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Corrosion resistance measurements of dental alloys

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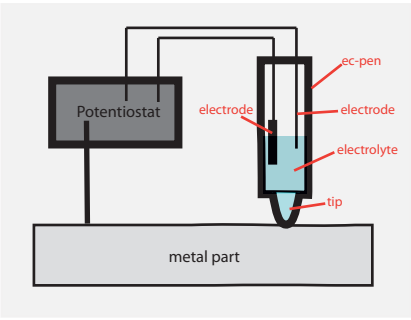
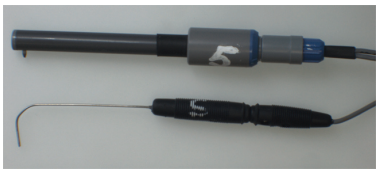
INTRODUCTION

Metallic alloys are widely used materials in dentistry, because of the mechanical stability and elasticity. Common dental metallic alloys are classified as high or reduced gold, Co-based, Ni-based, or Pd-Ag alloys. One of their main disadvantages, however, is the limited corrosion resistance, especially if more than one metal was incorporated in the patient's oral cavity. Therefore, many patients complain of taste irritations, metal taste, tongue burning, dry mouth, pain or irritation of the mucous membrane. These phenomena are often the result of metal ions released from the applied alloys during corrosion. Therefore, it is highly desirable to establish an objective tool for the in vivo measurement of corrosion resistance, as the recently introduced ec-pen.[1] The thin electrodes allow for electrochemical measurements directly at different locations within the oral cavity of the patient, which finally allow identifying the ion-releasing parts of the applied dental metals.

EC-PEN

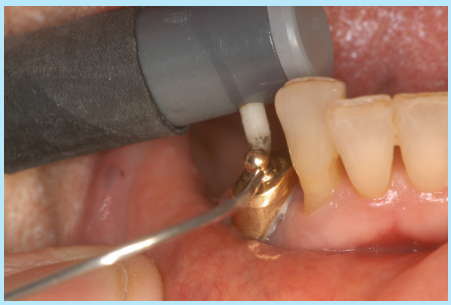
The present study is based on the ec-pen, which contains two electrodes as sensing heads (see figure below). Pushing the white-gray coloured tip towards the metal part of interest such as a crown, electrolyte is emitted to wet the surface and form electrical contact. This simple and fast procedure allows measuring the corrosion resistance within an area of about 2 mm². The present investigation comprises 26 patients, who received a crown or dentures and, subsequently, have complained of one of the symptoms mentioned above. The examined dental materials include alloys with high and reduced gold content as well as cobalt-based alloys, exclusively from well-established suppliers, as verified by means of energy-dispersive X-ray fluorescence analysis (EDX).





RESULTS

The ec-pen serves for impedance measurements to determine the corrosion potential of dental metals as illustrated in the image below for the *in vivo* situation. The visual inspection permits the discrimination between different levels of corrosion, which might be classified according to three levels: below detection limit, perceptible, and major corrosion. In more than 40% of the patients, corrosion was explicitly detected. In these cases, the measured impedance resistance was definitely well below 200 Ωcm². Comparing the visual inspection with the ec-pen experiments, we have found a strong correlation. Impedance resistance values for gold alloys below 150 Ωcm² correspond to major corrosion, data between 150 Ωcm² and 250 Ωcm² can be associated with a perceptible level of corrosion, and an impedance resistance measurement with results above 250 Ωcm² does not exhibit any detectable corrosion on the metallic parts.



DISCUSSION

The electrochemical *in vivo* measurements of the impedance and the phase elucidate the problems in the quantification, as seen by the rather large error bars. For the gold alloys, which are quite often damaged by corrosion, the impedance is a reliable parameter for the quantification of metal ion release. Here, the phase does not help discriminating the different degrees of corrosion. The much more stable cobalt-based alloys, however, show significant differences in the phase, which enables the dentist to validate the impedance relashionship.

Impedance [Ωcm²]

	with corrosion	without corrosion
High Au content alloy	114 ± 51	359 ± 148
Reduced Au content alloy	126 ± 57	490 ± 29
Co-based alloy	86 ± 44	744 ± 692

Phase [degree]

	with corrosion	without corrosion
High Au content alloy	26 ± 13	30 ± 26
Reduced Au content alloy	27 ± 19	23 ± 9
Co-based alloy	20 ± 17	60 ± 11

CONCLUSIONS

The results apply for the average values. Unfortunately, individual experiments can lead to mis-interpretations. Therefore, several data have to be collected to grant sufficient statistics. Furthermore, faults cannot be entirely excluded. First, the composition of saliva is patient-specific. Second, minor variations in the chemical composition and microstructure of the dental alloys from the different suppliers exist. Third, the handling of the ec-pen can prove difficult for small metallic parts, which can be even covered by non-conducting ceramics or polymers. Finally, metals are frequently soldered, which can induce strong corrosion and can be identified performing EDX-measurements on fragments. Nevertheless, the study on 26 patients has demonstrated that trained dentists obtain reliable data, which support the quantification of corrosion. Consequently, the dentist can treat the patient to eliminate the sources of metal ion release in dedicated manner.

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