ORIGINAL ARTICLE

Micro analysis of metals in dental restorations as part of a diagnostic approach in metal allergies

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Abstract

In dentistry, a variety of potentially allergenic metals are used, such as mercury, palladium, nickel, gold, chromium, cobalt and other metals. This paper describes a diagnostic approach from a dentist's point of view, which enables analysis of metals in a patient's oral cavity. If metal allergy is suspected, a micro analysis can be used to determine which metals are present in the restorations. When the exact composition of the dental materials is known, the patient can be tested *in vivo* (patch test) and/or *in vitro* (lymphocyte proliferation test) to reveal sensitization. Two patients with nickel allergy are described where removal of nickel-containing materials (bridge and orthodontic wire) resulted in the marked alleviation of symptoms and improvement of health. Finally, if allergy to specific metals has been established, the restorations containing the implicated metals should be removed to discontinue the exposure and thus facilitate the patient's health.

List of abbreviations:

EDAX:	Energy Dispersive X-ray Analysis
ELIspot:	Enzyme-Linked Immuno spot
MA:	Micro Analysis
MIF:	Migration Inhibition Factor
MELISA®:	MEmory Lymphocyte Immuno-Stimulation Assay
LTT:	Lymphocyte Transformation Test
SEM:	Scanning Electron Microscopy

Introduction

In the past decades the use of restorative and implant materials in medicine and dentistry has increased enormously. As a consequence, the frequency of effects due to implant materials and their effect on the patients' health has increased as well.

Local symptoms, such as lichenoid phenomena, burning and itching, may be recognized by the dentist during a routine check up. However, systemic effects are usually overlooked, as traditionally these belong under the medical surveillance. This is why dental journals mainly report local side-effects mainly [6, 10, 33, 34]. Literature on systemic effects of dental restorative materials is scarce, and randomized clinical trials on this topic have not been performed. Nevertheless, several publications describe systemic effects of allergy to metals [16]. For example, palladium originating from dental alloys may cause eczema of the skin [1]. Nickel is known to be a strong allergen, and in addition to skin effects, even systemic renal effects have been reported [27]. Twenty nail dystrophy (trachyonychia) caused by lichen planus in a patient with gold allergy has been reported by Yokozeki et al.

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[36]. Normal nails regenerated under the proximal nail folds 24 weeks after removing the gold restorations.

Marcusson described a connection between chronic fatigue syndrome and nickel allergy as determined by patch test [14]. Others confirmed these findings and described the improvement of health in patients with chronic fatigue syndrome following the replacement of allergy-causing dental implants [23, 26]. Beneficial effect of amalgam replacement has been reported in patients with allergy to inorganic mercury who suffered from various autoimmune diseases, such as multiple sclerosis [20] or autoimmune thyroiditis [20, 26].

From a biological perspective, effects of metal-based restorative materials may be due to toxic, galvanic, and/or immunologic effects. Since the degree of dissolution of metal-based dental restorations is small [4], toxic reactions occur mainly locally, while immunologic reactions may result in systemic effects. Guindy et al. reported local toxic effects of metals originating from dental restorations resulting in periodontitis and alveolar bone loss [7]. Ion release is a precondition for toxic and immunologic reactions. Even highly precious alloys will release ions due to corrosion; furthermore, galvanism increases the dissolution rate, and therefore the chance of developing immunologic or toxic reactions increases – especially when there is a great difference in nobility. Clinically, this may lead to a 'metal taste' and burning like sensations, symptoms frequently found in the Burning Mouth Syndrome [19].

To diagnose health effects of metals in dental restorations, it is necessary to determine to which dental metals the patient is exposed, and if the patient is allergic to the exposed metals. Metal allergies may be diagnosed either *in vivo* by a patch test or *in vitro* by a lymphocyte proliferation test, such as MELISA® [25, 28].

This paper describes a method for the investigation of dental alloys in patients with known or suspected metal allergies.

Materials and Methods

Micro analysis (MA)

A modified method for the determination of the composition of the alloys in dental restorations was used [5, 15, 35]. An Arkansas stone was used to take microscopically small samples from restorations (Fig. 1). The composition of the metal particles on the stone can be determined both qualitatively and quantitatively by Scanning Electron Microscopy (SEM) (Fig. 2) and Energy Dispersive X-ray Analysis (EDAX). The advantage of MA is that the quality of the patient's dental restorations is not affected as the extremely small damage caused by the stone can easily be polished. At the same time a reliable analysis of the composition of the alloy of the dental restoration can be obtained (resolution of 0.5wt%, with the exception of beryllium). Compared to other methods, it has the advantage of taking metal samples also in cases where nearly all metal is covered by the veneering porcelain, and the tip of the stone also works subgingivally. Due to the small size of the stone, it is usually also possible to take a sample of solder joints. In this way the metal composition of restorations present in the oral cavity may be determined.

Results

Case 1

A 50-year old woman with a complex medical history of allergy and immunologic diseases was referred to us by a dermatologist to investigate the oral exposure to metals from dental restorations. The patient was diagnosed with Hodgkin's disease in 1982. She suffered from various Type I and Type IV allergies and exhibited a high risk of anaphylactic reactions. Patch tests performed in 1978 showed allergy to cobalt, nickel, copper, palladium, nail polish, acetone, indigo-cotton and lanolin. Intra-orally she suffered from ulcerations and gum swellings. An allergic reaction to the metals in the cobalt-containing frame prosthesis in the upper jaw was suggested as a cause of the symptoms. Four years ago the prosthesis was replaced by two fixed partial dentures made of high gold-containing alloys. The two remaining metal crowns in the lower jaw were not replaced. This treatment did not alleviate the patient's symptoms.

In 2005 an optimized lymphocyte proliferation test, MELISA®, was performed to determine metal allergies [25, 28]. The patient's lymphocytes showed a strong proliferation induced by nickel *in vitro* (Stimulation Index 18.0), a moderate to titanium dioxide (Stimulation Index 4.6), and a weak to palladium (Stimulation Index 2.3). No proliferation was induced by cobalt.

MA of the two partial fixed dentures and the metal crowns was performed. These tests confirmed the compositions of the two bridges as specified by the dentist. One of the crowns contained 8wt% palladium. Although both crowns looked like gold, the second crown showed an unusual composition. It was made from so-called aluminum-copper bronze, composed of 15wt% aluminum, 46wt% copper, 9wt% cobalt, 17wt% nickel, 6wt% iron, 5wt% manganese and 1wt% zinc (Table 1).

The aluminum-copper bronze crown was made in 1978 just before patient consulted a dermatologist for a severe skin reaction on her face. Replacement of both crowns resulted in total disappearance of the oral complaints and relief of the systemic symptoms.

Case 2

A 45-year old woman with a known nickel allergy, as determined by patch test, was referred to our clinic since she claimed that her profound fatigue started after dental treatment. She suffered from migraine and pain in the joints of the wrists, hands and fingers, but had no visible oral problems. Upon oral examination, the patient had one bridge and a few amalgam fillings. To maintain the result of an orthodontic treatment, a stainless steel wire retainer had been cemented to the lower incisors. The MA test showed that the bridge was made of a high palladium-containing alloy without traces of nickel, while

Table 1. Composition in wt% of the alloy determined by EDAX of the restorations of case 1.

Tooth	Au	Pd	Pt	Ag	Al	Cu	Zn	Mn	Fe	Co	Ni
FPD upper left	78%		16%				5%				
FPD upper right	81%		14%				5%				
Crown 44/45	92%						8%				
Crown 46	45%	8%		35%		12%					
Crown 36					15%	47%	1%	5%	6%	9%	17%

Table 2. Composition in wt% of the alloy determined by EDAX of the restorations of case 2.

	Au	Pt	Cu	Ni	Fe	Cr	Pd	Sn	Ga
Front bridge	<1%		7%				87%		6%
Retainer				10%	72%	18%			

the stainless steel wire contained 10wt% nickel (Table 2). The wire was replaced by a glass fiber-based resin composite retainer. Two months after the removal of the nickel-containing retainer, the patient's profound fatigue disappeared.

Discussion

In this article, two patients with known or demonstrated nickel allergy experienced disappearance of skin symptoms, decreased fatigue, and general health improvement after removal of nickel-containing dental appliances. When dental restorations are suspected as a cause of a patient's complaints, one has to consider immunological and toxic side-effects. Special attention should be paid to mucosal changes such as discolorations, like amalgam tattoos [22], and lichenoid changes. Lichenoid reactions are usually caused by metal allergy/hypersensitivity [11, 12]. Inflammatory reactions of the gingiva adjacent to well-made, well-fitting restorations might not always be caused by microorganisms but also sometimes by toxic or immunological reactions of dental metal ions [35]. Bass and colleagues described the risk of sensitization to nickel due to long term exposure to nickel-containing appliances during routine orthodontic therapy [2].

Allergies caused by metals from dental restorations are a complex multi-disciplinary issue. The conditions in the oral cavity, such as the pH, the metal composition, and quality of the dental restorations, can affect the rate of ion release due to corrosion and galvanism [20]. Since dental alloys remain *in situ* for a long period of time, patients are continuously exposed to metal ions, and this phenomenon may contribute to induction or perpetuation of metal allergies. Nogi [18] showed that due to differences in saliva quality, the voltages between dental metals and the adjacent mucous membrane varied greatly, depending on the individual patient rather than on the types of metal. Certain alloys acted as cathodes in some patients, and as anodes in others. It has been shown that palladium copper alloys may produce relative high amounts of Pd^{2+} ions, which could explain the frequent incidence of hypersensitivity associated with the palladium-copper alloys [3].

The main discussion regarding systemic health effects caused by dental metals is due to the fact that often no local mucosa changes are visible in affected patients. The diagnosis of a metal allergy in such cases is based

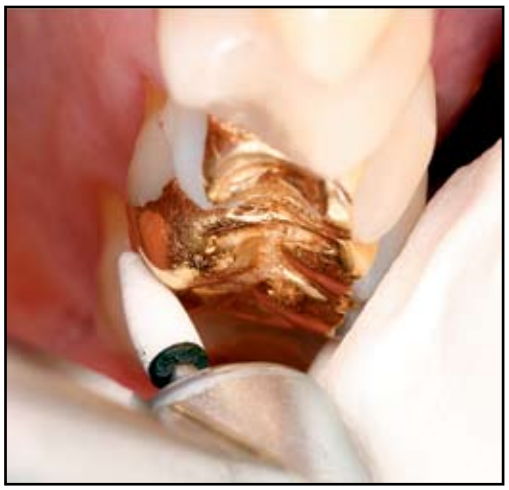

Figure 1: Micro sampling of dental restoration with an Arkansas polishing stone.

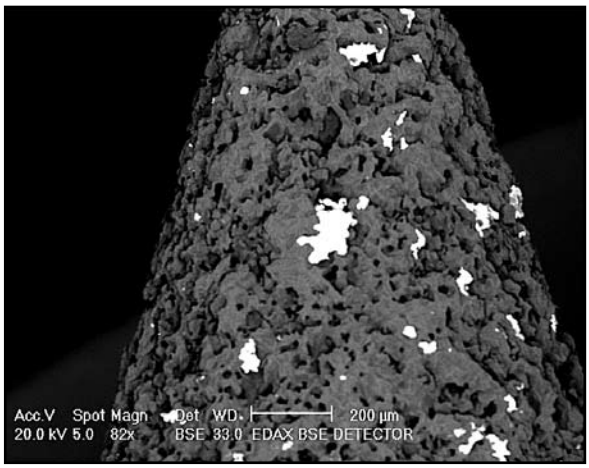

Figure 2: SEM picture of an Arkansas polishing stone. Due to the use of the back scatter detector the metal samples are lightened.

mainly on anamnesis and on *in vivo* or *in vitro* diagnostic allergy testing. In many countries the dermal patch test is the only test available for routine diagnostic purposes. In spite of being considered as 'golden standard' for the determination of allergic sensitization to metals through oral exposure, it does not meet the requirements of a standard, such as fixed procedures regarding test allergens, concentrations, and carriers and/or solvents. As a consequence, its reproducibility and reliability for the detection of an allergic sensitization to dental metals is low. Yet, special dental screening test batteries are available to evaluate the allergic sensitization of patients with the epidermal patch test [31]. For studies of metal allergies *in vitro*, different tests have been used, such as lymphocyte transformation test (LTT) [17, 21], MELISA® [23, 24, 25, 28, 29, 30], migration inhibition factor test [8, 9, 32], and ELISpo [13]. Most of these tests, except the MELISA® test and Beryllium-LTT, have not been standardized and validated [17, 28], and are therefore not fulfilling the needs for routine diagnostic testing. Finally, a proper diagnosis of metal allergies cannot be based on a single test, but should be the result of a diagnostic approach that covers issues such as allergic constitution, exposure to a possible allergens, sensitization to the exposed allergens and a known relationship between the symptoms and a possible sensitization.

Conclusion

Metal-based dental restorations and appliances may play an important role in metal allergy. Metal analysis, as described in this article, may facilitate the search for a metal-allergen of importance in a patient's inflammatory process. Since the majority of modern diseases are currently attributed to inflammatory processes, this method may have a key importance not only for the diagnosis but also for the treatment of diseases.

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