Corrosion of dental NiCrMo alloys

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Fig. 3.6 gives figures published by Marek [1984,Figs 3-4] of the effect of abrasion upon the corrosion potential of several amalgams. Fig. 3.7 similarly gives the effect of abrasion upon the corrosion potential of Wironium [Demel85, Fig. 3]. Abrasion is seen to decrease the corrosion potential strongly. Similar curves have been given for amalgam [Marek65b,Figs 11-12,15-16] and for a gold alloy (Degulor M) and a CoCr alloy (Remanit) [Marek65c,Figs 29-30,35].

3.4.2 Significance
In this study the potential of a restoration is called the 'electrical potential of a restoration', and not the 'corrosion potential of a restoration', as the potential is not necessarily a corrosion potential. The potential may instead be built up during simultaneous reduction (for instance of oxygen) and oxidation (for instance of lactic acid) of some salivary components at the metal surface in the absence of an anodic current caused by metal ion release [Yontc86].

Presently, little is known about the significance of the potential of a restoration. The potential can indicate whether a metal is in a passive or active state. Noble metals tend to have higher potentials, but some passive metals also show high potentials.

Some EPRs of amalgams are lower than the H+-reduction potential: -420 mV at pH 7. Such low potentials are a necessary condition for hydrogen damage [Bockr70,p.1342], consequently hydrogen damage is possible in amalgam restorations, and could indeed be the mechanism behind delayed expansion of amalgam [Schoo50, Phill82,p.344]. This should be verified by EPR measurement.

Most EPRs of amalgams, and all EPRs of the other alloys, are however higher than the H+-reduction potential. Contribution by H+-reduction [Phil82,p.292] to the cathodic current during the in vivo corrosion of dental restorations will consequently be rare.

Rheinwald initially claimed a potential difference between pairs of restorations larger than 100 mV to be pathological [Rhein53], but later retracted this assertion [Marek65a].

3.4.3 Possible applications
Correlation should be established between EPRs and the effects attributed to the corrosion of dental restorations mentioned at the beginning of Chapter 1.

The distinct influence of salivary or food components upon the in vivo corrosion of dental restorations can be studied by determining the effect upon the EPR of rinsing the mouth with solutions containing those components. The effect of polishing and abrasion can similarly be determined, which is of importance for wear corrosion.

The good electrical contact between the probe and the metallic restoration can be used for other purposes, such as recording the current that flows after connecting two restorations.

CHAPTER 4
Conclusions

On corrosion of dental NiCrMo alloys

• The uniform corrosion rate of dental NiCrMo alloys can be measured by the potentiostatic decayation technique and by chemical analysis by means of ICP-AES of the medium of a corrosion test cell.
• The uniform corrosion rates of dental NiCrMo alloys are low and decrease monotonously with time, approaching zero. Hence uniform corrosion by itself is probably unimportant; in the long run, wear, pit and crevice corrosion may be more important. The wear corrosion current is probably similar to the decaying corrosion current during uniform corrosion; hence the importance of an understanding of uniform corrosion.
• The uniform corrosion rate of dental NiCrMo alloys decreases with the molybdenum content.
• The present study has not considered the influence on corrosion of metallurgical properties such as pore presence and heat treatment. To obtain a comprehensive picture the effects of these factors should be studied.
• The uniform corrosion rate of passive alloys cannot be measured with the polarization resistance method, as the Stern-Geary equation is not valid in the case of passivation.
• The cathodic current of dental NiCrMo alloys, and possibly of other dental alloys as well, shows Tafel behavior. This allows the determination of the corrosion current from the corrosion potential.
• An equation similar to the Stern-Geary equation can be derived for passive alloys for which the anodic current decreases with time as e^-γt, the cathodic current shows Tafel behavior, and battery behavior (section 2.7.3) is absent.
On in vivo potentials of dental restorations

- The potential can be measured accurately.
- The accuracy of measurement is improved by:
  - not disturbing the restoration surface; for instance, a scratch can cause the metal to become active, causing in turn the potential to fall.
  - not disturbing the plaque covering the restoration. Plaque is anaerobic, and its disturbance would allow oxygen from air to reach the restoration, which in turn would cause its potential to rise.
  - avoiding the use of a probe tip consisting of platinum or palladium. These metals can interact with hydrogen and hydrogen sulfide, both present in the oral cavity, causing the potential to fall.
  - insulating the probe tip with wax, minimizing its interaction with salivary redox couples, which would change the potential of the probe tip.
- In 28 healthy subjects
  - the potentials of amalgam restorations tended to increase with the age of the restoration,
  - there was large scattering of the potentials,
  - potential differences larger than 50 mV between pairs of restorations were present in half the subjects. This large incidence shows that it is improbable that such potential differences are pathological.

General remarks

In order to obtain a good model of corrosion in the oral cavity and its effects, the following should be established:

a. The chemical composition of the oral cavity, including its variation with time and variation among individuals.

b. The types of corrosion that can occur (uniform corrosion, pit corrosion, galvanic corrosion, wear corrosion, etc.).

c. The effects of potentials and currents due to corrosion, including interaction of metallic restorations with physiological voltages and currents in the oral cavity.

d. Dose-effect relationships for corrosion products and electrical currents caused by corrosion, including the dispersion in intensity of the effects.

Presently, dental alloys are, to a large extent, tested clinically. For this reason the corrosion behavior of individual dental alloys should be monitored intensively in the clinic.

As long as a comprehensive model of the corrosion of dental restorations is absent, the formulation of norms for permissible corrosion rates of dental alloys is premature. The polarization resistance method is unsuited for the formulation of such norms, which contrasts with the statement 'Anodic polarization techniques are now almost universally accepted as the way in which corrosion resistance of dental alloys should be quantified' [VanNo89].

The author agrees with the following statement:
'Since restorations in the mouth are continuously subjected to abrasion and wear, protocols for corrosion assays of dental alloys should take this aspect into consideration' [DeMe85].

The methods developed in this study for the determination of in vitro corrosion rates and in vivo corrosion potentials are also of interest for alloys corroding in environments different from the oral cavity.

7 In cells electrical potential differences are present across many biomembranes and these potentials fulfill many physiological functions.