The Nickel Misconception

from: Dr. R. Strietzel, BEGO Bremer Goldschlägerei

Introduction

Recently a number of articles have appeared in the press that describe nickel and alloys containing nickel as toxic or at least as a cause for concern for biological reasons. In the pursuit of demagogic interests, half-truths are being propagated and facts (knowingly?) withheld here. By contrast, international literature describes around 20 to 250 cases (27, 28) of allergies caused by dental alloys containing nickel where orthodontic wires made of special steel are also used. Even if one took into consideration all known and documented cases in relation to the **annual** production of Wiron 99/BEGO, the potential risk of being sensitised through this alloy is lower than the risk of a food allergy (e.g. to strawberries). The following article will present a few of the facts in connection with the nickel issue.

Nickel in the environment:

The nickel concentration in the Earth's crust is around 0.015%. This makes nickel the 22nd most common element. Through the combustion of coal alone approx. 84 t of nickel are emitted annually in Germany (48). Thus, nickel is a ubiquitous metal found everywhere. Around 650,000 t of nickel a year are processed for industrial applications. The majority is used for the production of special steels, in the oil industry as well as for catalyzers in the chemical industry.

Nickel in dental alloys:

Nickel is the main component of nickel-chromium alloys and nitinol wires (Ni55Ti45) (9) as well as a component in several solders (AuNiZn type) and in steels for orthodontic wires (9).

Up to 70% of nickel-chromium alloys are composed of nickel. The decisive factor for the release of nickel through corrosion processes, however, is not the amount of nickel, but the quantity of chromium (Fig. 1). There are two types of nickel-chromium alloys. One group contains considerably more than 20% chromium while the other has less than 15%. The latter group also includes alloys to which beryllium has been added.

As shown in Fig. 1, the corrosion characteristics depend to a substantial extent on the chromium content (18-23, 29-31, 45, 49, 52-57, 69, 70). A chromium content of below 15% leads to increased ion release in **all** alloy components since the chromium share is not sufficient to passivate the entire surface. These alloys must be regarded as non-mouth-resistant. This group also includes alloys containing beryllium. It has been shown that the addition of beryllium leads to increased ion release (12, 13, 22, 71).

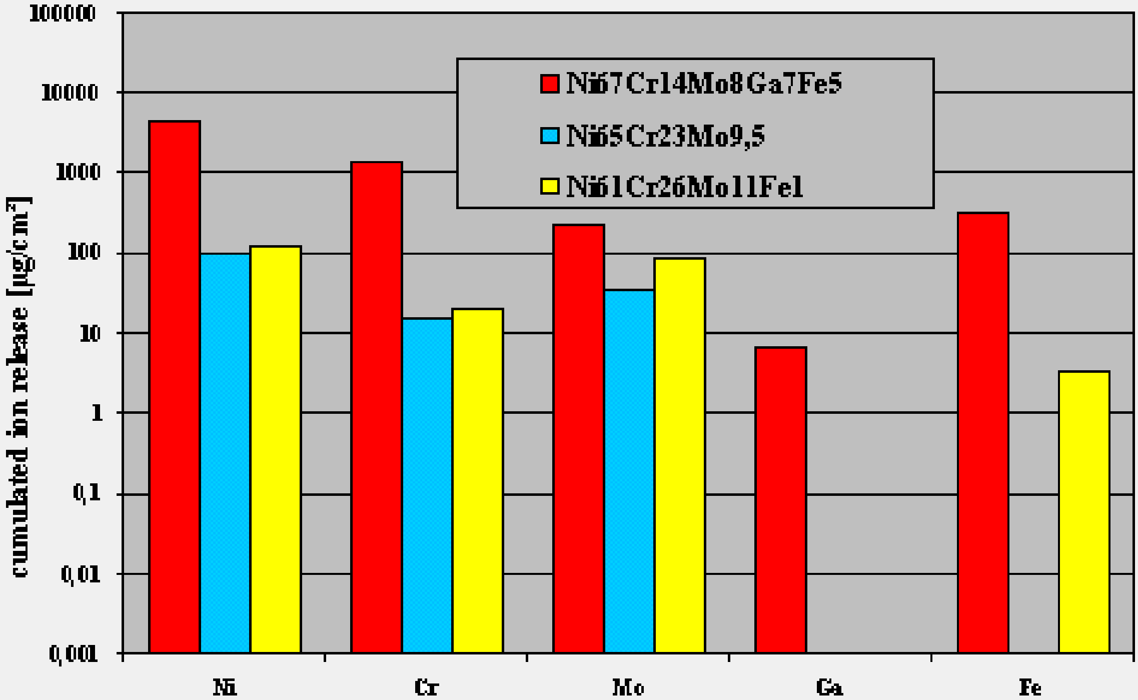

Fig. 1: Ion release as a function of chromium content (68, 69)

Fig. 2 shows the total ion release cumulated over four weeks for precious-metal and non-precious-metal alloys, for titanium and for amalgams. It has been demonstrated that nickel-chromium alloys with a chromium content over 20% can compete with cobalt-chromium alloys, which are considered to be mouth-resistant.

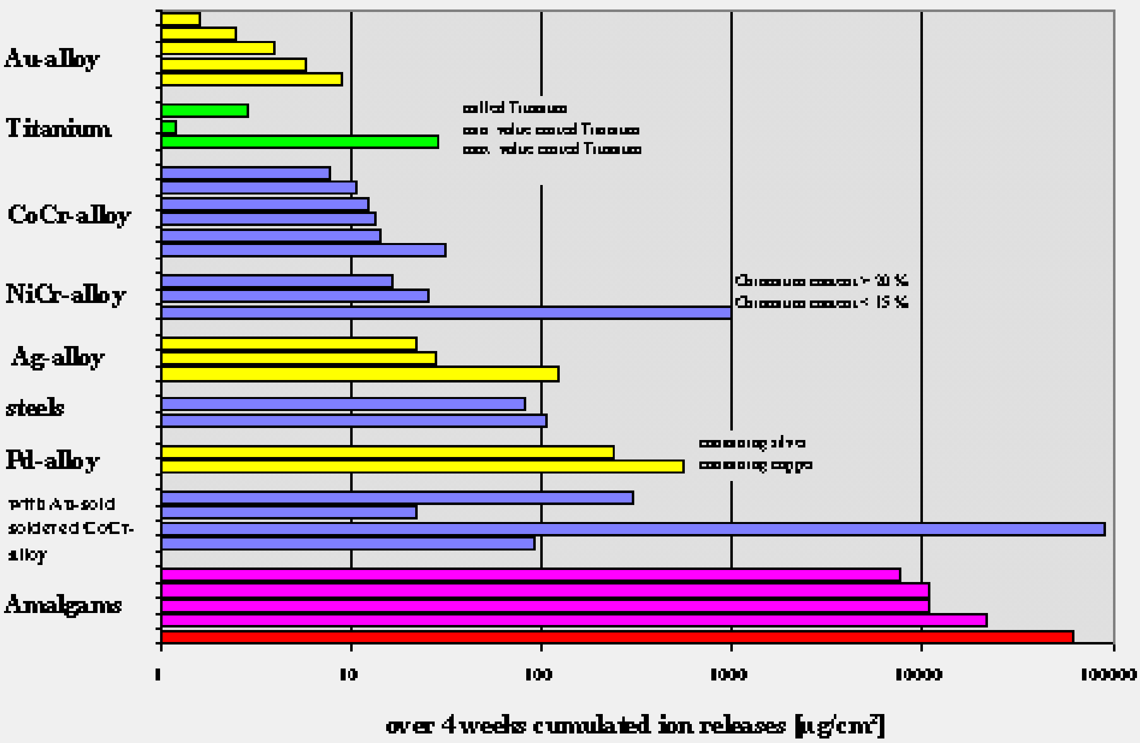

Fig. 2: Comparison of total ion releases of dental alloys, titanium and amalgams (logarithmic graph) cumulated over 4 weeks

Recasting tests and thermal treatments (14, 34, 38, 47, 59, 72, 73) show that nickel-chromium alloys display only slight changes due to corrosion behaviour, provided that the chromium content is adequate. Ceramic firing also produces only minimal increases in ion release (8, 33, 70). In addition, nickel-chromium alloys are insensitive to inorganic (chlorides, thiocyanates, fluorides (25, 70)) and organic anions (lactates, acetates, oxalates, tartrates (25)). Corrosion of mouth-resistant nickel-chromium alloys is avoided through the use of commercially available toothpastes and fluoridation agents (25).

Nickel is not only released due to corrosion of nickel-chromium alloys, orthodontic wires also release nickel. Steel wires (32, 36, 37, 40, 41, 51, 64) have higher corrosion rates than nitinol wires (10, 16). Orthodontic wires display about ten times the ion release of nickel-chromium alloys. Corrosion is reinforced during soldering. In this case, however, the solder acts as an anode and dissolves to an increasing extent (4, 7, 44, 58, 60, 61, 63). The formation of galvanic elements of orthodontic apparatus with other dental alloys or amalgams also leads to higher corrosion (5, 6).

Allergic reactions to orthodontic wires have been described (15, 35). Even if a nickel allergy exists, however, a reaction need not arise in the oral cavity (3). The higher ion release of orthodontic steel wires in comparison to nickel-chromium alloys leads to undesired effects in in-vivo tests (24, 26). Clinical cases rarely occur, however.

Biology of nickel:

Nickel numbers among the essential elements (46, 50). The human body contains about 10 mg and a daily uptake of 100 µg of nickel is recommended (48). ADRIAN refers to a daily uptake of 160 - 900 µg of nickel through food (1). Fish consumption (2, 39) may lead to a significant nickel uptake, but nuts and products made from nuts can have even higher nickel concentrations. These high values are not reached even by the initial corrosion of nickel-chromium alloys with insufficient chromium content (Fig. 3). If you compare the maximum nickel releases of Wiron 99, a nickel-chromium alloy with a chromium concentration of 23%, to the recommended daily uptake and food intake, you will see that the concentrations of released nickel ions under different, even extreme experimental conditions are far below the amount taken in through food. Even under the selected corrosive experimental conditions, the alloy proves to be adequately resistant to corrosion. It can be presumed that milder conditions prevail in the oral cavity (higher pH values, lower anion concentrations) and nickel release is therefore even lower under clinical conditions.

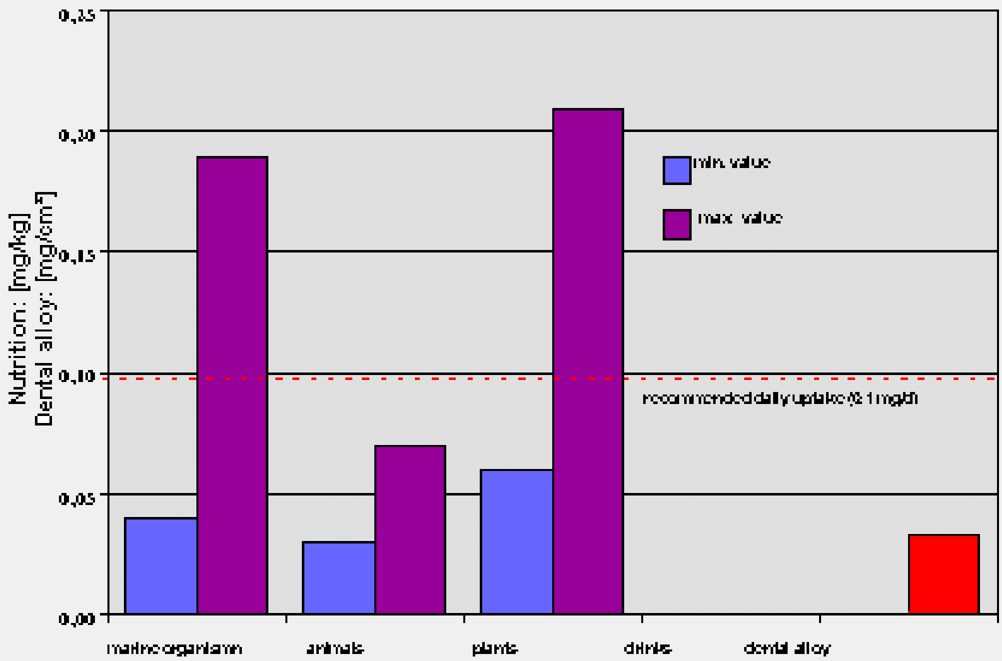

Fig. 3: Nickel uptake through food and through corrosion of dental alloys (nickel release in the first week of a nickel-chromium alloy with a chromium content of less than 15% was taken as the maximum value here)

Inorganic nickel compounds are not easily taken up out of the gastro-intestinal tract and apparently do not accumulate in the human body (17). They are primarily excreted via the kidney (11).

Nickel poisoning mainly affects the digestive tract and the central nervous system. Organic nickel compounds, by contrast, tend to attack the lungs, brain, liver, kidneys, suprarenal glands and spleen and display a high toxic effect (42), whereas nickel dust affects the lungs (11). Inorganic nickel compounds, which are very water-soluble in most cases, show embryotoxic effects in animal experiments (42). Nickel has a cytotoxic effect and displays the strongest reactions in animal experiments (in the form of nickel-chromium alloys - the chromium concentration must be examined here, see below) (62). A strong dose-dependent effect of the cytotoxic behaviour can be observed. Therefore, the test results cannot be transferred without a closer analysis. All metals and thus nickel, too, as well as compounds with a low molecular weight are not detected by the immune system and therefore cannot trigger any allergic reaction. Only if these substances are coupled to high-molecular-weight substances, such as proteins, can the immune system be activated. Like all metals, nickel acts as a so-called hapten (17).

Nickel compounds are generally very water-soluble and are thus quickly transferred into the gastro-intestinal tract along with saliva in the case of corrosion. For this reason, the contact time with the LANGERHANS cells, which serve as receptors, is very short. The structure of the mucous membranes of the mouth favours a more rapid penetration of nickel ions in comparison to the epidermis (67). As a result, the risk of sensitisation in the oral cavity is extremely low. Formation of a nickel depot in the human body has not been described.

Although nickel allergies are very common, use of nickel-chromium alloys need not necessarily lead to allergic reactions in the oral cavity (43, 66). The reason for this is the chemical behaviour of nickel and the structure of the mucous membranes of the mouth.

If one compares the figures for applied restorations to the cases of nickel allergies caused by nickel alloys (approx. 50 - 200 (27, 28), see above) that have been described in international literature, keeping in mind that this study also includes steel for orthodontic wires and no distinction is made between the nickel alloys, the cases are within the ppm range (ppm = parts per million). Nickel-chromium alloys are widespread particularly in the USA, eastern Europe, Asia and in the Arabian states. If these case figures are compared to the sales figures for the alloys (several tonnes a year, i.e. several hundred thousand restorations) and reported damage due to these alloys, there are no comprehensible grounds for the bad reputation of these alloys.

The initial corrosion of mouth-resistant nickel-chromium alloys (e.g. Wiron 88/BEGO) is around 4 µg/cm²d (65). Therefore, about 25 cm² of this alloy must corrode daily in order to attain the recommended daily quantity of nickel uptake of 100 µg (48). For this reason, potential sensitisation appears possible only in very sensitive persons and also only in the initial phase, i.e. shortly after fitting of the restoration.

Systemic-toxicological contamination can be ruled out based on the amounts released and the short biological half-life of nickel. As with all other metals, local toxic effects cannot be ruled out. Such effects may arise if serious production defects exist.

Summary

Nickel-chromium alloys with a chromium content of over 20% can be regarded as mouth-resistant. Their ion releases lie within the range of cobalt-chromium alloys and gold-reduced precious-metal alloys. Alloys with a chromium content of under 15%, on the other hand, must be regarded as non-mouth-resistant and should therefore not be used.

One cannot draw conclusions on the biocompatibility of nickel-chromium alloys with a chromium content of over 20% based on the chemical and biological reactions of pure, elementary nickel or nickel-chromium alloys with reduced chromium content. Such conclusions are not tenable and have no logical basis for material science reasons.

Beryllium must not be used for reasons of corrosion resistance and biocompatibility. Orthodontic wires made of steel also display more disadvantageous corrosion characteristics than mouth-resistant nickel-chromium alloys. If a nickel allergy has been detected and verified, nickel alloys and alloys containing nickel should not be used so as to avoid any possible reaction, though the latter need not necessarily arise. Testing by means of the so-called patch test may itself lead to sensitisation and is thus only permitted in Norway, for example, if sensitivity is suspected for justifiable reasons, and is otherwise prohibited.

The dynamic toxicity of nickel is of no relevance at all to dental alloys. Nickel is an essential element. The recommended daily uptake is significantly higher than the amount released by high-quality nickel-chromium alloys. This also applies to initial corrosion.

- Adress for reference requests: see below -

Address for correspondence

BEGO, Bremer Goldschlägerei
Wilhelm-Herbst GmbH & Co.
Dr. R. Strietzel
Wilhelm-Herbst-Straße 1
28359 Bremen
Tel. +49-(0)421/20 28 -130
Fax +49-(0)421/20 28 -115
e-mail: strietzel@bego.com