. On the other hand for 3 alloys a significant ion release was determined by means of AAS.

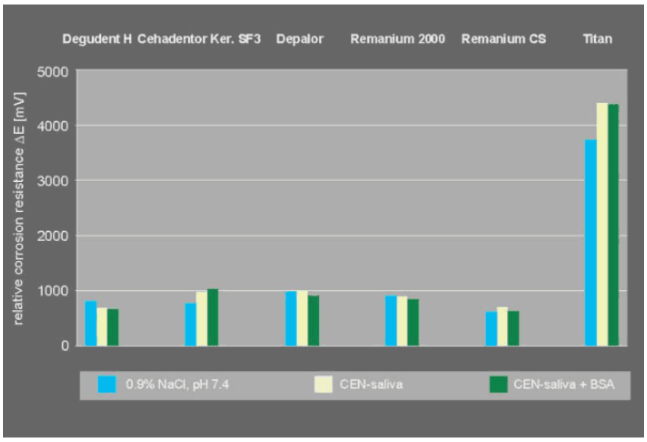


Fig. 6: Relative corrosion resistance Delta-E of test alloys in different electrolytes

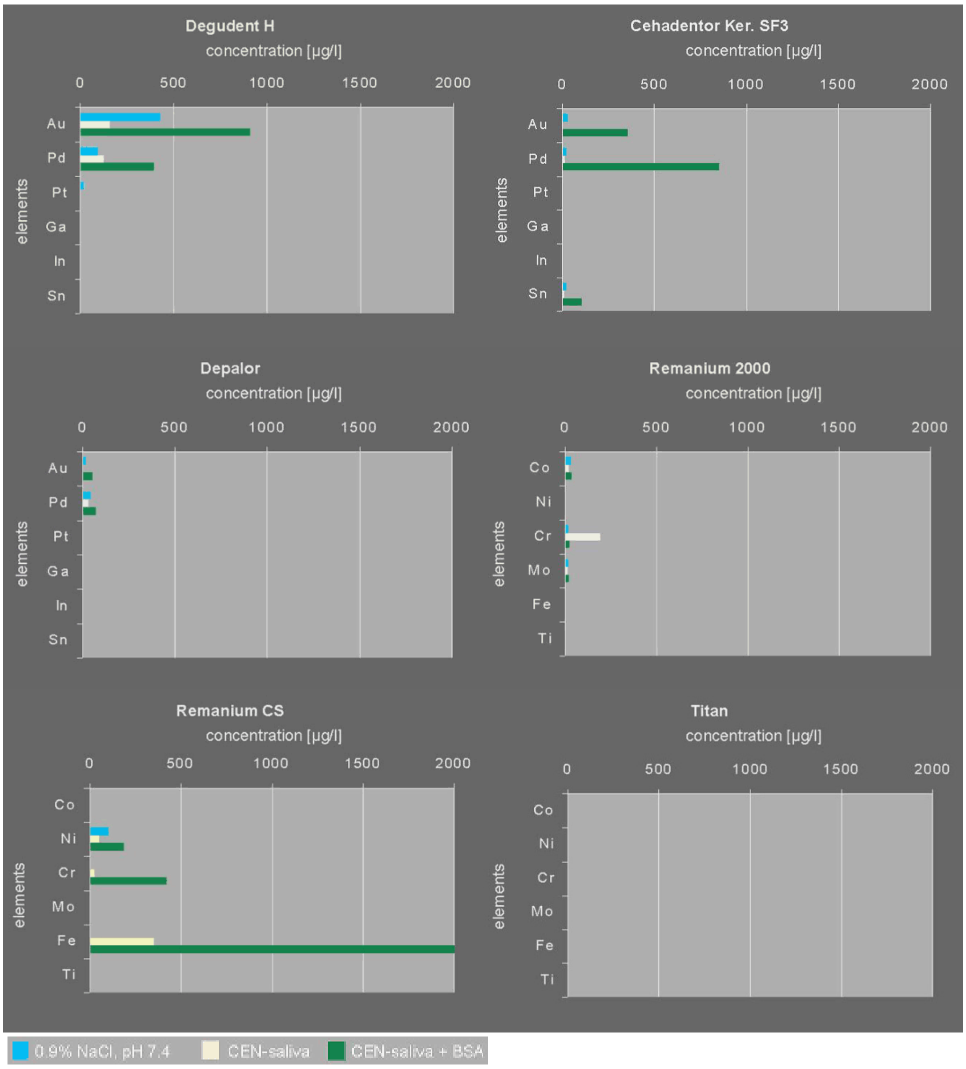


Fig. 7: Electrolyte concentration of released ions of tested alloys

Conclusions

Potentiodynamic and galvanostatic measurements have been carried out with the aim to investigate the influence of biological environment on corrosion behaviour of dental casting alloys. Both electrochemical methods are suitable to find comparable results. The influence of the composition of electrolyte on the corrosion behaviour of several types of dental casting alloys was shown.

By means potentiodynamic method the use of dextrose food solution with or without Strep. mut. effects an increase of passive current density, which decreased after longer measuring times. This phenomenon can be possibly ascribed to a formation of biofilm.

In general, from a variety of dental casting alloys a higher element release occurred in multicomponent electrolyte with protein compared with electrolytes without protein.

A ranking of corrosion behaviour of relevant dental casting alloys was found by both electrochemical methods. The potentiodynamic method describes the passive domain more clearly, however galvanostatic methods can be connected with a chemical analysis of electrolyte regarding ion release.

Corrosion tests should been carried out under biological environments. Reproducible results can be obtained with described bioreactor technique.

This poster was submitted by Dipl.-Ing. Ines Orlob.

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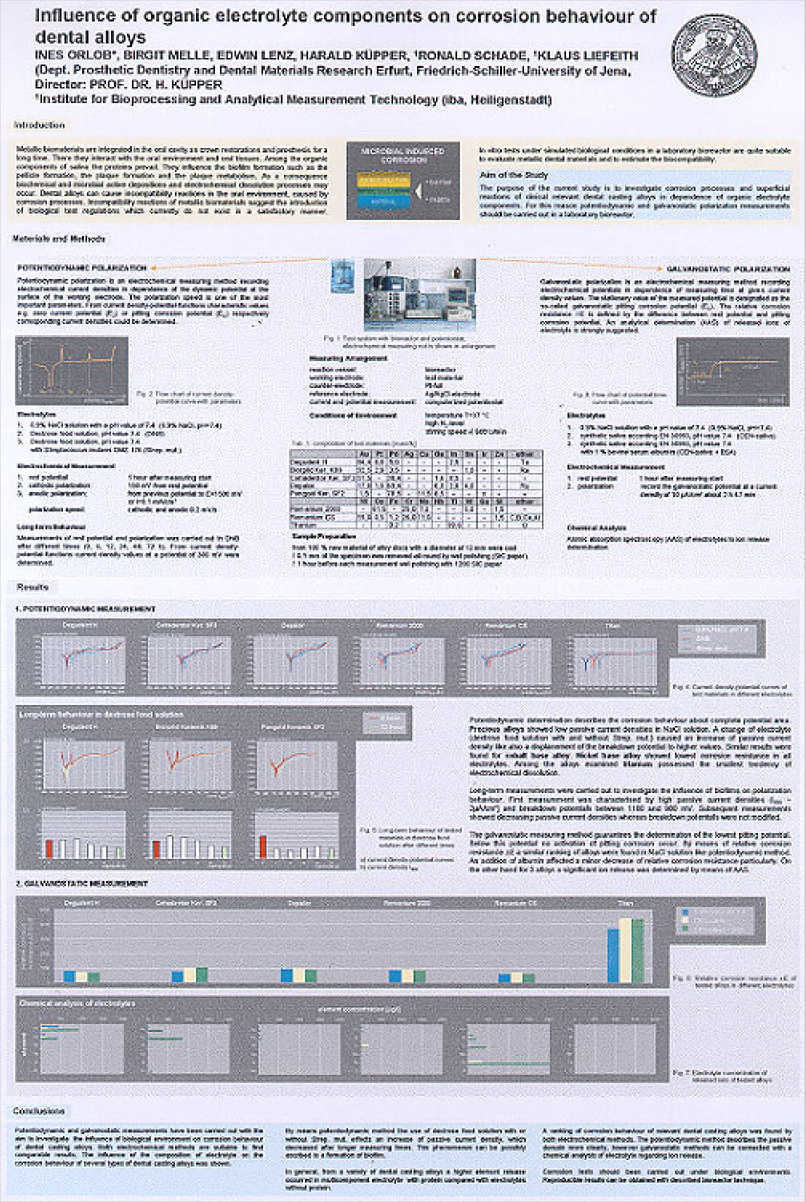

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