

Annotated Bibliography of Research Related to Systemic Nickel Allergy Syndrome (SNAS)

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In this SNAS bibliography, my annotations highlight what I found relevant. I encourage you to read the original works and form your own interpretations.

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1. SNAS and Nickel SCD Review Articles

Silverberg, N.B. et al., 2020. Nickel allergic contact dermatitis: Identification, treatment, and prevention. *Pediatrics*, 145(5).

https://www.researchgate.net/publication/340959429_Nickel_Allergic_Contact_Dermatitis_Identification_Treatment_and_Prevention

- A policy statement and review that focuses on pediatric dermatitis.

Ahlström, M.G. et al., 2019. Nickel allergy and allergic contact dermatitis: A clinical review of immunology, epidemiology, exposure and treatment. *Contact Dermatitis*, 1-15.

<https://onlinelibrary.wiley.com/doi/full/10.1111/cod.13327>

- A review of nickel allergy that includes both systemic and contact forms, but only discusses dermatitis as a symptom.

#goodread

Bergman, D. et al., 2016. Low nickel diet: A patient-centered review. *Journal of Clinical and Experimental Dermatology Research*, 7(355), p.2.

<https://www.longdom.org/open-access/low-nickel-diet-a-patientcentered-review-2155-9554-1000355.pdf>

- Review article, defines SNAS, SCD and ACD, describes a low nickel diet, reviews the literature regarding underlying immunology and hyposensitization treatment.

Goldenberg, A. and Jacob, S.E., 2015. Update on systemic nickel allergy syndrome and diet. *European Annals of Allergy and Clinical Immunology*, 47(1), pp.25-26.

<http://www.eurannallergyimm.com/cont/journals-articles/352/volume-update-systemic-nickel-allergy-syndrome-938allasp1.pdf>

- Letter to the editor regarding Pizzutelli's 2011 paper, disputing its claim that SNAS is "controversial".
- Provides a good definition of SNAS and a summary of its pathophysiology.

#goodread

Calogiuri, G.F. et al., 2014. Nickel hypersensitivity: A general review on clinical aspects and potential co-morbidities. *Journal of Allergy and Therapy*, 7, p.243.

<https://www.longdom.org/open-access/nickel-hypersensitivity-a-general-review-on-clinical-aspects-and-potential-comorbidities-2155-6121-1000243.pdf>

- A review of SNAS research dating back to 1975. Discusses symptoms, implants, food, dental materials.
- Defines 5 patterns of nickel sensitization:
 1. Prolonged contact/ACD
 2. Occupational respiratory exposure
 3. Gastrointestinal route (foods containing Ni): SNAS 1° type
 4. Implants containing Ni, including stents, pacemakers, dental materials, prostheses, needles: SNAS 2° type
 5. A combination of the above routes.

Lampel, H.P. and Silvestri, D.L., 2014. Systemic contact dermatitis: current challenges and emerging treatments. *Current Treatment Options in Allergy*, 1(4), pp.348-357.

<https://link.springer.com/article/10.1007/s40521-014-0029-6>

- Review article on SCD that includes SNAS.

Fabbro, S.K. and Zirwas, M.J., 2014. Systemic contact dermatitis to foods: nickel, BOP, and more. *Current Allergy and Asthma Reports*, 14(10), p.463.

http://www.aaifnc.org/Documents/symposium_2018/addendum/SystemicContactDiet2.pdf

- A review of SCD to several food-borne allergens: nickel, cobalt, chromium, BoP, PG, urushiol, sesquiterpene lactones, formaldehyde, garlic, propolis and sorbic acid.
- Says SCD is completely unrelated to type I (IgE) allergies, contrary to some other work.
- Classic presentation of SCD to nickel is hand dermatitis, itchy papules on the elbows and/or knees, and "widespread symmetric macropapular eruptions". Reappearance of prior sites of ACD in the absence of cutaneous exposure should strongly suggest SCD.
- Includes a table of common presentations for each allergen.

Katta, R. and Schlichte, M., 2014. Diet and dermatitis: Food triggers. *The Journal of Clinical and Aesthetic Dermatology*, 7(3), p.30.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3970830/>

- A review article on ACD and SCD that includes nickel.
- Lists treatments including diet and lifestyle changes to reduce nickel exposure, along with the other top contact allergens.

#goodread

Sharma, A.D., 2013. Low nickel diet in dermatology. *Indian Journal of Dermatology*, 58(3), p.240.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3667300/>

- A review of nickel allergy as a cause of dermatitis and its treatment via a low nickel diet.
- Covers food and non-food sources of nickel and non-dietary treatments.

Yoshihisa, Y. and Shimizu, T., 2012. Metal allergy and systemic contact dermatitis: An overview. *Dermatology Research and Practice*, 2012.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3369403/>

- A review of metal SCD with a section on nickel.
- Proposes using a blood test that measures Th1 and Th2 cytokine production to confirm the diagnosis of metal allergies.

Tamaro, A. et al., 2011. Topical and systemic therapies for nickel allergy. *Dermatitis*, 22(5), pp.251-255.

<https://pdfs.semanticscholar.org/8cea/8ea8633725f4b1c96a070e026c285d1ac846.pdf>

- A review article of treatments for SNAS, including topical, UVB, systemic immunosuppressive, zinc, low nickel diet, disulfiram, and hyposensitization therapies.

Pizzutelli, S., 2011. Systemic nickel hypersensitivity and diet: Myth or reality? *European Annals of Allergy and Clinical Immunology*, 43(1), p.5.

<http://www.eurannallergyimm.com/cont/journals-articles/211/volume-systemic-nickel-hypersensitivity-diet-myth-563allasp1.pdf>

- A very critical review of the SNAS literature up to 2011 that questions studies that support food-borne nickel as a symptom source and the low nickel diet as a treatment.
- Has a table demonstrating how variable the LND advice is from 11 different sources.
- Provides a good description of SNAS and SCD.
- Discusses how difficult it is to rigorously test for SNAS because nickel is ubiquitous, which makes double-blind testing difficult as consumed nickel is uncontrolled, and scoring is subjective.

- Concludes that more rigorous studies need to be done to establish that nickel allergy is indeed responsible for SNAS symptoms.
- Claims there is a “strong psychosomatic effect”, but has no citations to support the statement.

Petrucci, F. et al., 2009. Role of diet in nickel dermatitis. *The Open Chemical and Biomedical Methods Journal*, 2, pp.55-7.

<https://benthamopen.com/contents/pdf/TOCBMJ/TOCBMJ-2-55.pdf>

- A review of SCD and nickel sources, including dietary, and treatments.

Thyssen, J.P. and Maibach, H.I., 2008. Drug-elicited systemic allergic (contact) dermatitis—update and possible pathomechanisms. *Contact Dermatitis*, 59(4), pp.195-202.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1600-0536.2008.01367.x>

- A review of SCD to metals and drugs.
- Lists 10 different terms used in the literature for SCD, not including SNAS.
- SCD is a type 3 and 4 allergy, and the initial immune reactions may take place in both the skin and gastrointestinal mucosa. Metal allergies are Th1 and Th2 driven.
- Recommends using the term Systemic Allergic Dermatitis (SAD) instead of SCD since skin contact is not a requirement.
- Systemic symptoms of SAD include headaches, fever, malaise, arthralgia, vomiting and diarrhea.
- Patch testing should not be done prior to 6 weeks of an adverse reaction. Negative patch testing should be followed up with intradermal testing. The LTT is a useful adjunct test.

Jensen, C.S., Menné, T. and Duus Johansen, J., 2006. Systemic contact dermatitis after oral exposure to nickel: A review with a modified meta-analysis. *Contact Dermatitis*, 54(2), pp.79-86.

https://www.researchgate.net/publication/7290411_Systemic_contact_dermatitis_after_oral_exposure_to_nickel_A_review_with_a_modified_meta-analysis

- Meta-analysis of 9 studies finding that for patients with SCD or chronic eczema, 1% will react to oral nickel doses less than 0.22 mg using the more “sensitive” findings, which is a normal dietary exposure.

2. Low Nickel Diets and Dietary Treatment Studies

Rizzi, A. et al., 2017. Irritable Bowel Syndrome and nickel allergy: What is the role of the low nickel diet? *Journal of Neurogastroenterology and Motility*, 23(1), p.101.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5216640/>

- Patients with IBS and all other causes ruled out and a positive nickel patch test (20 of them) were put on the BraMa-Ni low nickel diet for 3 months. There was significant improvement in all subjective GI symptoms, but the overall health survey didn’t differ significantly.
- The intestinal permeability improved more for patients with moderate to severe skin reactions, and worsened for half of the patients.
- Confirms the high prevalence of anxiety and other psychological symptoms.

#histamine

Antico, A. and Soana, R., 2015. Nickel sensitization and dietary nickel are a substantial cause of symptoms provocation in patients with chronic allergic-like dermatitis syndromes. *Allergy & Rhinology*, 6(1), p.e56.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4388878/>

- Of 1726 patients with chronic allergic-like skin diseases and no IgE allergies, none had extracutaneous (SNAS) symptoms.
- 339 (20%) tested nickel positive, and 52 recovered by just avoiding contact with nickel.

- 207 achieved complete or near complete recovery by following their low-nickel diet (food list included). The diet was ineffective for 51.
- 185 had a positive oral challenge (on an empty stomach); in 26 the response was severe. Average time of reaction to challenge was 5.3 ± 2.5 hours, ranging from 3 to 12 hours.
- Discusses the role of histamine and mast cell degranulation.

Perez, L.D.M., França, A.T. and Zimmerman, J.R., 2015. Systemic nickel allergy syndrome, *World Allergy Organization Journal*, 8(S1), p.A89.

<https://waojournal.biomedcentral.com/articles/10.1186/1939-4551-8-S1-A89>

- Very brief overview of a Brazilian SNAS study with some language clarity issues.
- 331 patients with SNAS symptoms improved after 60 days on a low nickel diet; for those who went back to their regular diet, symptoms returned between 7 and 20 days.

#IgE

Ricciardi, L. et al., 2014. Systemic nickel allergy syndrome: Epidemiological data from four Italian allergy units. *International Journal of Immunopathology and Pharmacology*, 27(1), pp.131-136.

<https://journals.sagepub.com/doi/pdf/10.1177/039463201402700118>

- A statistical analysis of SNAS prevalence in an Italian allergy clinic. SNAS was confirmed in 98 patients (5.78%) of the 1,696 referred to an allergy clinic for a variety of symptoms (the reasons for referral are not well defined), having a positive patch test and responding to one month on a low nickel diet.
- The most common symptoms were cutaneous (51 patients), gastrointestinal (87 patients) and other systemic clinical manifestations (37 patients). The unexpected result is that cutaneous symptoms are not as common as gastrointestinal.
- An IgE-mediated food allergy was found in 16 out of the 98 SNAS patients (16.3%), and the authors propose that the higher incidence is caused by damage to the intestinal mucosa.
- Contains a table of the foods that triggered symptoms in the 98 patients.

#goodread

Mislankar, M. and Zirwas, M.J., 2013. Low-nickel diet scoring system for systemic nickel allergy. *Dermatitis*, 24(4), pp.190-195.

http://www.aafnc.org/Documents/symposium_2018/addendum/LowNickelDiet.pdf

- Provides a points-based scoring system for a low nickel diet, based on data on the nickel content of food from the FDA's Total Diet Study. [The basis of the Rebelytics LND.]

#histamine

Braga, M. et al., 2013. Systemic nickel allergy syndrome: nosologic framework and usefulness of diet regimen for diagnosis. *International Journal of Immunopathology and Pharmacology*, 26(3), pp.707-716.

<https://journals.sagepub.com/doi/pdf/10.1177/039463201302600314>

- Describes SNAS and presents the BraMa-Ni low nickel diet, a meal plan that is based on the BraMa diet "developed with purpose of minimizing the additive content and avoiding vasoactive amine foods" (histamine is one of the amines). [The reference for the BraMa diet does not exist and the source of nickel food measurements is not cited.]
- Oral nickel challenge elicited skin and GI symptoms, and that's all.
- 8 patients of 98 experienced GI symptoms with no skin symptoms.
- High rate of lactose intolerance in the SNAS population.
- Acceptance and adherence to the BraMa-Ni meal plan was much better than for the forbidden food list.

Picarelli, A. et al., 2011. Oral mucosa patch test: a new tool to recognize and study the adverse effects of dietary nickel exposure. *Biological Trace Element Research*, 139(2), pp.151-159.

https://www.researchgate.net/publication/41762034_Oral_Mucosa_Patch_Test_A_New_Tool_to_Recognize_and_Study_the_Adverse_Effects_of_Dietary_Nickel_Exposure

- 86 patients with at least one intestinal symptom related to nickel ingestion were tested with an oral mucosa patch test (omPT) and patch tests (5% NiSO₄).
- Not everyone had extra-intestinal symptoms.
- 38.4% had a positive patch test while 61.6% had a positive omPT. Of the 53 patients with a positive omPT, 6 showed a lesion within 30 minutes, indicating a Th2 or immediate-type (IgE) response. All omPT-positive patients had a relapse in their symptoms after the omPT.
- After 2 months on a low nickel diet (as per Sharma 2007) 52 of the 53 omPT-positive had improved symptoms.
- Discusses the variable responses and the combination of Th1 and Th2 cytokines involved in nickel allergy and ACD.

Zirwas, M.J. and Molenda, M.A., 2009. Dietary nickel as a cause of systemic contact dermatitis. *The Journal of Clinical and Aesthetic Dermatology*, 2(6), p.39.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923958/>

- Presents 3 case studies where patients' dermatitis cleared upon following a low nickel diet.
- Prior to the eruption two of the three had increased their intake of high nickel foods: whole grains, soy beans.
- "It should be noted that it has been the lead author's experience that there is not a correlation between a history of typical nickel contact dermatitis (earring dermatitis or infraumbilical dermatitis) and the likelihood of dietary nickel playing a role in a patient with widespread dermatitis or itch. The lack of a history of typical nickel reactions, in the authors' opinion, does not rule out nickel as a cause of widespread dermatitis or pruritus."
- Makes the valid point that a low nickel diet is harmless and inexpensive and so should be considered in patch-test positive cases.

Veien, N.K., Hattel, T. and Laurberg, G., 1993. Low nickel diet: An open, prospective trial. *Journal of the American Academy of Dermatology*, 29(6), pp.1002-1007.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/8245235/>

- 90 patients who had a positive patch test and oral challenge to 2.5 mg nickel were included in a low nickel diet trial for 1-2 months (defined by Denmark's data at the time) and asked to also avoid low nickel foods that were known to result in a flare such as red wine and herring. 17 patients did not respond, 15 had a reasonable benefit and 58 patients responded very well.
- Of those who saw some benefit, 55 completed a survey 1-3 years later. 40 continued to see benefit from the trial. However, it is not clear whether they continued the low nickel diet after the trial ended.
- Other dermatitis triggers that happened 3 or more times in the study group were: specific foods; menstrual period; psychological stress; and sweating.
- The patients who had the least benefit from the diet were those who had a strongly positive patch test. This could be because those with a strongly positive patch test react to minuscule amounts of endogenous nickel.

Gawkrodger, D.J., Shuttler, I.L. and Delves, H.T., 1988. Nickel dermatitis and diet: Clinical improvement and a reduction in blood and urine nickel levels with a low-nickel diet. *Acta dermato-venereologica*, 68(5), pp.453-455.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/2461035/>

- A 27-year-old nickel-sensitive female who had had continuous spontaneous flare-ups of eczema, including at sites of previous metal contact, experienced a clearing of her eruption after commencing a low-nickel diet. When on the diet, whole-blood and urinary nickel levels fell to half or less of pre-diet values and this coincided with the clinical improvement.

Kaaber, K., Veien, N.K. and Tjell, J.C., 1978. Low nickel diet in the treatment of patients with chronic nickel dermatitis. *British Journal of Dermatology*, 98(2), pp.197-201.

Abstract at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2133.1978.tb01622.x>

- Patients with chronic nickel dermatitis who reacted to an oral challenge were put on a low nickel diet for 6 weeks. 9 of the 17 improved, and 2 of those 9 were able to resume a normal diet without symptoms.
- There was a drop in nickel excretion while on the low nickel diet, with no difference between those who improved and those who did not.

3. Non-Dietary Treatments

Medications

Joshi, S.R. and Khan, D.A., 2018. Effective use of dupilumab in managing systemic allergic contact dermatitis. *Dermatitis*, 29(5), pp.282-284.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/30179979/>

- A case of refractory ACD to nickel in a 44-year-old man with numerous endovascular stents and vascular clips, with recurrent infections. Dupilumab, an atopic dermatitis treatment, improved his symptoms and reduced his infection rate.

Njei, R. and Konstantinoff, K., 2018. An unusual medical management for nickel allergy in patients with amplatzer occlusive device. *Open Journal of Clinical & Medical Case Reports*, 4(11).

<http://jclinmedcasereports.com/articles/OJCMCR-1420.pdf>.

- Case report of a woman with an atrial septal defect and no known prior nickel allergy who developed chest tightness, dyspnea and malaise immediately following implantation of a nitinol Amplatzer device.
- She was NOT tested for nickel allergy but had dermatitis that responded to steroid treatment.
- She experienced complete resolution of her symptoms with dual antiplatelet therapy (Aspirin and Clopidogrel).

Pigatto, P.D. et al. 1990. Disodium cromoglycate versus diet in the treatment and prevention of nickel-positive pompholyx. *Contact Dermatitis*, 22(1), pp.27-31. Abstract only.

<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0536.1990.tb01501.x>

- In 24 cases of dyshidrotic eczema caused by nickel that did not respond to a low nickel diet, disodium cromoglycate (a mast cell stabilizer) improved objective and subjective symptoms, coinciding with a reduction in intestinal permeability.

Nutritional Supplements

Onodera, R., et al., 2018. Zinc ions have a potential to attenuate both Ni ion uptake and Ni ion-induced inflammation. *Nature Scientific Reports*, 8(1), p.2911.

<https://www.nature.com/articles/s41598-018-21014-8>.

- An in vitro study (not directly in humans) showing that zinc, cobalt and manganese inhibit the uptake of nickel into cells, that Zn inhibits IL-8 production whereas Mn and Co enter cells and increase it, and that a zinc deficiency enhances nickel uptake into cells that surround implants. A zinc deficient state might therefore increase sensitivity to nickel.

Quirk, S.K. et al., 2016. Vitamin D in atopic dermatitis, chronic urticaria and allergic contact dermatitis. *Expert Review of Clinical Immunology*, 12(8), pp.839-847.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4985525/>.

- A review of vitamin D's role in AD, urticaria and ACD. Vitamin D enhances defences against microbes and inhibits excessive inflammation.
- There are no human studies of vitamin D in humans with ACD, only mice. The authors do not recommend supplementation for the purpose of suppressing ACD.

#vitaminC #histamine

Hagel, A.F. et al., 2013. Intravenous infusion of ascorbic acid decreases serum histamine concentrations in patients with allergic and non-allergic diseases. *Naunyn-Schmiedeberg's Archives of Pharmacology*, 386(9), pp.789-793.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/23666445>

- Intravenous ascorbic acid decreased histamine in the blood, with more of an effect on allergic patients than patients with infections.

#goodread

Sharma, A.D., 2011. Iron therapy in hand eczema: A new approach for management. *Indian Journal of Dermatology*, 56(3), p.295.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3132907/>

- Twelve patients prescribed a low nickel diet plus an iron supplement (15 mg twice daily before meals) fared better than a control group of 11 on the low nickel diet alone. After 12 weeks, 5/11 patients in the control group had complete recovery whereas the iron group had complete recovery in 10/12. Patients with anemia were excluded, i.e. the patients were not iron deficient.
- If a person has low iron, the body produces more divalent metal transporter (DMT) in order to absorb more of it. But it transports other metals as well, as they are available, including nickel. The DMT's preference in order of affinity is Fe > Zn > Mn > Co > Cd > Cu > Ni > Pb.

Patlar, S. et al., 2011. The effect of vitamin A supplementation on various elements in elite taekwondo players. *Biological Trace Element Research*, 139(3), pp.296-300.

https://www.researchgate.net/publication/42255893_The_Effect_of_Vitamin_A_Supplementation_on_Various_Elements_in_Elite-Taekwondo_Players

- Athletes given 100 mg Vitamin A daily for 6 weeks had "significantly reduced" blood levels of nickel relative to values before supplementation (reduced from 70 to 40 µg/L).

Kuroishi, T. et al., 2009. Biotin status affects nickel allergy via regulation of interleukin-1 β production in mice. *The Journal of Nutrition*, 139(5), pp.1031-1036.

<https://academic.oup.com/jn/article/139/5/1031/4670338>

- In mice, swelling from injected NiCl₂ was significantly higher in biotin-deficient mice than in controls. Supplementation at a rate equivalent to the human dose of 10-40 mg/day reduced the swelling.

#histamine

Kehoe, C.A. et al., 2000. Plasma diamine oxidase activity is greater in copper-adequate than copper-marginal or copper-deficient rats. *The Journal of Nutrition*, 130(1), pp.30-33.

<https://academic.oup.com/jn/article/130/1/30/4686063>

- In rats fed a diet that was either deficient, marginal or adequate in its copper content, it was found that plasma DAO activity was significantly lower in both copper-deficient and copper-marginal groups when compared to the copper-adequate group. [DAO breaks down histamine. If this is true in humans as well, we need to ensure we're not copper deficient.]

#vitaminC

Solomons, N.W. et al., 1982. Bioavailability of nickel in man: Effects of foods and chemically-defined dietary constituents on the absorption of inorganic nickel. *The Journal of Nutrition*, 112(1), pp.39-50.

https://www.researchgate.net/publication/16401187_Bioavailability_of_Nickel_in_Man_Effects_of_Foods_and_Chemically-Defined_Dietary_Constituents_on_the_Absorption_of_Inorganic_Nickel3

- When 5 mg of nickel was added to milk (whole), black coffee (with sugar), tea (with lemon and sugar), orange juice or Coca-Cola, serum nickel was significantly lower than control (water) in all cases except cola. Serum nickel was also lower when taken with 1 g ascorbic acid.
- Comparing nickel absorption when taken with meals, a North American breakfast of eggs, toast, bacon and coffee suppressed nickel significantly more than a Guatemalan breakfast of beans, corn tortillas and coffee.

Probiotics

Lombardi, F. et al., 2020. The effects of low-nickel diet combined with oral administration of selected probiotics on patients with Systemic Nickel Allergy Syndrome (SNAS) and gut dysbiosis. *Nutrients*, 12(4), p.1040.

<https://www.mdpi.com/2072-6643/12/4/1040>

- The study included 51 patients with SNAS (confirmed by oral provocation and patch test) who had symptoms including gastrointestinal, cutaneous, and others such as headaches, pain, fatigue, swelling, mouth sores, and ulcers. Exclusions were SIBO, active autoimmune pathologies, infections, and multiple sensitivities to respiratory allergens.
- A urine test determined the dominant type of dysbiosis: 66% had fermentative dysbiosis, 31% had mixed dysbiosis, and only 4% had putrefactive dysbiosis. The two patients with putrefactive dysbiosis did not agree to take a probiotic.
- All 51 patients followed a low nickel diet for 3 months. 22 patients were also given a probiotic supplement consistent with their dysbiosis type:
 - Fermentative: *L. casei* LC18, *L. acidophilus* LA3, *L. reuteri* LR200, *L. rhamnosus* LRH11, *L. fermentum* LF350, *L. plantarum* LPB22, *Streptococcus thermophilus* STB32 (taken by 16)
 - Putrefactive: *B. lactis* BL 04, *B. breve* BB 03, *B. bifidum* BB 06, *B. longum* BL 05 (taken by 0)
 - Mixed: *Streptococcus thermophilus* DSM, *B. breve* DSM 24732, *B. longum* DSM 24736, *B. infantis* DSM 24737, *L. paracasei* DSM 24733, *L. acidophilus* DSM 24735, *L. delbrueckii* subsp *bulgaricus* DSM 24734, *L. plantarum* DSM 24730 (taken by 6)
- In all 51 patients the indicators of dysbiosis decreased significantly after 3 months, and the oral reaction threshold increased. In the group of 22 patients who took probiotics, the portion who fixed their dysbiosis was greater than in the group of 27 who did not (73% vs. 41%).
- It is worth noting that in the fermentative group, the subgroup who took probiotics started off with less severe grades of dysbiosis, so it may have been easier for them to fix their dysbiosis.

Randazzo, C.L. et al., 2015. Probiotic supplementation in systemic nickel allergy syndrome patients: Study of its effects on lactic acid bacteria population and on clinical symptoms. *Journal of Applied Microbiology*, 118(1), pp.202-211.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/jam.12685>

- Patients had a positive patch test, GI reactions, recurrent abdominal pain and cutaneous reactions such as urticaria, itching and eczema after ingestion of nickel-containing food. There were 9 in the experiment and 7 placebo; both followed a low nickel diet.

- The experimental group was given 1 tablet BioGaia *L. reuteri* for 2 weeks. Symptoms were measured at baseline, 2 weeks and 4 weeks.
- There was significant improvement of all cutaneous symptoms after 2 weeks of probiotic treatment.
- GI symptoms took longer to improve, but decreased by 4 weeks.

Ricciardi, L. et al., 2010. PA27 Clinical evidence of enteric flora changes in systemic allergy to nickel (SNAS): A randomized double-blind placebo-controlled study. *Digestive and Liver Disease*, 42, p.S352.

https://www.researchgate.net/publication/241119998_PA27_CLINICAL_EVIDENCE_OF_ENTERIC_FLORA_CHANGES_IN_SYSTEMIC_ALLERGY_TO_NICKEL_SNAS_A_RANDOMIZED_DOUBLE-BLIND_PLACEBO-CONTROLLED_STUDY

- Summary report of a study of 20 patients with confirmed SNAS. 11 were given *L. Reuteri DSM 17938*, 9 placebo. The probiotics group experienced statistically significant changes in the severity scoring index compared to placebo, as well as a significant reduction in drug consumption (antihistamines, antisecretory) and a significant increase in well days.

Rosenfeldt, V. et al., 2003. Effect of probiotic Lactobacillus strains in children with atopic dermatitis. *Journal of Allergy and Clinical Immunology*, 111(2), pp.389-395.

[https://www.jacionline.org/article/S0091-6749\(02\)91373-4/fulltext](https://www.jacionline.org/article/S0091-6749(02)91373-4/fulltext)

- Concluded that *L. rhamnosus 19070-2* and *L. reuteri DSM 122460* was beneficial in the management of atopic dermatitis in 43 children aged 1-13, with the effect more pronounced when the child had a positive IgE skin prick test.
- A small proportion worsened with treatment.

Oral Hyposensitization

Tammaro, A. et al., 2017. Effects of TIO NICKEL in patients with ACD and SNAS: Experience on 700 patients in Italy. *Journal of the European Academy of Dermatology and Venereology*, 31(4), pp.e189-e191.

- A Letter to the Editor on hyposensitization of 700 adult patients with SNAS: while on a low nickel diet, a 10 ng capsule was given three times per week for the first 2 weeks, 100 ng three times per week in the third and fourth week and 500 ng capsules three times per week in the fifth and sixth week. This was followed by a 500 ng tablet three times per week for 3 years, with an unrestricted diet.
- After 3 years patch tests were still positive but less severe. Patients reported improved symptoms after 4 weeks, and complete remission at the end of therapy.

Di Gioacchino, M. et al., 2014. Nickel oral hyposensitization in patients with systemic nickel allergy syndrome. *Annals of Medicine*, 46(1), pp.31-37.

<https://www.tandfonline.com/doi/full/10.3109/07853890.2013.861158>

- A double-blind placebo-controlled trial of oral nickel hyposensitisation. 141 patients met inclusion criteria, split into 4 groups with different final levels of oral nickel in the hyposensitization process.
- Patients began hyposensitization after a month on the low-nickel BraMa-Ni diet.
- The group taking the highest dose, 1.5 µg, fared the best with reintroduction of high nickel foods, with the lower doses not differing significantly from placebo.

Ricciardi, L. et al., 2012. Systemic nickel allergy: Oral desensitization and possible role of cytokines interleukins 2 and 10. *International Journal of Immunopathology and Pharmacology*, 26(1), pp.251-257.

<https://journals.sagepub.com/doi/pdf/10.1177/039463201302600127>

- 22 women diagnosed with SNAS via oral exposure to nickel sulfate underwent oral hyposensitization, increasing in dose over two years. Higher-nickel foods were reintroduced gradually after 9 weeks on a low nickel diet.

- After 2 years there was a significant improvement in VAS scores and the oral challenge was negative in 18 patients. There was a statistically significant decrease in the levels of the IL-2 cytokine.

Spiewak, R., 2011. Immunotherapy of allergic contact dermatitis. *Immunotherapy*, 3(8), pp.979-996.
<http://mail.radoslawspiewak.net/2011-4.pdf>

- A review of hyposensitization for ACD with a focus on nickel among others.
- Talks about the studies that imply that oral exposure through orthodontics prior to ear piercing can reduce sensitization rates, but more investigation is needed on how much nickel is released from the orthodontics.
- Talks about the nickel hyposensitization publications: that their quality is poor, and that some use doses equivalent to less than a tablespoon of water and claim great success rates, which is too good to be true. Appropriate doses need to be investigated. States that current legislation is not enough. "...data published until now do not allow for any definite statement about the effectiveness of oral hyposensitization in nickel-allergic patients."
- Provides a similar review for poison sumac hyposensitization in the USA in the 19th century, of poorly designed studies and grandiose claims - is history repeating itself?
- Discusses an alternative pathway for nickel intolerance that is beyond my comprehension but refers to other work that may explain.

Cirla, A.M., 2011. Systemic nickel allergy syndrome. Biological monitoring of dietary nickel intake and induction of immunotolerance. *Clinical and Translational Allergy*, 1(1), p.P108.
https://www.researchgate.net/publication/251399335_Systemic_nickel_allergy_syndrome_Biological_monitoring_of_dietary_nickel_intake_and_induction_of_immunotolerance

- 152 patients who patch tested positive for nickel were split into 2 groups: those with A) contact dermatitis and B) those with other skin issues ("urticaria-like, pruritus-erythema and cutaneous rash").
- Group B had significantly more nickel in their urine than group A.
- Group B was put on a low nickel diet for 6 months, after which time their urinary nickel was lower but 30 of the 87 still had episodes of urticaria and itching. 12 of them were given the Lofarma hyposensitization treatment; all improved after 8 months on the highest dose.

Bonamonte, D. et al., 2011. Efficacy of oral hyposensitization in allergic contact dermatitis caused by nickel. *Contact Dermatitis*, 65(5), pp.293-301. Access via
https://scholar.google.ca/scholar?hl=en&as_sdt=0%2C5&as_vis=1&q=author%3Abonamonte+Efficacy+of+oral+hyposensitization+in+allergic+contact+dermatitis+caused+by+nickel&btnG=

- 28 patients with a contact allergy to nickel and nothing else went on a low nickel diet, and 50 µg of nickel (given as NiSO₄·6H₂O) was given daily for 3 months.
- Patch testing was done at 0, 1 and 3 months. The body surface area involved decreased, the visual analog score increased, and the lowest concentration of NiSO₄ to elicit a reaction increased.
- Half of the patients relapsed in the year following the study.
- The role of the low nickel diet in this study and afterwards is unclear.

Minelli, M. et al., 2010. Oral hyposensitization to nickel induces clinical improvement and a decrease in TH1 and TH2 cytokines in patients with systemic nickel allergy syndrome. *International Journal of Immunopathology and Pharmacology*, 23(1), pp.193-201.
<https://journals.sagepub.com/doi/pdf/10.1177/039463201002300117>

- 23 SNAS patients on a low nickel diet and receiving NiOH (gradually increasing over 10 weeks and maintaining for 12 months) had a greater success rate of nickel-rich food re-introduction, decreased drug use, improved visual analog score, and decreased cytokines after treatment, compared to 12 controls on a low nickel diet alone.

- All SNAS patients (confirmed by oral challenge) were given NiOH capsules 3 times a week at increasing doses from 0.1 ng to 3 µg in 10 weeks with a maintenance phase of 1.5 µg a week for a period of 12 months. Two could not tolerate the highest dose. All 35 participants continued a low nickel diet.
- The tested cytokines were lower in the treated group than in the diet alone group on average, but it should be noted that the standard deviations of these measurements are very large.
- Nickel-containing foods were re-introduced gradually, starting at 4 months. The controls were not able to reintroduce nickel-rich foods.

Tammaro, A. et al., 2009. Allergy to nickel: First results on patients administered with an oral hyposensitization therapy. *International Journal of Immunopathology and Pharmacology*, 22(3), pp.837-840.

<https://journals.sagepub.com/doi/pdf/10.1177/039463200902200330>

- 67 patients followed a low nickel diet for 10 weeks while also doing slowly increasing hyposensitization.
- After a year at the maintenance dose, 67% reported full remission, and 27% reported improvement in symptoms.

Schiavino, D. et al., 2006. A clinical trial of oral hyposensitization in systemic allergy to nickel. *International Journal of Immunopathology and Pharmacology*, 19(3), pp.593-600.

<https://journals.sagepub.com/doi/pdf/10.1177/039463200601900315>

- 290 patients were selected (mostly female) with systemic cutaneous symptoms and/or digestive symptoms. Patients were given standard prick and patch tests to identify allergens.
- Patients followed a low nickel diet and avoided stainless steel utensils for 4 weeks, and patients who improved at least 80% did an oral challenge test, increasing dose until symptoms appeared.
- 136 patients participated in hyposensitization over 315 days, 95 in a control group that did a low nickel diet alone.
- Ninety-four patients (69.1%) completed the protocol, and after returning to a free dietary regimen, 64 (47.0%) reported a complete remission of symptoms, 23 (16.9%) had symptom improvement higher than 80%, rarely presenting mild cutaneous and/or digestive symptoms and 7 (5.2%) had a partial benefit, reintroducing only some of these foods (limited diet).
- In the control group, after 1 year on a low nickel diet alone, 78 patients (82.1%) presented a relapse of pre-existing systemic symptoms when nickel-containing foods were reintroduced.

Morris, D.L., 1998. Intradermal testing and sublingual desensitization for nickel. *Cutis*, 61(3), pp.129-132.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/9538953/>

- Eighty-five percent of the thirty-nine patients showed subjective improvement in their dermatitis after sublingual hyposensitization and all showed objective evidence of decreased intradermal sensitivity.

Santucci, B. et al., 1988. Nickel sensitivity: Effects of prolonged oral intake of the element. *Contact Dermatitis*, 19(3), pp.202-205.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/3191682/>

- An early attempt at desensitization. In 25 patients with a positive patch test, 22 had a systemic reaction to an oral challenge of 10 mg NiSO₄ in water.
- 17 patients followed a regimen of 3 mg NiSO₄/day in water for 1 month, then 6 mg NiSO₄/day for 1 month, then 10 mg NiSO₄/day for 1 month (equivalent to 0.67, 1.34, and 2.24 mg Ni/day, respectively). 14 were able to complete the regimen; the others became symptomatic. Repeat patch testing and wearing of earrings elicited the same response as before the trial, i.e. it was not effective.
- Gradually increasing to 10 mg did not provoke a reaction, whereas the challenge did.
- The authors hypothesize a mechanism other than hyposensitization: "By analogy to the absorption of other metal ions such as arsenic, conditions of impermeability of intestinal cells to the element may be

created following prolonged intake. An evaluation of the serum nickel levels in such patients could help to verify our hypothesis." Their hypothesis appears to be confirmed in future work.

Sweating

Genuis, S.J. et al., 2011. Blood, urine, and sweat (BUS) study: monitoring and elimination of bioaccumulated toxic elements. *Archives of Environmental Contamination and Toxicology*, 61(2), pp.344-357.

https://www.researchgate.net/publication/47701626_Blood_Urine_and_Sweat_BUS_Study_Monitoring_and_Elimination_of_Bioaccumulated_Toxic_Elements

- We excrete over 13 times more nickel in sweat than in urine.

Cohn, J.R. and Emmett, E.A., 1978. The excretion of trace metals in human sweat. *Annals of Clinical & Laboratory Science*, 8(4), pp.270-275.

<http://www.annclinlabsci.org/content/8/4/270.full.pdf>

- Sweat was collected from 9 adults after cycling for 90 minutes, alternating with resting in 10 minute cycles, and all-over sweat as well as armpit sweat was collected. The nickel in whole-body sweat was $55 \pm 16 \mu\text{g/L}$. The nickel in armpit sweat was much higher but incredibly variable, $293 \pm 194 \mu\text{g/L}$.

#histamine #IgE

Förström, L., Goldyne, M.E. and Winkelmann, R.K., 1975. IgE in human eccrine sweat. *Journal of Investigative Dermatology*, 64(3), pp.156-157.

<https://core.ac.uk/download/pdf/82795096.pdf>

- States that histamine and other inflammatory agents are present in sweat, provides references.
- Shows the presence of IgE in sweat, and says the other immunoglobulins are there.

Hohnadel, D.C. et al., 1973. Atomic absorption spectrometry of nickel, copper, zinc, and lead in sweat collected from healthy subjects during sauna bathing. *Clinical Chemistry*, 19(11), pp.1288-1292.

<http://clinchem.aaccjnls.org/content/clinchem/19/11/1288.full.pdf>

- Nickel concentration in sweat was found to be 52 ± 36 (range 7-180) $\mu\text{g/L}$ for men and 131 ± 65 (range 39-270) $\mu\text{g/L}$ for women.

Chelation

Giampreti, A. et al., 2016. N-acetyl-cysteine as effective and safe chelating agent in metal-on-metal hip-implanted patients: Two cases. *Case Reports in Orthopedics*, 2016.

<http://downloads.hindawi.com/journals/crior/2016/8682737.pdf>

- In two elderly patients with hip implants that gave them cobalt and chromium toxicity, NAC was a safe and effective chelation agent. [It may work for nickel as well.]

Sears, M.E., 2013. Chelation: harnessing and enhancing heavy metal detoxification - A review. *The Scientific World Journal*, 2013.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3654245/>

- Natural substances that have been shown to prevent uptake of heavy metals include: dietary fibres such as grains and fruit; natural polymers such as citrus pectin, alginate and chlorella; sulphur-containing foods such as allium or brassica; supplements including taurine, methionine, alpha lipoic acid, N-acetyl cysteine (NAC), selenium, and minerals such as calcium, zinc, iron and magnesium. Results are mixed for cilantro.
- Nickel is not included in this review, so other reviews are more appropriate for the pharmaceutical chelators. However it does cover combination therapies using two chelators with different strengths.

- Blood, urine and hair measurements only indicate exposures in recent days or months.
- Chelation should be titrated up slowly since aggressive treatment causes too fast a shift in both essential and toxic elements. There is a rebound of levels in the blood following discontinuation, as the elements migrate from tissue and bone back into the bloodstream where they have greater effect (redistribution). [This may explain why symptoms sometimes worsen in the first few months of a low nickel diet.]
- Adequate hydration and bowel regularity are essential so that mobilization equals excretion.
- Products that stop metals from being reabsorbed in the intestines include cholestyramine, psyllium, charcoal, and thiolized silica.
- Mineral status must be monitored.
- Allergic reactions have been reported with DMSA, DMPS and CaNa₂EDTA.

Flora, S.J. and Pachauri, V., 2010. Chelation in metal intoxication. *International Journal of Environmental Research and Public Health*, 7(7), pp.2745-2788.

<https://www.mdpi.com/1660-4601/7/7/2745/htm>

- Nitriolotriacetic acid (NTA) has been shown to possess the ability to mobilize nickel from brain, heart, kidney and liver of nickel poisoned rats.
- Most chelating agents have serious side effects.

Smolik, S. et al., 2008. Characteristics of chelation ability of chosen metal ions by protective ointments containing Na₂H₂EDTA. *Acta Poloniae Pharmaceutica*, 65(1), pp.125-128.

https://ptfarm.pl/pub/File/Acta_Poloniae/2008/1/125.pdf

- In an *in vitro* study, a barrier cream containing 10% EDTA at pH 7.0-7.4 was found to be effective for binding nickel and cobalt, for prevention of nickel and cobalt dermatitis due to occupational exposure.
- Barrier creams alone do not affect allergic reaction.

Sharma, A.D., 2006. Disulfiram and low nickel diet in the management of hand eczema: A clinical study. *Indian Journal of Dermatology, Venereology, and Leprology*, 72(2), p.113.

<http://www.ijdv.com/article.asp?issn=0378-6323;year=2006;volume=72;issue=2;spage=113;epage=118;aulast=Shar>

- Study comparing a low nickel diet with disulfiram to a control group on a normal diet with placebo found that 10/11 patients with chronic vesicular hand dermatitis and nickel allergy improved on the diet with medication, versus 1/10 in the control group. All patients reacted to oral nickel sulfate challenge (showing systemic dermatitis).
- The study does not compare the diet alone to the medication alone.

Blanuša, M. et al., 2005. Chelators as antidotes of metal toxicity: therapeutic and experimental aspects. *Current Medicinal Chemistry*, 12(23), pp.2771-2794.

https://www.researchgate.net/publication/7464295_Chelators_as_Antidotes_of_Metal_Toxicity_Therapeutic_and_Experimental_Aspects

- The recommended treatments for nickel *toxicity* are sodium diethylcarbodiithioate (DDTC) and disulfiram, based on very limited human data. Disulfiram has been observed to cause hepatotoxicity and possible redistribution of nickel in the brain.
- BDCG and 2,3-dimercaptosuccinic acid (DMSA) have been used in experiments on animals.
- Refers to a case where British-Anti-Lewisite (BAL), a chelator that can get into cells, was used for nickel poisoning (Sunderman1981), but that reference says it is relatively ineffective.

Neuvonen, P.J. and Olkkola, K.T., 1988. Oral activated charcoal in the treatment of intoxications. *Medical Toxicology and Adverse Drug Experience*, 3(1), pp.33-58.

https://www.researchgate.net/publication/257286591_Oral_Activated_Charcoal_in_the_Treatment_of_Intoxications

- Most metals are not efficiently adsorbed to activated charcoal. Nickel is not specifically mentioned, however.
- Large doses may cause vomiting. Constipation and diarrhea have occurred. Be wary of fillers such as sorbitol and sodium bicarbonate.

Christensen, O.B. and Kristensen, M., 1982. Treatment with disulfiram in chronic nickel hand dermatitis. *Contact Dermatitis*, 8(1), pp.59-63.

Abstract at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0536.1982.tb04137.x>

- In 11 patients with nickel allergy and hand eczema, 2 patients healed and 8 improved with disulfiram treatment. Mild relapses occurred in all patients within 2-16 weeks of discontinuation.
- Liver enzymes should be monitored during treatment.

Sunderman, F.W., 1981. Chelation therapy in nickel poisoning. *Annals of Clinical and Laboratory Science*, 11(1), pp.1-8.

<http://www.anclinlabsci.org/content/11/1/1.full.pdf>

- In 1911 nickel was used to treat epilepsy, chorea, migraine and neuralgia, and it was reported to have “peculiar and elective power in controlling the damaging effects of sexual vice on the nervous system.”
- Discusses allergic dermatitis and exposure via diet and cooking equipment.
- A review that recommends a low nickel diet, Dithiocarb (DDC) or antabuse (possibly on a week-on/week-off schedule) and topical steroids with or without DDC for nickel dermatitis.
- Noted that DDC did not have significant side effects or lower essential mineral levels in rat and dog experiments.

Kaaber, K. et al., 1979. Antabuse treatment of nickel dermatitis. Chelation—A new principle in the treatment of nickel dermatitis. *Contact Dermatitis*, 5(4), pp.221-228.

Abstract at <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0536.1979.tb04855.x>

- In 11 patients with nickel allergy and hand eczema, 7 patients healed, 2 improved, and 2 were unchanged with Antabuse treatment. Relapses occurred in 6 patients on discontinuation.
- 9 of 11 had a flare at the beginning of treatment.
- 7 experienced side effects including fatigue, headaches and dizziness. The treatment was discontinued in 4 because of side effects.

4. IBS and GI Symptoms

Borghini, R. et al., 2020. Beneficial effects of a low-nickel diet on relapsing IBS-like and extraintestinal symptoms of celiac patients during a proper gluten-free diet: Nickel allergic contact mucositis in suspected non-responsive celiac disease. *Nutrients*, 12(8), p.2277.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7468824/>

- A study of patients with celiac disease who did not improve with, or relapsed after, a strict gluten-free diet. Of 102 patients who had been on a gluten-free diet for at least a year, 20 met the inclusion (significant GI symptoms) and exclusion (IgE allergies, cancer, lactose intolerance, IBD, H. pylori) criteria. All 20 had a positive oral mucosa patch test to nickel and were diagnosed with nickel allergy.
- After 3 months on a gluten-free low-nickel diet, the average ratings for all GI symptoms improved except that there was an increase in constipation.

- The increase in higher-nickel foods due to alternative grains in a gluten-free diet causes an increase in SNAS symptoms, which accounts for the lack of improvement or relapse in symptoms despite the improvement in celiac markers.
- Discusses FODMAP/Ni overlap (but misplaces some low nickel foods in the overlap, e.g. garlic, onion).

Brown, B.I., 2019. Does Irritable Bowel Syndrome exist? Identifiable and treatable causes of associated symptoms suggest it may not. *Gastrointestinal Disorders*, 1(3), pp.314-340.

<https://www.mdpi.com/2624-5647/1/3/27>

- IBS is a diagnosis that clusters several underlying identifiable and treatable causes for the same symptom presentation into one classification - it's kind of meaningless. There are many different underlying causes for the symptom presentation. The article reviews the various causes.
- There is a short section on "Nickel-related intestinal mucositis" as a cause of IBS symptoms.

Kageyama, Y. et al., 2019. Higher incidence of zinc and nickel hypersensitivity in patients with irritable bowel syndrome. *Immunity, Inflammation and Disease*, 7(4), pp.304-307.

<https://onlinelibrary.wiley.com/doi/full/10.1002/iid3.274>

- Of 147 patients with IBS, 68% were allergic to at least one metal (Ni, Zn, Au, Pd) while of 22 controls it was 32%. As usual, nickel was the most common sensitizer. For nickel it was 39.6% in the IBS group vs. 21.1% in the controls. Gold and palladium did not show a statistically significant difference.
- Implies that "hypersensitivity reaction to orally derived zinc and nickel may underlie aberrant immune activation in the IBS mucosa."

Borghini, R. et al., 2017. New insights in IBS-like disorders: Pandora's box has been opened. *Gastroenterology and Hepatology from Bed to Bench*, 10(2), pp.79-89.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5495893/>

- A review of IBS and its possible causes, including Nickel Allergic Contact Mucositis.
- Also lists some treatments, surprisingly including iron supplementation without a deficiency diagnosis.

Borghini, R. et al., 2016. Nickel-related intestinal mucositis in IBS-like patients: Laser doppler perfusion imaging and oral mucosa patch test in use. *Biological Trace Element Research*, 173(1), pp.55-61.

<http://nikaut.com/wp-content/uploads/2016/03/12011-016-0650-2.pdf>

- Oral mucosa patch testing (omPT) requires qualitative evaluation and is subject to error. The authors propose the use of laser Doppler perfusion imaging (LDPI) to augment omPT to diagnose intestinal mucositis caused by nickel allergy. LDPI uses a laser to detect increased blood flow to tissues, and gives a quantitative result.
- In their test group, all patients with nickel allergy and GI symptoms showed an increase in mean perfusion value pre- and post-omPT. There was no increase in the control group.

Pasqui, F. et al., 2015. Adverse food reaction and functional gastrointestinal disorders: Role of the dietetic approach. *Journal of Gastrointestinal and Liver Diseases*, 24(3), pp.319-327.

<https://pdfs.semanticscholar.org/0f49/668417e94419f5b3fbcaee3cc7d93bd7b43a.pdf>

- A review of GI disorders that briefly includes SNAS, its diagnosis and treatment.

Cazzato, I.A. et al., 2011. Fecal calprotectin in Systemic Nickel Allergy Syndrome (SNAS). *Gastroenterology*, 140(5), p.S-283.

[https://www.gastrojournal.org/article/S0016-5085\(11\)61137-2/pdf](https://www.gastrojournal.org/article/S0016-5085(11)61137-2/pdf)

- Elevated concentrations of calprotectin, a calcium and zinc binding protein, are found in the feces of 20 SNAS patients.
- The levels decreased drastically after weeks on a low nickel diet, along with significant symptom improvement.

5. Links to Other Conditions

Skin Conditions

Çifci, N., 2019. Nickel sensitivity in rosacea patients: A prospective case control study. *Endocrine, Metabolic and Immune Disorders - Drug Targets*.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/30621570>

- Nickel allergy in the patient (rosacea) and control group (no rosacea) was found to be 52.5%, 22.5% respectively.

Nakayama, H. and Chen, K., 2018. How to treat metal hypersensitive alopecia areata and atopic alopecia. *Clinical Dermatology Research Journal*, 2018.

https://www.scitechnol.com/peer-review/how-to-treat-metal-hypersensitive-alopecia-areata-and-atopic-alopecia-itzi.php?article_id=7543

- Metal allergy was found with severe types of alopecia areata (AA) at the rate of 69.9% and the elimination of metal allergens from dental metals and cooking instruments leads to satisfactory hair regrowth and long-term prevention of severe relapse of AA at the rate of 75.5%.
- Has a good description of how a metal becomes an allergen, by binding with keratin, and a possible explanation of why Ni/Co and Ag/Hg tend to appear together.
- The authors recommend against oral nickel challenge because of the illness it can cause, calling it unethical. In one case of alopecia, the hair loss was worsened by an oral challenge to NiSO₄.
- Provides a review of 8 case studies where alopecia was cured by removing the allergenic dental metals and/or avoiding stainless steel pots and pans and instead using ceramics, enamel-coated or glassware.
- Gives patch-testing statistics for 104 alopecia cases, 229 AD cases, and 336 contact dermatitis cases.
- Type IV mite allergy is also a common cause of alopecia; treatment is environmental remediation.
- Treatment must be done quickly (less than 6 years) before dermal fibrosis destroys the hair follicles.

Hundley, K. et al., 2017. Central facial inflammation: A manifestation of nickel allergy: 5402. *Journal of the American Academy of Dermatology*, 76(6).

[https://www.jaad.org/article/S0190-9622\(17\)30751-X/fulltext](https://www.jaad.org/article/S0190-9622(17)30751-X/fulltext)

- A case of SCD due to dietary nickel presenting as an inflammatory process mimicking rosacea. One month prior to onset she began a strict vegetarian diet, which is known to be high in nickel.
- She began a low nickel diet, daily vitamin C, and iron supplements. Her facial eruption improved dramatically within 5 weeks and completely resolved in 5 months. A challenge with her previous diet reproduced the facial inflammatory dermatosis.

Kato, K. et al., 2010. Systemic nickel allergy presenting as papuloerythroderma-like eruptions. *Acta Dermato-venereologica*, 90(6), pp.655-656.

<https://www.ingentaconnect.com/contentone/mjl/adv/2010/00000090/00000006/art00026>

- A case study of an 82-year-old woman who had pruritic papules on her entire body for 4 years. She patch-tested positive to nickel and chrome, and oral challenge with 2 mg nickel induced diffuse erythema with pruritus on her trunk and extremities; no such effect was seen with chrome or salt control. The reaction peaked at 2 days after the challenge.

Non-Celiac Wheat Sensitivity (NCWS)

Mansueto, P. et al., 2019. Non-celiac wheat sensitivity: A search for the pathogenesis of a self-reported condition. *Italian Journal of Medicine*, 13(1), pp.15-23.

<https://italjmed.org/index.php/ijm/article/download/itjm.2019.1070/1157/>

- A review of non-celiac wheat sensitivity, including its comorbidities with other allergies and sensitivities including nickel allergy. Some immunologic pathways are shared between NCWS and nickel allergy.

Limone, B.A. et al., 2017. Complementary intradermal and patch testing for increased diagnostic accuracy of nickel allergy in non-celiac wheat insensitivity. *Nutrients*, 9(6), p.536.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5490515/>

- A letter to the editor in support of testing patients with non-celiac wheat sensitivity for nickel allergy, as proposed in D'Alcamo's 2017 paper.

D'Alcamo, A. et al., 2017. Contact dermatitis due to nickel allergy in patients suffering from non-celiac wheat sensitivity. *Nutrients*, 9(2), p.103.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5331534/>

- In 60 patients diagnosed with non-celiac wheat sensitivity, 10% also had a positive nickel patch test, double that of the control group.

Lactose Intolerance

Cazzato, I.A. et al., 2011. Lactose intolerance in systemic nickel allergy syndrome. *International Journal of Immunopathology and Pharmacology*, 24(2), pp.535-537.

<https://journals.sagepub.com/doi/pdf/10.1177/039463201102400230>

- In 178 SNAS patients and 60 healthy controls, a lactose breath test was positive in 74.7% of the SNAS group compared to 6.6% of the control group.
- The authors hypothesize that in SNAS patients, the nickel-induced pro-inflammatory status could temporarily impair the brush border enzymatic functions, resulting in hypolactasia.

Ulcerative Colitis and Crohn's Disease

Kageyama, Y. et al., 2020. Higher Prevalence of Nickel and Palladium Hypersensitivity in Patients with Ulcerative Colitis. *International Archives of Allergy and Immunology*, pp.1-6.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/32316004/>

- In 65 patients with ulcerative colitis and 22 controls, a significantly greater proportion of UC patients were hypersensitive to nickel or palladium. The severity of the sensitivity to nickel and palladium was also significantly greater for UC patients than for HC.

Schoelmerich, J. and Rogler, G., 2000. Correlation between nickel allergy towards dentures and Crohn's disease: A case report. *Gastroenterology*, 118(4), p. A1135.

[https://www.gastrojournal.org/article/S0016-5085\(00\)80350-9/pdf](https://www.gastrojournal.org/article/S0016-5085(00)80350-9/pdf)

- The authors report a case of a woman who had severe Crohn's disease that began after she started using dentures that contained nickel. There were obvious signs of oxidation in the mouth. After not using the dentures, the patient fully recovered.

Heartburn, GERD and EoE

Nucera, E. et al., 2019. Eosinophilic oesophagitis (in nickel-allergic patient) regressed after nickel oral desensitization: A case report. *International Journal of Immunopathology and Pharmacology*, 33, p.2058738419827771.

<https://journals.sagepub.com/doi/full/10.1177/2058738419827771>.

- A case of a 48-year-old woman diagnosed with SNAS and suffering from eosinophilic oesophagitis not responsive to topical steroids. After immunotherapy and on a low nickel diet, oesophagogastroscopy showed complete macroscopic and histological resolution.

Stanghellini, V. et al., 2016. Nickel sensitization in patients with gastro-esophageal reflux disease. *United European Gastroenterology Journal*, 4(2), pp.184-190.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4804365/>

- Patients with GERD but no neoplastic diseases, relevant skin lesions, dermatitis, known autoimmune diseases or previously diagnosed nickel allergy, or current treatment with steroidal or antihistaminergic therapies were included in the study. These were split into erosive vs. non-erosive groups. The control group did not have GERD.
- All patients were patch tested for nickel allergy. All GERD patients were instructed to follow a standard GERD diet, and the nickel allergic patients also a low-nickel diet, for 6 months.
- Nickel sensitization was significantly more common among patients with GERD than patients without GERD (39.5% vs. 16.4%, respectively). Asthma was also more frequent in the nickel allergic group.

Campanale, M. et al., 2014. Nickel free-diet enhances the *Helicobacter pylori* eradication rate: A pilot study. *Digestive Diseases and Sciences*, 59(8), pp.1851-1855.

https://www.researchgate.net/publication/260527866_Nickel_Free-Diet_Enhances_the_Helicobacter_pylori_Eradication_Rate_A_Pilot_Study

- Since *H. Pylori* requires a nickel-containing enzyme, patients diagnosed with *H. Pylori* infection but without SNAS, food allergies, drug allergies, liver disease, neoplasms, kidney failure or who had recently used antimicrobial agents, bismuth compounds, proton pump inhibitors (PPI) or H2 receptor antagonists, were studied for the effect of a low nickel diet on treatment.
- Those who added a low nickel diet to a round of two antibiotics had a significantly higher eradication rate (22 out of 26 for the diet plus antibiotics vs. 12 out of 26 for the antibiotics alone).

Metabolic Conditions

Watanabe, M. et al., 2018. Overweight and obese patients with nickel allergy have a worse metabolic profile compared to weight matched non-allergic individuals. *PloS One*, 13(8), p.e0202683.

<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0202683>

- In 1128 obese and overweight patients, 666 displayed at least 2 SNAS symptoms and were tested for nickel allergy, and 463 of those patch-tested positive for nickel.
- The nickel-allergic were found to have lower insulin-like growth factor 1 (IGF-1) and a higher rate of growth hormone deficiency.
- [It is not clear to me why they excluded almost 500 obese patients who did not show at least 2 symptoms of SNAS from their sample. Wouldn't this bias the result?]

Lusi, E.A. et al., 2015. High prevalence of nickel allergy in an overweight female population: A pilot observational analysis. *PloS One*, 10(3), p.e0123265.

<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0123265>

- In an overweight population, nearly 60% were nickel allergic. Of the 24 overweight females who completed the trial, the average waist circumference decreased by almost 12 cm.
- There was no control group for the low nickel diet without nickel allergy. Since the diet was calorie controlled as well as low nickel, the caloric restriction alone may be responsible for the weight loss.

Lubrano, C. et al., 2015. Nickel sensitivity in Italian overweight-obese patients. *European Journal of Public Health*, 25(suppl_3).

https://academic.oup.com/eurpub/article/25/suppl_3/ckv175.253/2578741

- Summary report of 641 obese patients tested for nickel allergy. Patch tests were positive in 430 patients (63.1%). This group showed higher BMI and waist circumference, reduced lean mass percentage, a slightly increased prevalence of metabolic syndrome (51% vs 41%), higher triglyceride, HOMA-IR and C-reactive protein. Basal and stimulated levels of GH and IGF-1 were significantly lower in the group with Ni allergy.

Endometriosis

Borghini, R. et al., 2020. Irritable Bowel Syndrome-like disorders in endometriosis: Prevalence of nickel sensitivity and effects of a low-nickel diet. An open-label pilot study. *Nutrients*, 12(2).

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7071203/>

- Of 31 patients referred to gynecology, with confirmed endometriosis and gastrointestinal symptoms, 28 (90.3%) patients had a positive oral mucosa patch test for nickel.
- After 3 months of a low-nickel diet, all gastrointestinal, extra-intestinal and gynecological symptoms showed a statistically significant reduction. (Pelvic pain dropped from a 7 to a 4!)

Borghini, R. et al., 2018. Relationship between nickel allergic contact mucositis and nickel-rich diet in symptomatic women suffering from endometriosis. *Digestive and Liver Disease*, 50(2), p. e234.

[https://www.dldjournalonline.com/article/S1590-8658\(18\)30650-9/fulltext](https://www.dldjournalonline.com/article/S1590-8658(18)30650-9/fulltext) (This is just an abstract, see the other reference.)

- 14 out of 16 symptomatic women with both endometriosis and gastrointestinal symptoms tested positive for nickel allergy. After 3 months on a low nickel diet, all showed statistically significant improvement.

Thyroid

Wesner, E., Sung, C.T. and Jacob, S.E., 2019. Letter to the Editor: SNAS and thyroid autoimmunity risk. *Endocrine*, 63(2), pp.401-402.

<http://website60s.com/upload/files/26-letter-to-the-editor.pdf>

- Short letter that describes how chronic autoimmune thyroiditis may be related to SNAS through Th1/IFN γ and Th2/IL-4 pathways.

Takir, M., Turkoglu, O. and Turkoglu, Z., 2017. Thyroid hormone and ultrasonographical analyses in patients with nickel allergy. *Eurasian Journal of Medicine and Oncology*, 1(3), pp.145-148.

<https://www.ejmo.org/pdf/Thyroid%20Hormone%20and%20Ultrasonographical%20Analyses%20in%20Patients%20with%20Nickel%20Allergy-02996.pdf>

- 79 patients and 43 controls were studied for a relationship between thyroid conditions and nickel allergy.
- Mean platelet volume and total IgE levels were significantly high in the patient group, and monocyte and eosinophil levels were low.

- Thyroid function was the same in both groups, but the incidence of thyroid cysts and thyroiditis was significantly higher in patients with nickel allergy.

Andrioli, M. et al., 2015. Systemic nickel allergic syndrome as an immune-mediated disease with an increased risk for thyroid autoimmunity. *Endocrine*, 50(3), pp.807-810.

<http://www.maurominelli.it/immunologia-allergologia/wp-content/uploads/2015/06/Systemic-nickel-allergic-syndrome-as-an-immune-mediated-disease.pdf>

- To study the risk of chronic autoimmune thyroiditis (CAT) in SNAS patients, 239 subjects with some form of immune-mediated inflammatory disorder were recruited. 136 were diagnosed with SNAS.
- All of the subjects had normal thyroid function, but 26.5% of the subjects with SNAS versus 12.7% of those without SNAS were diagnosed with CAT based on antibodies (TGAb or TPOAb) or ultrasound.
- CAT is twice as prevalent in patients with SNAS than in patients with other immune-mediated disorders.

Respiratory Conditions

Kolberg, L. et al., 2020. Nickel allergy is associated with wheezing and asthma in a cohort of young German adults: Results from the SOLAR study. *ERJ Open Research*, 6(1).

<https://openres.ersjournals.com/content/6/1/00178-2019.abstract>

- A statistical look at 2051 people for links between nickel allergy and wheezing, asthma and rhinitis.
- “Our results suggest that self-reported nickel allergy is associated with incident wheezing. Whether this association is due to environmental or genetic predisposition, or due to an overlap of the mechanisms of type I and type IV hypersensitivity, needs to be elucidated.”

Gelardi, M. et al., 2017. Allergic and nonallergic rhinitis and skin sensitization to metals: Is there a link? *European Annals of Allergy and Clinical Immunology*, 49(3), pp.106-109.

<http://www.eurannallergyimm.com/cont/journals-pdf/491/complete-issue.asp?page=11>

- Investigates the relationship between rhinitis and metal hypersensitivity by separating rhinitis into groups: allergic rhinitis, non-allergic rhinitis, and overlapping. Compared to a control group, non-allergic rhinitis and overlapping had a higher incidence of metal allergy.
- Concludes that “it is conceivable that the association of metal sensitisation and nonallergic rhinitis is not simply “by chance”, and would deserve further investigations.”

Brera, S. and Nicolini, A., 2005. Respiratory manifestations due to nickel. *Acta Otorhinolaryngologica Italica*, 25(2), p.113.

<https://www.actaitalica.it/issues/2005/2-05/Brera.pdf>

- In 20 patients with a positive nickel patch test and rhinitis, 7 also had a positive prick test to nickel (35%).
- Nickel allergy was confirmed to be the cause of rhinitis via a provocation test.
- Those who maintained a low nickel diet for 2-4 months experienced a reduction in symptoms.

Burning Mouth Syndrome

Lynde, C.B., Grushka, M. and Walsh, S.R., 2014. Burning mouth syndrome: Patch test results from a large case series. *Journal of Cutaneous Medicine and Surgery*, 18(3), pp.174-179.

<https://pdfs.semanticscholar.org/481a/1570140bb1c8f1309f47d9c2fe4798315122.pdf>

- Of 132 patients with burning mouth syndrome, 66 had possibly relevant positive patch test results, of which nickel and the gallates were the most prevalent.

Fibromyalgia and Chronic Fatigue Syndrome

Bjørklund, G., Dadar, M. and Aaseth, J., 2018. Delayed-type hypersensitivity to metals in connective tissue diseases and fibromyalgia. *Environmental Research*, 161, pp.573-579. Abstract and summary at <https://www.dermatitisacademy.com/delayed-type-hypersensitivity-to-metals-in-connective-tissue-diseases/>

- A review of more than 100 studies and two case reports that found positive associations between metal allergies and connective tissue diseases or fibromyalgia.

Regland, B. et al., 2001. Nickel allergy is found in a majority of women with chronic fatigue syndrome and muscle pain — and may be triggered by cigarette smoke and dietary nickel intake. *Journal of Chronic Fatigue Syndrome*, 8(1), pp.57-65.

https://www.melisa.org/pdf/cfs_nickel.pdf

- A not-very-rigorous study, but interesting as a coincidental observation of another study.
- In a trial of a staphylococcus vaccine to treat CFS, the unresponsive group was found to have a higher rate of a) a history of contact dermatitis to metals and b) smokers. People who had a history of dermatitis and were smokers were the least likely to have a good response to the treatment. 16 who had an adverse reaction to the treatment were tested with MELISA and 81% had a nickel allergy, a “substantial number” of which were also smokers.
- Case study 1: A patient who was unresponsive to treatment gave up smoking and her daily chocolate and oatmeal, and had full remission of her muscle pain after 2 months. Her symptoms returned when she began smoking again.
- Case study 2: A patient who became worse with treatment had no history of dermatitis and a strongly positive MELISA test to nickel. She went on a low nickel diet and 3 months later had improvement in her symptoms, continuing to improve at 6 months. When she eats a high nickel food she experiences an increased fatigue within two hours, lasting 3-4 days.
- “If the main purpose is to assess nickel hyperreactivity with general symptomatology of ill-being, such as chronic fatigue and muscle pain, an in vitro test of lymphocyte reactivity may prove to be a better reference than a skin test.”

Sterzl, I. et al., 1999. Mercury and nickel allergy: risk factors in fatigue and autoimmunity. *Neuroendocrinology Letters*, 20, pp. 221-228.

<http://www.melisa.org/pdf/nialler.pdf>

- 62 fatigued patients and 13 healthy controls were tested using MELISA. The fatigued patients were more frequently found to be allergic to metals, nickel and mercury having the highest rate.
- Two subjects were treated by removing dental restorations. In one case, a heavy smoker had amalgams removed and her pain disappeared and fatigue lessened significantly after two months. In the second case, a dental technician had her amalgams removed and left her occupation to reduce exposure; her ACD disappeared and fatigue decreased significantly.
- The second subject tested positive only to nickel and only had amalgam fillings. This indicates that nickel was present in the amalgam.
- The healthy controls reacted to Cd, Hg, Pb, Pd; lead was most prevalent at 33.3%, and Hg/Pd tied for least at 8.3%. Suggests that exposure and immune response may not necessarily lead to symptoms.

Marcusson, J.A., Lindh, G. and Evengard, B., 1999. Chronic fatigue syndrome and nickel allergy. *Contact Dermatitis*, 40(5), pp.269-272.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/10344482/>

- In 50 patients with chronic fatigue syndrome (CFS) and 73 controls, allergy to nickel occurred in 36% of patients in the CFS group and in 19% of subjects in the control group.

- The authors suggest that allergy to nickel, or metal cross-reacting with nickel, could be either a contributing cause of CFS, or simply a “marker” symptom.

6. Exposure Sources

Darsow, U. et al., 2012. Influence of dietary factors, age and nickel contact dermatitis on nickel excretion. *Contact Dermatitis*, 67(6), pp.351-358.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/22928956>

- Using urinary excretion and foods logs, the authors determined that nickel-rich food correlates with renal nickel excretion, and that frequent ingestion of supplements and stagnant tap water increases renal nickel excretion.
- A higher mean was seen in older women (in contrast to Bartos) and cookware containing nickel.
- The range of nickel concentration in urine went very high for smokers, even though the average was the same as for non-smokers.

Skin Contact

Ahlström, M.G. et al., 2018. Short contact with nickel causes allergic contact dermatitis: an experimental study. *British Journal of Dermatology*, 179(5), pp.1127-1134.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/bjd.16935>.

- This experimental study showed that relatively short repeated skin contact (3 x 10 min) with metallic nickel elicits allergic nickel dermatitis in irritated skin and at sites with previous dermatitis.
- SLS was used 24 hours prior to application of the metal disc to disturb the skin barrier.
- Blood flow in the area increased in the group pretreated with SLS, as well as reactions occurring. There were no reactions in the group that wasn't pretreated with SLS, or the control group.

Nixon, R.L. et al., 2018. Does clinical testing support the current guidance definition of prolonged contact for nickel allergy? *Contact Dermatitis*, 79(6), pp.356-364.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/cod.13095>.

- Repeated exposure to a nickel disc for multiple 30 minute periods only induced a reaction for certain in 1 nickel-allergic patient, and inconsistently in 4 others, out of 20. There was no pre-treatment of the skin.

Skin Penetration

Midander, K., Schenk, L. and Julander, A., 2020. A novel approach to monitor skin permeation of metals in vitro. *Regulatory Toxicology and Pharmacology*, p.104693.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/32505642/>

- Using pig skin and artificial sweat, skin absorption of nickel alone or in combination with chromium and cobalt was measured. Nickel is absorbed much more readily for nickel than for cobalt or chromium. Absorption of nickel was faster when it was alone.
- Metals can permeate the skin to end up in systemic circulation.

Malmberg, P. et al., 2018. Imaging mass spectrometry for novel insights into contact allergy – a proof-of-concept study on nickel. *Contact Dermatitis*, 78(2), pp.109-116.

https://www.researchgate.net/publication/321254264_Imaging_mass_spectrometry_for_novel_insights_into_contact_allergy_-_a_proof-of-concept_study_on_nickel_SKIN_PENETRATION_STUDY_OF_NICKEL_SULFATE

- When skin is exposed to nickel sulfate, the ions accumulate in the stratum corneum.
- There is increased penetration at hair follicles (other work referenced).

Filon, F.L., 2018. Penetration of Metals Through the Skin Barrier. In *Metal Allergy* (pp. 67-74). Springer, Cham. Abstract at https://link.springer.com/chapter/10.1007/978-3-319-58503-1_7.

- "...metals can penetrate and permeate the skin in an amount in the range of ng/cm²/h if applied in metallic or nano-form, while soluble metal salts can penetrate the skin in higher amounts. The time needed for permeation is quite long, ranging between 2 and 15 h."

Pharmaceuticals and Supplements

International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH), (2019). Guideline for Elemental Impurities: Q3D(R1).

https://database.ich.org/sites/default/files/Q3D-R1EWG_Document_Step4_Guideline_2019_0322.pdf

- This international standard sets the permitted daily exposure (PDE) for nickel impurities in a pharmaceutical to 220 µg (upper limit).

Boetzel, R. et al., 2018. An elemental impurities excipient database: a viable tool for ICH Q3D drug product risk assessment. *Journal of Pharmaceutical Sciences*, 107(9), pp.2335-2340.

<https://www.sciencedirect.com/science/article/pii/S0022354918302120>

- A database of elemental impurities was created by a consortium of pharmaceutical companies.
- Provides a hypothetical case study of a daily dose of 2x50 mg tablets of "Greatstuff" (as described in the ICH training package at <https://www.ich.org/page/quality-guidelines>) and shows its worst-case (maximum value in the database) excipient content as: microcrystalline cellulose 1.1 µg; calcium hydrogen phosphate dihydrate (aka dibasic calcium phosphate) 20 µg; magnesium stearate 0.036 µg; croscarmellose sodium 3.6 µg; talc 0.14 µg; hydroxypropylmethyl cellulose (aka hypromellose) 0.48 µg. The total intake for that worst-case hypothetical medication is then 25 µg.

Schwalfenberg, G., Rodushkin, I. and Genuis, S.J., 2018. Heavy metal contamination of prenatal vitamins. *Toxicology Reports*, 5, pp.390-395.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5978005/>

- In 26 brands of prenatal vitamins collected in Edmonton: "All 51 samples contained Ni. The upper limit of exposure for Ni according to the USP guidelines is 60 µg/day and the maximum found in any sample was 34 µg/day. The average was about 5 µg/day."
- More than half of the brands tested were above the acceptable limits for lead.

Cardoso, P. et al., 2017. Determination of nickel and manganese contaminants in pharmaceutical iron supplements using energy dispersive x-ray fluorescence. *Applied Spectroscopy*, 71(3), pp.432-437.

https://run.unl.pt/bitstream/10362/68439/1/applied_spectro_phar_editedSAGE_Rev1_1_.pdf

- Found iron supplements contained between 12 and 36 µg nickel/dose.

Adolfo, F.R. et al., 2016. Simultaneous determination of cobalt and nickel in vitamin B12 samples using high-resolution continuum source atomic absorption spectrometry. *Talanta*, 147, pp.241-245.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/26592602>

- Nickel in B12 supplements was found to range from 9.48 to 26.20 µg/L. Not sure how this translates to a dose.

Li, G. et al., 2015. Elemental impurities in pharmaceutical excipients. *Journal of Pharmaceutical Sciences*, 104(12), pp.4197-4206.

<https://onlinelibrary.wiley.com/doi/pdf/10.1002/jps.24650>

- Shows iron-based excipients (fillers) are highest in nickel (up to 154 µg/g).

Patlar, S. et al., 2011. Elements in sera of elite taekwondo athletes: Effects of vitamin E supplementation. *Biological Trace Element Research*, 139(2), pp.119-125.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/20195919>

- Athletes given 300 mg Vitamin E for 6 weeks had “significant increases” in blood levels of nickel relative to values before supplementation.
- [It is not clear whether the supplement contained nickel, or vitamin E released nickel stored in tissue.]

Avula, B. et al., 2010. Quantitative determination of multiple elements in botanicals and dietary supplements using ICP-MS. *Journal of Agricultural and Food Chemistry*, 58(16), pp. 8887-8894.

Abstract at <https://pubs.acs.org/doi/abs/10.1021/jf101598g>

- A variety of supplements were tested (21 in total). Nickel was found in “low concentrations in most of the samples” they tested.

van der Voet, G.B. et al., 2008. Clinical and analytical toxicology of dietary supplements: A case study and a review of the literature. *Biological Trace Element Research*, 125(1), pp.1-12.

https://is.muni.cz/el/1411/jaro2013/MNAF101p/um/39474980/Clinical_and_Analytical_Toxicology_of_Dietary.pdf

- Shows some herbal supplements having relatively high nickel content (up to 1.6 µg/g).
- Nature Made vitamin A had .055 µg/g. Mason Vitamin Inc. vitamin C had 0.013 µg/g. Prolab Nutrition Inc.’s Pure Whey was below the detection limit (0.5 ppb). [Note that these are for a specific batch! No guarantees for any other batch!]
- Herbals and botanicals had the highest nickel, some over 1.5 µg/g.

Ponce de León, C.A., Bayón, M.M. and Caruso, J.A., 2002. Trace element determination in vitamin E using ICP-MS. *Analytical and Bioanalytical Chemistry*, 374(2), pp.230-234.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/12324842>

- Found nickel in vitamin E at 0.060 µg/g in one product, and undetectable in another.

Gloves

Garçon, M. et al., 2017. Nitrile, latex, neoprene and vinyl gloves: A primary source of contamination for trace element and Zn isotopic analyses in geological and biological samples. *Geostandards and Geoanalytical Research*, 41(3), pp.367-380.

<https://onlinelibrary.wiley.com/doi/full/10.1111/ggr.12161>

- There is trace nickel in nitrile, latex, neoprene and vinyl gloves. Vinyl appears to have relatively less and latex relatively more of all of the elements tested.

Pesticides

Defarge, N., de Vendômois, J.S. and Séralini, G.E., 2017. Toxicity of formulants and heavy metals in glyphosate-based herbicides and other pesticides. *Toxicology Reports* 5, pp. 156-163.

<https://www.sciencedirect.com/science/article/pii/S221475001730149X>

- Pesticides and herbicides were examined for their heavy metal content, and nickel was found in most of the samples.
- Nickel was most significant in fungicides and insecticides, but nearly all of them exceeded the EU admissible level of 20 ppb. However, at their recommended dilutions it appears that only 4 of the 23 samples exceeded this limit.

Household items

Duchesnay, I. et al, 2020. Generalised urticaria following ingestion of a nickel-plated coin in a 4-year-old girl. *BMJ Case Reports CP*, 13(9), p.e234601.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/32900721/>

- A 4-year-old girl swallowed a nickel-plated coin (2% nickel overall) and had a systemic reaction (urticaria) beginning 24 hours after ingestion, unresponsive to antihistamines, and continuing until 2-3 days after its removal with steroid treatment.

Ringborg, E., Lidén, C. and Julander, A., 2016. Nickel on the market: a baseline survey of articles in 'prolonged contact' with skin. *Contact Dermatitis*, 75(2), pp.77-81.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/27125984/>

- Nickel was found by DMG test in:
 - Utensils: Thimbles, crochet hooks, knitting needles, needles (all), paintbrushes (many), pens
 - Electronic devices: Laptop computers (all), activity bracelets, computer mice, mobile phones
 - Accessories: Handbags, wallets, umbrellas (most)

Hamann, C.R. et al., 2013. The cost of nickel allergy: a global investigation of coin composition and nickel and cobalt release. *Contact Dermatitis*, 68(1), pp.15-22.

http://www.laserwords.co.in/offprint/cod_68-1/cod_12008_web.pdf.

- 850 coins of 361 different denominations or issues from 52 countries were collected and analysed with X-ray fluorescence spectrometry and nickel and cobalt spot tests.
- Brazil is the only country that had no DMG-positive coins.
- Approximately 40% of coins world-wide are DMG-negative.

Midander, K. et al., 2014. Nickel release from white gold. *Contact Dermatitis*, 71(2), pp.109-111.

<https://pdfs.semanticscholar.org/db16/9d3b95c00783f7a7f13029480192056cc90b.pdf>.

- White gold discs made of 6% nickel were submerged in artificial sweat, and the nickel released was measured at various times. It was found that nickel is initially released at a high rate in the first few minutes, and then declines rapidly.
- The decline exists but is less pronounced for the other alloys tested, including a 5p coin (CuNi).
- "The pattern of nickel release, with an instant and initially relatively high nickel release rate, is important for understanding why nickel can be deposited onto the skin and cause hand eczema by short and repetitive contact."

Thyssen, J.P. and Maibach, H.I., 2008. Nickel release from earrings purchased in the United States: the San Francisco earring study. *Journal of the American Academy of Dermatology*, 58(6), pp.1000-1005.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.519.6947&rep=rep1&type=pdf>.

- 267 inexpensive earring samples (max \$50, average \$10) were purchased in San Francisco and tested with DMG. A smaller portion of them were positive for nickel from stores targeting mature women, and there was no correlation with price.

Hafner, M.D.F.S., Chen, J.C.S. and Lazzarini, R., 2018. Evaluation of nickel and cobalt release from mobile phone devices used in Brazil. *Anais brasileiros de dermatologia*, 93(1), pp.151-153.

http://www.scielo.br/scielo.php?pid=S0365-05962018000100151&script=sci_arttext.

- Of 20 mobile phones used in Brazil, 64.7% tested positive for nickel, with 41.1% positive results for the charger input and 23.5% for other tested areas. None of them was positive for cobalt. Nickel release was more common in older models.

Cooking and Serving

Chen, Y. et al., 2019. Study on the influence of metal materials on the migration of heavy metals in stainless steel kitchenware. In *IOP Conference Series: Materials Science and Engineering* (Vol. 490, No. 2, p. 022032). IOP Publishing.

<https://iopscience.iop.org/article/10.1088/1757-899X/490/2/022032/pdf>.

- Martensite (20Cr13, 30Cr14, 50Cr15MoV, Germany1.4116) leaches more nickel than austenitic (430 and 306 stainless) on average. Some of the martensite samples were orders of magnitude higher. However, there were not a great number of samples of each type. The 30Cr14 and 50Cr15MoV had the highest nickel migration.

Zhou, J. et al., 2018. Determination of the migration of harmful metals from plastic drinking straw by inductively coupled plasma mass spectrometry. *Shipin Kexue/Food Science*, 39(8), pp.276-281.

Abstract at <https://www.cabdirect.org/cabdirect/abstract/20193083038>.

- In 71 samples of commercially available straws, the migration amounts nickel exceeded the national standard limit according to Drinking Water Health Standards (GB 5749-2006) by 60.6%.

Papuc, C. et al., 2017. The influence of cookware on the concentration of trace metals and lipid peroxidation in pork muscle. *Revista de Chimie*, 68(7), pp.1476-1480.

<https://pdfs.semanticscholar.org/7385/af266ecb9625bd8779029713418994e61e04.pdf>

- Pork was used to determine the nickel leached from aluminum, ceramic coated aluminum, brass and stainless steel pans, with acid.
- After 50 minutes at 200°C, aluminum < stainless steel < brass < ceramic.

Lomolino, G., Crapisi, A. and Cagnin, M., 2016. Study of elements concentrations of European seabass (*Dicentrarchus labrax*) fillets after cooking on steel, cast iron, teflon, aluminum and ceramic pots. *International Journal of Gastronomy and Food Science*, 5, pp.1-9.

<https://www.sciencedirect.com/science/article/pii/S1878450X16300270>

- In this study, fish was cooked in several types of pan, all from the same brand (Ballarini), and the nickel was measured raw and after cooking, and with acid.
- The result: cast iron < steel < teflon < ceramic < aluminum. This will depend highly on the composition of the materials used in this brand (since steel can be many different metal mixtures, and the aluminum pan must also be a nickel-containing alloy).

Khaniki, G.J., Khosravi, R., Nazmara, S. and Foroushani, A.R., 2016. Migration of heavy metals into water and lemon juice stored in cast iron containers. *AFST*, 17(2), pp.1-10.

http://www.afst.valahia.ro/images/documente/2016/issue2/full/w17_full.pdf

- After an hour, a new cast iron pan released 8.6 µg Ni into boiling water and 0.3 µg Ni into boiling vinegar. An old cast iron pan released 21.4 µg Ni into boiling water and 1.2 µg Ni into boiling vinegar. This is opposite to what they say about stainless steel pans: here acidity reduces the nickel leached, and old pans release more nickel than new pans.
- The paper was unclear due to language difficulties. It does not appear that the cast iron was seasoned.

Szynal, T., Rebeniak, M. and Mania, M., 2016. Migration studies of nickel and chromium from ceramic and glass tableware into food simulants. *Roczniki Państwowego Zakładu Higieny*, 67(3).

http://agro.icm.edu.pl/agro/element/bwmeta1.element.agro-370d9294-213d-422e-9de7-82ae4222c70a/c/RPZH_2016_Vol_67_No_3_pp_247-252.pdf

- Ceramic dishes and glassware with decorated rims were filled with vinegar up to 1 mm below the overflow edge and placed in a dark room at a temperature of 22°C and left for 24 hrs. Glassware was filled to the rim (I think, another translation barrier) with 4% acetic acid for 24 hours at 22°C or 0.5% citric acid for 2 hours at 70°C.
- Nickel was only detectable for one of the 172 ceramic dishes: a decorated ceramic bowl at 0.04 mg/L.
- In all glassware, nickel was undetectable (below 0.02 mg/L).

Bassioni, G., Korin, A. and Salama, A.E.D., 2015. Stainless steel as a source of potential hazard due to metal leaching into beverages. *Int. J. Electrochem. Sci*, 10, pp.3792-3802.

<http://www.electrochemsci.org/papers/vol10/100503792.pdf>

- Pieces of stainless steel (grade 201) cookware were refrigerated in sweetened fruit juice to test for leaching nickel. pH and exposure time were factors in how much was released.
- To estimate nickel intake, a scenario where 3 people share a beverage container that is a 10x14 cm cylinder was used. Nickel release was as high as 4 milligrams/person, in lemon juice.

Dong, Z., Lu, L., Liu, Z., Tang, Y. and Wang, J., 2014. Migration of toxic metals from ceramic food packaging materials into acid food simulants. *Mathematical problems in engineering*, 2014.

<http://downloads.hindawi.com/journals/mpe/2014/759018.pdf>

- To represent ceramic food storage containers (made of glazed clay), glazed clay ceramic tiles were made and studied for how much nickel would be extracted at various temperatures and in contact with different structures of acids. The nickel release increased with temperature, maximum at about 180 µg per square centimetre. All increased linearly with the square root of time (sideways parabola with time) at low temperature but becomes linear at 60 °C.
- At room temperature the amount of leaching is much smaller, but judging from the graph it is still about 5 µg/sq.cm after about 30 days, which could add up to a lot. At high temperatures that amount is released in about a day.
- Different structures of acids leach different amounts. Citric acid leached the most at high temperatures.

Dan, E.U. and Ebong, G.A., 2013. Impact of cooking utensils on trace metal levels of processed food items. *Ann. Food Sci. Technol*, 14(2), pp.350-5.

http://www.afst.valahia.ro/images/documente/2013/issue2/full/section3/s03_w09_full.pdf

- Rice, beans, yam and plantain were cooked in aluminum and stainless steel pans and the nickel amounts compared to uncooked. The foods all picked up nickel from the pots, with the stainless steel pot leaching higher amounts in all cases.

Kamerud, K.L., Hobbie, K.A. and Anderson, K.A., 2013. Stainless steel leaches nickel and chromium into foods during cooking. *Journal of Agricultural and Food Chemistry*, 61(39), pp.9495-9501.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4284091/>

- Used tomato sauce to determine that nickel contribution is dependent on stainless steel grade, cooking time, and how new the cookware is.
- They found that the nickel leaches out in high levels the first 5 times it is used, then stabilizes. At the 10th use, they reported 88 µg being leached out into tomato sauce, which for SNAS is still significant.

Santonen, T., Stockmann-Juvala, H. and Zitting, A., 2010. Review on toxicity of stainless steel. Finnish Institute of Occupational Health, Helsinki.

<http://www.julkari.fi/bitstream/handle/10024/134863/Review%20on%20toxicity%20of%20stainless%20steel.pdf?sequence=1>

- A review of how stainless steel is made, its designations (alloy compositions), and release of metals, including nickel, from cooking equipment and articles in contact with skin.
- A review of articles to date on nickel released from steel cookware concludes that the nickel released is “inconsistent”. The report sometimes uses the term “negligible” but does not define what that means.
- Although carried out independently by the Finnish Institute of Occupational Health, the study was commissioned by the International Stainless Steel Forum (ISSF) and the European Confederation of Iron and Steel Producers (EUROFER), which may introduce a bias. The individual papers should be consulted.

Flint, G.N. and Packirisamy, S., 1995. Systemic nickel: the contribution made by stainless-steel cooking utensils. *Contact Dermatitis*, 32(4), pp.218-224.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/7600777/>

- The amount of nickel picked up by various foods from an S30400 stainless steel saucepan was investigated: rhubarb; apricot; lemon marmalade; green tomato chutney; and potatoes.
- Rhubarb and apricots were the only foods that picked up significant amounts of nickel.
- The amount of nickel picked up decreased with the number of uses of the pan (more nickel when the pan was new). After 5 uses, the maximum nickel extracted was 8 µg per 140 g serving.

Kuligowski, J. and Halperin, K.M., 1992. Stainless steel cookware as a significant source of nickel, chromium, and iron. *Archives of environmental contamination and toxicology*, 23(2), pp.211-215.

<https://pubmed.ncbi.nlm.nih.gov/1514841/>

- Vinegar was boiled in 11 pans for 5 minutes then tested for nickel.
- Result: Mild (carbon) steel < Aluminum alloy < 1 of the 7 Stainless < Porcelain enamel on steel < Cast iron < All other stainless (i.e. most the stainless steel leached significant amounts of nickel into the vinegar).

Coffee Makers and Kettles

Janda, K., et al., 2020. Mineral composition and antioxidant potential of coffee beverages depending on the brewing method. *Foods*, 9(2), p.121.

<https://www.mdpi.com/2304-8158/9/2/121/pdf>

- The composition of coffee brewed in various devices was compared. A French press gave roughly the same nickel content as a simple infusion (control), Aeropress and espresso coffee makers were roughly equivalent and had slightly more nickel, and a drip method gave on average more nickel and a much wider range.

Müller, F.D., Hackethal, C., Schmidt, R., Kappenstein, O., Pfaff, K. and Luch, A., 2015. Metal release from coffee machines and electric kettles. *Food Additives & Contaminants: Part A*, 32(11), pp.1959-1964.

<http://www.innocua.net/web/download-4377/5-2-2016-metal-rele.pdf>

- Eleven electric kettle devices and 8 coffee machines were investigated: 2 coffee pod (coffee is packaged in a filter bag); 3 coffee capsule (coffee is in a plastic container); and 3 portafilter espresso machines. The portafilter espresso machines leached the most nickel, but only immediately after descaling. Two of the pod machines continued to release significant amounts of nickel for 3 days after descaling.

- On the first day of use and the day after decalcification, the nickel level was highest. Decalcification resulted in a large release of metals (max. 780 µg/kg Ni, a pod machine) for the first cup afterwards, which demonstrates how important it is to rinse them many times after decalcification.
- Five cups were brewed per day, and the first cup of the day almost always had the highest nickel level.
- Checking the supplemental data, it is clear that on the third day of use all three types of coffee machine performed about equally. After decalcification, though, the pod machines continued to release significant amounts of nickel 3 days afterwards (ranging from 7 to 150 µg/L), while the other machines were back to baseline by the third day.
- The maximum release from kettles was 4.9 µg/L.

Berg, T., Petersen, A., Pedersen, G.A., Petersen, J. and Madsen, C., 2000. The release of nickel and other trace elements from electric kettles and coffee machines. *Food Additives & Contaminants*, 17(3), pp.189-196. https://www.researchgate.net/publication/12490009_The_release_of_nickel_and_other_trace_elements_from_electric_kettles_and_coffee_machines

- Ten out of 26 kettles sold on the Danish market released more than 50 µg/L nickel to water. The heating elements were nickel-plated copper, chromium-plated copper, stainless steel, gold-plated and Teflon-coated aluminum. The nickel-plated copper and chromium-plated copper kettles were the ones that exceeded the 50 µg/L limit. Only one of the stainless steel kettles released measurable amounts of nickel.
- New and newly descaled kettles released a lot more nickel for the first few uses. They recommend that water be “boiled and discarded several times after descaling prior to the use of the kettle for food purposes.”
- Coffee machines did not release significant amounts of nickel. 13 of 15 had a heating element made of aluminum, one copper, and one Cu/stainless steel. The latter two and 3 of the aluminum elements machines were tested for nickel, and only one of these released measurable nickel (>1 µg/L).

Airborne Sources

Aldgini, H.M. et al., 2019. Determination of metals as bio indicators in some selected bee pollen samples from Jordan. *Saudi Journal of Biological Sciences*. <https://www.sciencedirect.com/science/article/pii/S1319562X19300397>

- Pollen collected from bee apiaries was found to contain nickel, at concentrations ranging from undetectable (<0.01 ug/g) up to 2.839 ug/g.

Pavlova, D. et al., 2016. Pollen morphology and localization of Ni in some Ni-hyperaccumulator taxa of *Alyssum L.*(Brassicaceae). *Plant Biosystems*, 150(4), pp.671-681. https://www.researchgate.net/publication/268817416_Pollen_morphology_and_localization_of_Ni_in_some_Ni-hyperaccumulator_taxa_of_Alyssum_L_Brassicaceae

- The pollen of some species of brassicaceae were found to have as much as 600 ug/g nickel. [These are hyperaccumulators mind you.]

Mann, E. et al., 2010. Does airborne nickel exposure induce nickel sensitization? *Contact Dermatitis*, 62(6), pp.355-362. http://www.laserwords.co.in/offprint/cod_62-6/cod_1725_web.pdf

- In 309 school-age children, statistically significant associations were shown between exposure to nickel in ambient air and urinary nickel concentration as well as between urinary nickel concentration and nickel sensitization.
- Higher sensitization rates were associated with higher airborne nickel levels.

Cosmetics and Personal Care Products

Karimi, G. and Ziarati, P., 2015. Heavy metal contamination of popular nail polishes in Iran. *Iranian Journal of Toxicology*, 9(29), pp.1290-1295.

http://ijt.arakmu.ac.ir/files/site1/user_files_3a0bf3/parziarati-A-10-297-1-5a145c0.pdf

- The human nail is more permeable than skin and it consists of 10-30% water. Soluble metals can easily pass through it.
- There were 150 samples from 13 brands, and 13 colours (including clear). All colours contained nickel, ranging from 0.85 µg/mL to 6.73 µg/mL.

Ouremi, O.I. and Ayodele, O.E., 2014. Lipsticks and nail polishes: Potential sources of heavy metal in human body. *International Journal of Pharmaceutical Research and Allied Sciences*, 3(4), p.45.

<https://ijpras.com/storage/models/article/l6SjbJlknBqP63somtSnLzXWTFwxd7OSp7KmoYVSjxol2iVTURTwfcU6FpP7/lipsticks-and-nail-polishes-potential-sources-of-heavy-metal-in-human-body.pdf>

- This study showed that heavy metals in the nail polishes and lipsticks were above the proposed limit of metal in cosmetics as set by Health Canada (2009).
- Nickel in nail polishes ranged from 1.88 – 4.22 µg/ml, and in lipstick the range was 12.2 – 20.4 µg/g.

Smoking/Vaping

Neu, H.M. et al., 2020. Cigalike electronic nicotine delivery systems e-liquids contain variable levels of metals. *Scientific Reports*, 10(1), pp.1-11.

<https://www.nature.com/articles/s41598-020-67789-7>

- The metal content of the e-liquids in e-cigarette cartridges purchased in Maryland, US, was tested. The United States Pharmacopeia (USP) limit of 0.5 µg/g for nickel was exceeded in 3 of 4 brands, ranging from: 0-1.5 µg/g for blu; 0.21-1.06 µg/g for Vuse Solo; and 0-11 µg/g for Vuse Vibe.
- [The USP limit is based on toxicity, not allergy.]

Mahmood, I. et al., 2019. Investigation of toxic metals in the tobacco of Pakistani cigarettes using proton-induced X-ray emission. In *Ion Beam*. IntechOpen.

<https://www.intechopen.com/online-first/investigation-of-toxic-metals-in-the-tobacco-of-pakistani-cigarettes-using-proton-induced-x-ray-emission>

- The concentration of nickel in the tobacco of 19 brands of cigarette available in Pakistan was measured, ranging from 0.08 to 1.03 µg/g with an average of 0.31 µg/g in local brands and from 0.33 to 0.5 µg/g with an average of 0.43 µg/g in imported.

Jain, V. et al., 2019. Comprehensive chemical characterization of natural American Spirit cigarettes. *Tobacco Regulatory Science*, 5(4), pp.381-399.

<https://www.ingentaconnect.com/contentone/trsg/trs/2019/00000005/00000004/art00008?crawler=true&mimetype=application/pdf>

- Really comprehensive.
- Tobacco tested contained 0.56 - 3.24 µg Ni/g. Filters did not influence the nickel amount.

Stojanović, D., Nikić, D. and Lazarević, K., 2004. The level of nickel in smoker's blood and urine. *Central European Journal of Public Health*, 12(4), pp.187-189.

https://www.researchgate.net/profile/Konstansa_Lazarevic2/publication/8066082_The_level_of_nickel_in_smoker's_blood_and_urine/links/544ce79a0cf2d6347f45be62.pdf

- Cigarettes (2.32–4.20 mg/kg) and tobacco (2.20–4.91 mg/kg) contain a high amount of nickel regardless of the kind and the origin of tobacco.
- Nickel content in the blood of smokers (0.01–0.42 µg/l) was higher than in the blood of non-smokers (0.01–0.26 µg/l) although this difference was not statistically significant. In the urine of smokers (<0.01–8.20 µg/l) there was a significantly higher concentration of nickel than in the urine of non-smokers (<0.01–4.60 µg/l).

Goniewicz, M.L. et al., 2014. Levels of selected carcinogens and toxicants in vapour from electronic cigarettes. *Tobacco Control*, 23(2), pp.133-139.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4154473/>

- Electronic cigarettes contain 0.11 - 0.29 µg nickel per 150 puffs. This amount is comparable to the control, a Nicorette inhaler, which is a plastic tube with a nicotine cartridge.

Williams, M. et al., 2013. Metal and silicate particles including nanoparticles are present in electronic cigarette cartomizer fluid and aerosol. *PLoS One*, 8(3), p.e57987.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3603976/>

- Puffing an electronic cigarette (EC) activates a battery that in turn heats liquid containing flavoring, a humectant(s) such as propylene glycol or vegetable glycerin, and nicotine. Some models, such as the one used in this study, do not contain nicotine. Early models of EC had separate atomizers for heating and cartridges for holding fluid. As EC have evolved, the atomizer and cartridge have often been combined into a single unit called a “cartomizer”. This paper provides a good description of a cartomizer’s insides.
- In 10 puffs, an EC was found to have 0.005 µg nickel, compared to 0.073 ng and 0.0014–0.003 µg nickel in regular cigarettes quoted from other studies.
- The study was based on one brand of EC purchased on multiple occasions over a two year period.

Tattoos

Battistini, B. et al., 2020. Quantitative analysis of metals and metal-based nano-and submicron-particles in tattoo inks. *Chemosphere*, 245, p.125667.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/31877461/>

- Tattoo inks in Italy in 2019 were tested for multiple metals. Metal content has improved since 2009.
- Nickel ranged from 0.14 to 1.54 µg/g.
- There is no limit set for nickel, just “as low as technically achievable”. Chromium, cobalt and nickel were well above the safe limit in some inks in the Italian survey of 2009 (Forte et al., 2009), they are now near or below 1 µg/g (Basketter et al., 2003).

Schreiber, I. et al., 2019. Distribution of nickel and chromium containing particles from tattoo needle wear in humans and its possible impact on allergic reactions. *Particle and Fibre Toxicology*, 16(1), pp.1-10.

<https://particleandfibretoxicology.biomedcentral.com/articles/10.1186/s12989-019-0317-1>

- Nano- and micrometer sized particles are abraded from tattoo needles when using TiO₂-containing ink as result of pure mechanical stress. These particles contain Ni and Cr and are permanently deposited in tattooed skin and are translocated to lymph nodes. The particle deposition is significant upon usage of TiO₂ white ink but less so with carbon black ink. [Bright colours contain titanium.]
- Particles larger than 2 µm are translocated to the lymph nodes.
- Conclusion: Previously, the virtually inevitable nickel contamination of iron pigments was suspected to be responsible for nickel-driven tattoo allergies. The evidence from our study clearly points to an additional entry of nickel to both skin and lymph nodes originating from tattoo needle wear with an as yet to be assessed impact on tattoo allergy formation and systemic sensitization.

Tuchowska, A. et al., 2019. Health Risks Related to Tattoo Procedure. *Central European Journal of Sport Sciences and Medicine*, 26(2), pp.41-46.

http://psjd.icm.edu.pl/psjd/element/bwmeta1.element.psjd-d98ba66e-d854-4b68-8f93-e593847fe81e/c/04_tuchowska.a-kruk.j-sagan.p.pdf

- Tattoo inks contain heavy metals and acrylates that can lead to hypersensitivity reactions, as well as carcinogens and other toxic substances.
- Consents for tattoo procedures are not as expanded as those for medical procedures and do not contain all the necessary elements.

Cobb, H.K. et al., 2017. Systemic contact dermatitis to a surgical implant presenting as red decorative tattoo reaction. *JAAD Case reports*, 3(4), p.348.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5521023/>

- A case of a woman who, within 2 weeks of a cobalt-chrome foot implant being placed, developed an allergic reaction to the red ink areas of her tattoos, some far from the implant. The surgical site was scaly and there was pain and stiffness but no sign of implant failure.
- She patch tested positive to cobalt, palladium and nickel.
- After removal of the implant, the pain and skin reactions resolved.

Laux, P. et al., 2016. A medical-toxicological view of tattooing. *The Lancet*, 387(10016), pp.395-402.

https://www.researchgate.net/publication/280497471_A_medical-toxicological_view_of_tattooing

- "Reactions [of an allergic nature] can appear months or years after the tattoo was done. This is a remarkably long period of sensitisation induction and, although the exact reasons have not yet been elucidated, this delayed complication is an example of the much wider problem—intradermal deposit of tattoo pigments results in lifelong exposure."

Jacobsen, E. et al., Eds., 2012. Chemical substances in tattoo ink. *Survey of Chemical Substances in Consumer Products no. 116*, Miljøstyrelsen.

<https://www2.mst.dk/Udgiv/publications/2012/03/978-87-92779-87-8.pdf>

- 61 samples of 10 different colour series of tattoo ink were tested. All 61 inks had a nickel concentration that exceeded the limit set by the Council of Europe's ResAP(2008) Table 3. Actual values ranged from 0.03-18 µg/g, with no colour a clear winner.

Bocca, B., 2013. Heavy metals in tattoo inks. *First International Conference on Tattoo Safety*, Berlin.

<https://mobil.bfr.bund.de/cm/343/heavy-metals-in-tattoo-inks.pdf>

- 56 inks from 4 suppliers were tested. Median nickel content ranged from 0.14-0.45 µg/g for each supplier, with a maximum of 9.6 µg/g.
- Anything above 1 µg/g should not be in contact with skin. 9 of the 56 samples were above that limit.

Forte, G., Petrucci, F., Cristaudo, A. and Bocca, B., 2009. Quantification of sensitizing metals in tattooing pigments by SF-ICP-MS technique. *The Open Chemical and Biomedical Methods Journal*, 2(1).

<https://benthamopen.com/contents/pdf/TOCBMJ/TOCBMJ-2-42.pdf>

- 13 colours of tattoo ink were bought from one supplier in Italy. All were contaminated with nickel, ranging from 37.5 to 2318 ng/g, at an average of about 0.5 µg/g.

Engel, E. et al., 2008. Modern tattoos cause high concentrations of hazardous pigments in skin. *Contact Dermatitis*, 58(4), pp.228-233.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/18353031/>

- Pig skin was tattooed and analyzed to determine the amount of ink that was deposited. The concentration of pigments ranged from about 0.6 to 9.4 mg/cm² of tattooed skin (mean 2.53 mg/cm²) depending upon the size of the pigment crystals, the pigment concentration applied to the skin surface, and the respective procedure of tattooing.

Dental

Chitra, P., Prashantha, G.S. and Rao, A., 2019. Long-term evaluation of metal ion release in orthodontic patients using fluoridated oral hygiene agents: An in vivo study. *Journal of the World Federation of Orthodontists*.

Abstract at [https://www.jwfo.org/article/S2212-4438\(19\)30048-7/abstract](https://www.jwfo.org/article/S2212-4438(19)30048-7/abstract)

- Nitinol archwires leached heavily at 30 days when fluoridated toothpaste and mouthwash was used, but not when unfluoridated controls. At 6 months the nickel levels returned to baseline.

Quezada-Castillo, E., Aguilar-Castro, W. and Quezada-Alván, B., 2019. Corrosion of galvanic pairs of dental alloys copper base with silver amalgams in artificial saliva. *Matéria (Rio de Janeiro)*, 24(1).

http://www.scielo.br/scielo.php?pid=S1517-70762019000100327&script=sci_arttext

- “Two or more dissimilar metals in the mouth form batteries that generate galvanic currents, due to electrolytic contact through the saliva or the root fluids; these pairs interact by direct, indirect or intermittent contact.”
- The corrosion between silver amalgams and 3 copper-based alloys in artificial saliva was studied.
- Pair high-copper silver amalgams with copper-based dental alloys for the least corrosion. The corrosion products released in greater quantity in the electrolytic medium are formed by Hg, Cu, Zn and Ni ions.

Jafari, K., Rahimzadeh, S. and Hekmatfar, S., 2019. Nickel ion release from dental alloys in two different mouthwashes. *Journal of Dental Research, Dental Clinics, Dental Prospects*, 13(1), p.19.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6571516/>

- Oral-B and Listerine mouthwashes were tested to determine in vitro whether they increase nickel leaching from metal discs (74% Ni).
- Both significantly increased nickel ion release when compared to distilled water, however since the units of measurement are not reported it is difficult to guess the magnitude of the effect.
- They recommend that the nickel allergic should not use Listerine.

Lee, J.J. et al., 2015. Evaluation of effect of galvanic corrosion between nickel-chromium metal and titanium on ion release and cell toxicity. *The Journal of Advanced Prosthodontics*, 7(2), pp.172-177.

<https://synapse.koreamed.org/DOIx.php?id=10.4047/jap.2015.7.2.172>

- To assess the amount of metal ions released due to galvanic corrosion, three Ni-Cr alloys were each placed in a saliva solution with a sample of titanium, one in contact with the Ti and one not in contact as a control. The results showed a significant increase in the release of ions in the contacting group compared to the control group, and that the primary ion released was always Ni.

Pigatto, P.D. et al., 2014. Systemic allergic contact dermatitis associated with allergy to intraoral metals. *Dermatology Online Journal*, 20(10).

https://www.researchgate.net/publication/270653544_Systemic_allergic_contact_dermatitis_associated_with_allergy_to_intraoral_metals

- A case is presented wherein corrosion of dental restorations, indicated by an amalgam tattoo, resulted in systemic nickel allergy syndrome. Hypersensitivity to nickel was confirmed with a lymphocyte transformation test (LTT) and skin patch testing. The rashes resolved 8 months after removal of an

amalgam filling and implant crown located next to one another. (Note the implant itself, Ti, was not removed.)

- Amalgam contains 8-9 ppm nickel.
- In the case they present, the problem arises from the interaction of the metals in the amalgam with the metals in her implant. Before they added her implant, the amalgam wasn't an observable problem.

Stejskal, V., 2014. Metals as a common trigger of inflammation resulting in non-specific symptoms: Diagnosis and treatment. *The Israel Medical Association Journal: IMAJ*, 16(12), pp. 753-758.

<http://www.ima.org.il/IMAJ/ViewArticle.aspx?year=2014&month=12&page=753>

- Links metal allergies to CFS and FM. All 5 patients improved after removal of bodily metal. In 4 cases, the patient was allergic to multiple metals including nickel.
- Full recovery took between 1 and 10 years.

Zohdi, H., Emami, M. and Shahverdi, H.R., 2012. Galvanic corrosion behavior of dental alloys. In Salas, B.V. and Schorr, M. (Ed.), *Environmental and Industrial Corrosion – Practical and Theoretical Aspects* (pp. 157-168). IntechOpen.

http://cdn.intechopen.com/pdfs/41216/intech-galvanic_corrosion_behavior_of_dental_alloys.pdf

- Placing stainless steel brackets or amalgam in direct contact with nitinol arch wire is not recommended, because it increases the corrosion rate of the nitinol arch wire. Ceramic brackets should be used instead of stainless steel brackets to help reduce galvanic corrosion.
- Corrosion can increase with surface area ratio of cathode/anode.
- Fluoride can impair the corrosion resistance of some alloys.
- Corrosion increases with pitting and crevices in the alloy.
- Temperature and pH changes due to foods and oxygen content of saliva also affect corrosion.

Amini, F. et al., 2011. Metal ion release from fixed orthodontic appliances — an in vivo study. *The European Journal of Orthodontics*, 34(1), pp.126-130.

<https://academic.oup.com/ejo/article/34/1/126/518051>

- This retrospective study was carried out on 28 subjects (16 females and 12 males) who had undergone fixed orthodontic therapy for a duration of 12–18 months. A same-gender brother or sister (total of 28 subjects) was selected as a control.
- The mean salivary nickel (Ni) content in subjects with and without a fixed orthodontic appliance was 18.5 ± 13.1 and 11.9 ± 11.4 ng/ml, respectively.

Ciszewski, A., Baraniak, M. and Urbanek-Brychczyńska, M., 2007. Corrosion by galvanic coupling between amalgam and different chromium-based alloys. *Dental Materials*, 23(10), pp.1256-1261.

Abstract at <https://www.sciencedirect.com/science/article/abs/pii/S0109564106002983?via%3Dihub>

- An in vitro study of the corrosion of a nickel-chrome or cobalt-chrome alloy paired with silver amalgam.
- It was found that nickel or cobalt (depending on the alloy used) appeared in the saliva solution and increased in concentration over time.

Muris, J. and Feilzer, A.J., 2006. Micro analysis of metals in dental restorations as part of a diagnostic approach in metal allergies. *Neuroendocrinology Letters*, 27(1), pp. 49-52.

<http://www.melisa.org/pdf/Micro-analysis.pdf>

- Two case studies are described to document the process of diagnosing allergy to dental metals. Removal of just the offending metals resulted in complete resolution of skin rashes (case 1) and fatigue (case 2).

- Cites a Japanese article [Nogi89] that found that the cell voltage in the mouth varies greatly depending on saliva properties, and less so on the metal composition, making it very individual.

Taher, N.M. and Al Jabab, A.S., 2003. Galvanic corrosion behavior of implant suprastructure dental alloys. *Dental Materials*, 19(1), pp.54-59.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/12498897>

- A study of the corrosion of titanium coupled with various alloys in artificial saliva. The least acceptable couples were Ti/amalgam, Ti/Ti and Ti/R2000(CoCr), while the Ti/RCS(NiCr) couple showed unstable galvanic corrosion behavior. The Ti/Ti pairing requires further investigation.
- Acceptable alloys to use with titanium implants were Pontallor-4 (Au), R800 (CoCr), Jelstar (AgPd).

Fovet, Y., Pourreyron, L. and Gal, J.Y., 2000. Corrosion by galvanic coupling between carbon fiber posts and different alloys. *Dental Materials*, 16(5), pp.364-373.

Abstract at <http://www.ncbi.nlm.nih.gov/pubmed/10915898>

- Carbon posts embedded in resin were assessed when paired with Au alloy, NiCr, and amalgam in artificial saliva. They conclude that galvanic activity is likely with carbon posts are paired with amalgam, may occur with NiCr, and improbably (inducing very low currents) with gold alloy.
- States that corrosion of metal posts within post and core restorations has become well-known.

Nogi, N., 1989. Electric current around dental metals as a factor producing allergenic metal ions in the oral cavity. *Nihon Hifuka Gakkai Zasshi. The Japanese Journal of Dermatology*, 99(12), pp.1243-1254.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/2622059>

- An in vivo study of corrosion of dental metals in the mouth. Probes were used in the mouths of patients with and without allergic symptoms. They found that the cell behaviour varies with the metals involved, but is even more sensitive to the oral environment of the individual patient, which can even change the direction of current flow.
- The mucous membrane itself acts as a cathode, with membrane-to-metal having higher voltages than metal-to-metal; the presence of another metal is not required to complete the circuit. Amalgam and silver alloys are more likely to be anodes and dissolve into the saliva. The presence of food affects voltage as well.

Spiechowicz, E., Glantz, P.O., Axell, T. and Chmielewski, W., 1984. Oral exposure to a nickel-containing dental alloy of persons with hypersensitive skin reactions to nickel. *Contact dermatitis*, 10(4), pp.206-211.

<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1600-0536.1984.tb00101.x>

- 10 adults with nickel allergy agreed to have one or more restorations placed that were 66% nickel (under ceramic crowns and bridges). In the 1-3 years follow-up, none of them had a dermal or mucosal reaction. "No local, distant or general reactions" - presumably that includes GI etc.
- Only the one alloy was present in all patients. "If more complex material situations are created, the oral electrochemical activity may increase, thereby influencing the possibility for biological reactions."
- "Allergic reactions may develop after many years when corrosion and/ or attrition have released sufficient ions to trigger reactions."

Medical

Mehta, V., Vasanth, V. and Balachandran, C., 2011. Nickel contact dermatitis from hypodermic needles. *Indian Journal of Dermatology*, 56(2), p.237.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3108538/>

- Two case studies are presented, patients with a 1+ and 2+ nickel allergy having dermatitis to needles in a hospital setting.

- The DMG test was negative but the needles sampled had 8% nickel.
- Concludes with a time limit for infusions while using steel needles based on the EU Nickel Directive.

Bircher, A.J., Schmidli, F., Strub, C., Müller, B. and Scherer, K., 2009. Systemic allergic dermatitis reaction to nickel released from an eyelet in an intravenous catheter. *Contact Dermatitis*, 61(3), pp.180-182.

- Case study of a woman on IV nutrition who presented with a widespread rash in the large folds. Extensive allergy testing resulted in a positive reaction only to a nickel patch test. Oral challenge with nickel gave her a reaction in 4 hours. The catheter was used to deliver glucose for 3 hours and there was no reaction.
- The metal eyelet in the catheter was analyzed and found to be over 80% nickel.
- Cites previous work where the glucose solution was found to contain significant nickel after being passed through the catheter.
- Implies that long-term exposure to nickel may be the root cause of systemic dermatitis.

Orthopedic Implants

Haddad, S.F. et al., 2019. Exploring the incidence, implications, and relevance of metal allergy to orthopaedic surgeons. *JAAOS Global Research & Reviews*, 3(4), p.e023.

https://journals.lww.com/jaaosglobal/Fulltext/2019/04000/Exploring_the_Incidence,_Implications,_and.3.aspx

- 100 patients who were referred for allergy testing, either before or after having an implant placed, were split into 2 groups based on their history of dermatitis.
- In those with dermatitis, 32% were allergic to nickel. In those without dermatitis, 10% were allergic to nickel. [Therefore dermatitis isn't a great indicator of allergy.]
- "The clinical manifestations of metal implant hypersensitivity can be nonspecific and difficult to trace to a symptomatic implant. Patients with contact dermatitis may present with widely varying complaints, including systemic eczematous dermatitis versus skin reactions. Swelling and pain at the implant site are common, mimicking nonunion or surgical site infection. Occasionally, hypersensitive patients may develop draining sinus tracts and soft-tissue necrosis surrounding symptomatic implants."
- "The presence of a metal allergy history or a positive patch test does not prove the causality of postoperative complications relating to a suspected allergic reaction, although such findings should raise suspicions and warrant further investigation."

Zondervan, R.L. et al., 2019. Improved outcomes in patients with positive metal sensitivity following revision total knee arthroplasty. *Journal of Orthopaedic Surgery and Research*, 14(1), p.182.

<https://josr-online.biomedcentral.com/articles/10.1186/s13018-019-1228-4>

- 46 patients underwent a revision surgery of their TKA; 39 were allergic to metals (80% to nickel) and 7 were not. On average, the reactive group had more pain before revision, but a greater range of motion. The average pain decreased to comparable levels for the allergic and non-allergic groups at 6 weeks post-revision. The average pain for the allergic group continued to decrease even up to the final checkup after 1 year. There was not enough data to assess the non-allergic group's progress at 1 year.
- On a graph of percent change in pain vs. sensitivity score, it appears that in 5 cases the pain actually increased post-revision, and in 7 cases it remained the same, so pain decreased in 34/46 = 74%. These appear to be mainly for LTT sensitivity scores < 4 ("non-reactive" and "mildly reactive" ranges). Unexpectedly, the pain increase was greatest for those in the "mildly reactive" range. [Maybe the revision created a second allergy, or scar tissue?] Yet, all patients reported being satisfied after the revision.
- Patients with the highest LTT sensitivity scores actually had a *less* dramatic reduction in pain.

Dmochowski, J.M., Royal, J.T. and Lourie, G.M., 2019. Could a titanium ulnar shortening plate trigger a metal allergy? A case report. *Journal of Wrist Surgery*. DOI: 10.1055/s-0039-1677742.

<https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0039-1677742>

- Case report of a woman who had a plate made of titanium alloy and pure titanium screws implanted to repair an injured wrist. Both contained trace amounts of nickel. A different pain developed. There was no evidence of implant loosening, no infection, and normal nerve conduction, but there was some edema.
- On removal, there was dark debris and obvious inflammation. Her patch test showed nickel as her only metal allergy, even though she claimed no previous skin reactions to metals. At 3 months her pain was resolved.

Frigerio, E. et al., 2011. Metal sensitivity in patients with orthopaedic implants: A prospective study. *Contact Dermatitis*, 64(5), pp.273-279.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.860.7159&rep=rep1&type=pdf>

- One year post-implantation (72 patients), 5 patients who had initially tested negative for a metal allergy became positive for at least one or more metal constituents of the prosthesis on at least one or the other test.
- Suggests that exposure to the metals in the prostheses led to sensitization.
- Some patients tested positive when they had no history of allergic reaction. Authors conclude that testing prior to choosing an implant is important.
- Most of the patients tested positive for nickel (21%), followed by cobalt (8%), palladium (3%), chromium (2%), and molybdenum (2%). Positivity for cobalt, chromium and palladium was always associated with a positive reaction to nickel, probably because of cross-reactivity. There were no positive results for titanium or vanadium before or after, due to lower sensitization rates.

Harloff, T. et al. 2010. Titanium allergy or not? "Impurity" of titanium implant materials. *Health*, 2(04), p.306.

<https://ceraroot.com/download/titanium-allergy-or-not.pdf>

- Several pure Ti and Ti alloy samples were analyzed for a variety of metals by spectral analysis. The samples contained 10-310 ppm Ni (median about 120). Suggests coating Ti with ceramic to prevent corrosion.

Schuh, A. et al., 2005. Allergic potential of titanium implants. *Der Orthopade*, 34(4), pp.327-8.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/15706453>

- Five samples of pure Ti and Ti-Al-V alloys were analyzed for nickel content using spectral analysis. A nickel content of 120-340 ppm was found.

Vascular, Cardiac and Other Implants

Grande, A. et al., 2014. Life-threatening allergic vasculitis after clipping an unruptured aneurysm: Case report, weighing the risk of nickel allergy. *Surgical Neurology International*, 5(Suppl 4), p.S161.

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4109169/>

- This case report describes a young woman who developed a life-threatening allergic vasculitis after undergoing elective clipping of a posterior communicating artery aneurysm. A nickel-containing clip was replaced with a titanium clip, which resolved symptoms. No allergy testing was carried out.

Fernandes, P. et al., 2019. Severe migraine associated with nickel allergy requiring surgical removal of atrial septal device. *The Annals of Thoracic Surgery*, 108(3), e183 - e184.

Abstract at [https://www.annalsthoracicsurgery.org/article/S0003-4975\(19\)30224-3/abstract](https://www.annalsthoracicsurgery.org/article/S0003-4975(19)30224-3/abstract)

- A case of a 16-year-old male patient who required surgical explantation of an atrial septal device 6 years after closure because of debilitating headaches. He had a grade 1 reaction to nickel after skin

testing. Intraoperatively, the device had not fully endothelialized. Immediately after removal of the device, his headaches completely resolved.

Esparaz, A.M. and Ahmed, M., 2017. Resolution of metallic biliary stent allergic reaction after partial stent removal in a patient with nickel sensitivity. *Cardiovascular and Interventional Radiology*, 40(7), pp.1118-1122. Page 1 available at

<https://search.proquest.com/openview/422daaf2d6b53a33b9400926eb460c76/1?pq-origsite=gscholar&cbl=54058>

- A case of a 62-year-old woman with a complex history of abdominal surgery presenting with chronic right upper-quadrant abdominal pain progressing in severity for several years. She also had allergic symptoms associated with eating.
- She had developed nickel sensitivity after biliary metal stent placement one year earlier. Symptoms resolved following partial removal of the non-epithelialized portion of the biliary stent.

Jetty, P. et al., 2013. Superficial femoral artery nitinol stent in a patient with nickel allergy. *Journal of Vascular Surgery*, 58(5), pp.1388-1390.

<https://www.sciencedirect.com/science/article/pii/S0741521413002048>

- A case of a patient who developed a systemic allergic reaction following placement of a nitinol stent in the superficial femoral artery for claudication symptoms. Shortly after, he was tested for contact dermatitis and found to have a severe reaction to nickel. His symptoms of severe itch and generalized rash resolved within days following stent explantation and reconstruction with a vein graft.
- There was a stent fracture that may have increased nickel release.
- SCD after stent placement may be underrecognized.

Aliağaoğlu, C. et al., 2012. Relation of nickel allergy with in-stent restenosis in patients treated with cobalt chromium stents. *Annals of Dermatology*, 24(4), pp.426-429.

<https://synapse.koreamed.org/DOIx.php?id=10.5021/ad.2012.24.4.426>

- The nickel amount is more in cobalt chromium coronary stents (35% nickel and 20% chromium, respectively) than the stainless steel stents.
- Of 61 patients with unrelieved symptoms after stent insertion, 31 who did not have eczema and had not been patch tested and were found to have in-stent restenosis (ISR) were included in the study. [It is unclear why these were excluded since eczema could be a symptom of SCD; does this not underestimate the patch test positive rate?]
- According to the patch test results, 7 of 31 patients (23%) in ISR group had nickel contact allergy, while none of the 30 patients (0%) in non-ISR group had nickel allergy (statistically significant). Two patients in the ISR group and one patient in the non-ISR group had a positive test result for cobalt.

Rabkin, D.G. et al., 2009. Unusual presentation of nickel allergy requiring explantation of an Amplatzer atrial septal occluder device. *Clinical Cardiology*, 32(8), pp.E55-E57.

<https://onlinelibrary.wiley.com/doi/pdf/10.1002/clc.20427>

- A case study of a woman who had an Amplatzer device (nitinol) implanted, followed by persistent dull pain at 18 months. There was a small amount of fluid buildup.
- She had a history of reacting to jewelry, and a patch test revealed that she was allergic to nickel.
- The device was removed and a pericardial patch closure performed. The tissue had fibrosis and chronic inflammatory changes. At 1 month the pain had resolved.

Fisher, J.R., Rosenblum, G.A. and Thomson, B.D., 1982. Asthma induced by nickel. *JAMA*, 248(9), pp.1065-1066.

<https://jamanetwork.com/journals/jama/article-abstract/377202>

- A woman presenting with a nine-month history of right upper quadrant (RUQ) abdominal discomfort and swelling of her face, lips, and hands, accompanied by stridor and wheezing, but without skin rash or urticaria. She had her gallbladder removed 10 months before, and her symptoms began four weeks later. Her episodes of wheezing and swelling were, at times, precipitated by eating and were also exacerbated by certain activities (e.g. shaving her legs). Her nickel patch test produced immediate localized swelling and itching, and bronchospasm.
- Stainless Steel Hemoclips were used in the surgery. A DMG test on the clips was negative, but taping them to the patient's arm resulted in quick recurrence of symptoms.
- Her symptoms resolved quickly on removal of the clips. Occasional mild hand and facial swelling, without respiratory symptoms, is managed with a low nickel diet and environmental avoidance.

7. Bioavailability

Peeters, K. et al., 2017. Nickel speciation in cocoa infusions using monolithic chromatography – Post-column ID-ICP-MS and Q-TOF-MS. *Food Chemistry*, 230, pp.327-335.

<https://www.sciencedirect.com/science/article/pii/S0308814617304259>

- The Ni²⁺ cation is considered to be the most bioavailable species.
- Three forms of nickel were found in cocoa through mass spectrometry: nickel gluconate (around 40%), Ni²⁺ (much lower), and nickel citrate, in descending order.

Bartos, A., Majak, I. and Leszczyńska, J., 2014. Uptake and assimilability of nickel in the course of systemic allergy: Implications for elimination diet. *Food Research International*, 55, pp.412-417.

<https://kundoc.com/pdf-uptake-and-assimilability-of-nickel-in-the-course-of-systemic-allergy-implicatio.html>

- Nickel exposure largely depends on the food matrix that either favors or confines its availability for human digestive enzymes.
- Average daily consumption found to be 227 ± 70 µg/day for students (20) and 161 ± 60 µg/day for senior staff (9).
- Nickel uptake is an aggregate of individual, geographical, seasonal and cultural dietary factors.
- Food samples were dissolved in 36% HCl and porcine pepsin added to simulate digestion.
- A variety of foods were tested to determine their release rate (nickel compared before and after digestion). Baguette and caraway seeds had the highest nickel release rate. Corn, red bean, basil, nutmeg, paprika, clove, walnut and roasted peanuts all had below 50% release rate. Nuts and cocoa are all around 50%.
- In the blood of 15 male and 15 female healthy students, there was a higher baseline amount of nickel in the women. They assume the difference is from cutaneous exposure, i.e. jewelry. When comparing the men's intake to blood sera they estimate a total 16% nickel uptake, in agreement with WHO findings.

Nielsen, G.D. et al., 1999. Absorption and retention of nickel from drinking water in relation to food intake and nickel sensitivity. *Toxicology and Applied Pharmacology*, 154(1), pp.67-75.

<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.892.377&rep=rep1&type=pdf>

- More nickel is absorbed when taken on an empty stomach.
- Serum levels of nickel increase 13-fold when nickel is taken on an empty stomach compared to taken with scrambled eggs. Clearance rates increase when nickel is taken after eggs. 9/20 patients with pompholyx hand eczema experienced aggravation of eczema during the study.

Sunderman Jr, F.W. et al., 1989. Nickel absorption and kinetics in human volunteers. *Proceedings of the Society for Experimental Biology and Medicine*, 191(1), pp.5-11.

Abstract at <https://journals.sagepub.com/doi/abs/10.3181/00379727-191-42881>

- More nickel is absorbed when taken on an empty stomach.

- Nickel was given to human volunteers with food and on an empty stomach. It was found that 20%-40% of the nickel was ingested from the water dose, whereas only 1% was ingested from the food dose.

8. Accumulation and Elimination

Melo, D.R. and Leggett, R.W., 2017. A biokinetic model for systemic nickel. *Health physics*, 112(1), pp.18-27.

<https://www.osti.gov/servlets/purl/1336598>

- A theoretical model of how nickel travels around the body, including plasma and red blood cells; kidneys, bladder and urine; liver, small intestine, colon and feces; bone; and soft tissues.

Schaller, K.H. et al., 2007. Elimination kinetics of metals after an accidental exposure to welding fumes. *International Archives of Occupational and Environmental Health*, 80(7), pp.635-641.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/17323068>

- The elimination of nickel was found to be biphasic in an accidentally exposed welder. The half-life for nickel was 25 and 610 days (in urine) and 30 and 240 days (in blood).
- The exposure was very high, leading to toxicity symptoms.
- [This man was down to 15% of the initial level in about 3 months. By 1 year it was at around 2%.]

Patriarca, M., Lyon, T.D. and Fell, G.S., 1997. Nickel metabolism in humans investigated with an oral stable isotope. *The American Journal of Clinical Nutrition*, 66(3), pp.616-621.

<https://academic.oup.com/ajcn/article/66/3/616/4655789>

- Two male and two female subjects with no health issues and regular bowel habits were given an isotope of nickel that could be tracked separately from the nickel normally found in the body, on an empty stomach.
- The percentage absorption calculated from the amount of ⁶²Ni excreted in the feces ranged from 29% to 40%. Urinary excretion over 5 d ranged from 51% to 82% of the absorbed dose. Plasma ⁶²Ni peaked between 1.5 and 2.5 h after ingestion and decreased by a factor of >10 over the next few days.
- A considerable fraction of the absorbed nickel dose (34.8 ± 13.4%) was still retained 5 days after ingestion, a higher amount than that found in studies that did not use a traceable isotope.

Bergman, M., Bergman, B. and Söremark, R., 1980. Tissue accumulation of nickel released due to electrochemical corrosion of non-precious dental casting alloys. *Journal of Oral Rehabilitation*, 7(4), pp.325-330.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/6931883/>

- Metal alloys used in dental restorations were implanted subcutaneously in mice for 5 months, and how the nickel distributed in the mice was looked at. Nickel accumulated in the soft tissue around the implants for all of the alloys (51-91 ppm), but interestingly it only accumulated in organs for two of the 5 alloys: all organs for Ticon, and kidney and pancreas for Neydium. No nickel was found in the brain for any of the alloys.
- "The oral cavity often presents exceptional conditions for electrochemical corrosion. The corrosion products may be taken up by the saliva and the soft and hard tissues and transported throughout the body seeking a specific target organ where they may accumulate and cause an allergic reaction."

Bergman, B. et al., 1980. The distribution of nickel in mice. *Journal of Oral Rehabilitation*, 7(4), pp. 319-324.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/6931882>

- A single dose of a radioactive isotope of nickel was injected in mice. The distribution of the nickel isotope was measured at intervals over 3 weeks.
- Early on the nickel was highest in the kidneys, bladder, lung, skin, eyes, hair, cartilage, and blood.

- At 3 weeks the most nickel was in the lung tissues, central nervous system and skin.

Tossavainen, A. et al., 1980. Application of mathematical modelling for assessing the biological half-times of chromium and nickel in field studies. *Occupational and Environmental Medicine*, 37(3), pp.285-291.

<https://oem.bmj.com/content/oemed/37/3/285.full.pdf>

- In welders and electroplaters, samples were collected for 5 days after summer vacation. Not toxic levels. The elimination half-life was found to be 17-39 hours for nickel in urine, and 20-34 hours for nickel in plasma.

Torjussen, W. and Andersen, I., 1979. Nickel concentrations in nasal mucosa, plasma, and urine in active and retired nickel workers. *Annals of Clinical & Laboratory Science*, 9(4), pp. 289-298.

<http://www.annclinlabsci.org/content/9/4/289.full.pdf>

- In retired nickel plant workers, the elimination half-life of nickel from nasal mucosa was found to be 3.5 years.

Oskarsson, A. and Tjalve, H., 1979. An autoradiographic study on the distribution of $^{63}\text{NiCl}_2$ in mice. *Annals of Clinical & Laboratory Science*, 9(1), pp. 47-59.

<http://www.annclinlabsci.org/content/9/1/47.full.pdf>

- In mice injected intravenously with a nickel isotope, after 3 weeks radioactivity could be seen in the kidneys, cartilage, connective tissues, skin, lung, brain and spinal cord.

Horak, E. and Sunderman, F.W., 1973. Fecal nickel excretion by healthy adults. *Clinical Chemistry*, 19(4), pp.429-430.

<https://pdfs.semanticscholar.org/dabb/eae709d2c0819c3536d22a515b7d35752968.pdf>

- The fecal excretion of nickel averaged $258 \pm 126 \mu\text{g/day}$ (range 80 to 540 $\mu\text{g/day}$). Fecal excretion is evidently the major route for elimination of nickel from the human body (in healthy adults).

9. Testing

Dodd, M. and Begley, A., 2019. The Utility of MELISA testing for metal allergy in patients requiring TMJ replacement. *British Journal of Oral and Maxillofacial Surgery*, 57(10), p.e87.

- In 30 patients, 51% had positive MELISA tests to nickel (among other metals). 11 patients also had patch testing of whom 46% had concordant results, that is, 46% of patients showing nickel allergy with MELISA were negative to patch testing.

Zhu, T.H. et al., 2018. The medical necessity of comprehensive patch testing. *Dermatitis*, 29(3), pp.107-111.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/29613858>

- The T.R.U.E. patch test has a 66% allergen detection rate at best. Testing with supplemental allergens beyond a screening series, depending on the individual patient's history and findings, is needed to increase diagnostic accuracy.
- In some cases it is more appropriate to forgo limited and standard patch testing and go straight to a comprehensive test in order to provide a cure for the patient.

Fonacier, L. and Noor, I., 2018. Contact dermatitis and patch testing for the allergist. *Annals of Allergy, Asthma and Immunology*, 120(6), pp.592-598

[https://www.annallergy.org/article/S1081-1206\(18\)30163-7/fulltext](https://www.annallergy.org/article/S1081-1206(18)30163-7/fulltext)

- Review article of diagnosis, patch testing and treatments that includes systemic dermatitis to nickel.
- Patch tests should be removed and read at 48 hours, read again at 3-7 days (96 hours optimally), and finally at 7-10 days for late bloomers such as metals (nickel sulfate, gold sodium thiosulfate, palladium chloride, potassium dichromate, cobalt chloride), some antibiotics (neomycin), topical corticosteroids, and dyes (paraphenylenediamine).

Ständer, S. et al., 2017. Evaluation of lymphocyte transformation tests as compared with patch tests in nickel allergy diagnosis. *Contact Dermatitis*, 76(4), pp.228-234.

http://www.laserwords.co.in/offprint/COD_202ad50b_COD12751/cod12751.pdf

- In a study of 100 subjects, 50 with suspected nickel allergy and 50 with no skin symptoms on metal contact, patch test results and patient history were compared to LTT blood tests.
- The LTT had 96% specificity (2/50 false positives) and 88% sensitivity (2/18 false negatives).
- The LTT response was positive in 13 of the 32 patch test-negative/ history-positive patients.
- A considerable discussion is had about the errors possible in patch testing. In particular, nickel is known for its ability to give late patch test reactions, which may account for some of the patch test-negative/ history-positive differences.
- Concludes that LTT is an important additional tool for determining nickel allergy, particularly in people who cannot have patch testing, to confirm a negative patch test result, and in patients sensitized to nickel by internal exposure, for example patients with metal implants.
- The study excluded patients who had implants or piercings containing nickel as this may result in nickel allergy without cutaneous manifestations.

Schaeffer, A.C. et al., 2016. The reproducibility of nickel, cobalt and chromate sensitization in patients tested at least twice in the period 1992–2014 with TRUE Test. *Contact Dermatitis*, 75(2), pp.111-113.

- Of 115 subjects who patch tested positive for nickel allergy, 107 were positive on the second test (67%).
- The persistence of weak, positive reactions to nickel tended to decrease as the time interval between testing increased, whereas the reproducibility of strong, positive reactions was stable over time.
- Errors in patch testing were not discussed.

Thyssen, J.P. et al., 2010. Sensitivity and specificity of the nickel spot (dimethylglyoxime) test. *Contact Dermatitis*, 62(5), pp.279-288.

<http://www.academia.edu/download/46171289/j.1600-0536.2010.01709.x20160602-32366-x88ln1.pdf>.

- Earrings were tested both by x-ray fluorescence and DMG swab.
- The sensitivity of the DMG test (true positive rate) was 59.3% and the specificity (true negative rate) was 97.5%.
- A test with 59.3% sensitivity detects 59.3% of objects with nickel (true positives) but 40.7% with nickel go undetected (false negatives).
- A test with 97.5% specificity correctly reports 97.5% of objects without nickel as test negative (true negatives) but 2.5% of objects without nickel are incorrectly identified as test positive (false positives).

10. **Polysensitization**

Adler, W., Gefeller, O. and Uter, W., 2017. Positive reactions to pairs of allergens associated with polysensitization: analysis of IVDK data with machine-learning techniques. *Contact Dermatitis*, 76(4), pp.247-251.

- In the Information Network of Departments of Dermatology (IVDK) data, when there were two positive patch test results, nickel ACD was most often paired with fragrance mix I, potassium dichromate, cobalt chloride and Myroxylon pereirae (balsam of peru).

Limone, B.A. and Jacob, S.E., 2017. Insights into the global effect of nickel dermatitis on polysensitization. *Annals of Allergy, Asthma & Immunology*, 118(6), p.749.

[https://www.annallergy.org/article/S1081-1206\(17\)30304-6/abstract](https://www.annallergy.org/article/S1081-1206(17)30304-6/abstract)

- A letter stressing the importance of early diagnosis of nickel allergy due to the high prevalence (>50%) of polysensitization with nickel, which happens because the weakening of the skin's barrier enables sensitization to other allergens.
- Four statistically significant pairings with nickel are fragrance mix 1, chrome, cobalt and balsam of peru.

Schwitulla, J., Gefeller, O., Schnuch, A. and Uter, W., 2013. Risk factors of polysensitization to contact allergens. *British Journal of Dermatology*, 169(3), pp.611-617.

<https://onlinelibrary.wiley.com/doi/full/10.1111/bjd.12423>

- Clinical data of 126,878 patients patch tested by departments comprising the IVDK network between 1995 and 2010 were analyzed for polysensitization risk factors.
- 14.6% were allergic to nickel; of those, 46.5% had no other positive results and 25.5 % had 2 or more other positive results. In contrast, for the 5.5% allergic to cobalt, 48.2% of those had 2 or more other positive results (similar to BoP, fragrances and a whole bunch of others). -> Nickel is more of a "solitary allergen".
- Nearly 15% of the patients were allergic to one of the fragrance mixes!
- Patients with leg, feet and armpit sites were at the highest risk of 3+ allergens (hands next).

Tu, M.E. and Wu, Y.H., 2011. Multiple allergies to metal alloys. *Dermatologica Sinica*, 29(2), pp.41-43.

<https://www.sciencedirect.com/science/article/pii/S1027811711000401>

- Tested 53 subjects for metal allergies. Lists the combinations of metal allergies found; gold, cobalt, palladium and mercury compounds were most frequently seen with nickel. Of 37 with nickel allergy, 15 were allergic to at least one other metal: 5 were also allergic to palladium, 5 to gold, 5 to some form of mercury, 5 to cobalt, 2 to chromium, and 2 to copper.

Durosaro, O. and el-Azhary, R.A., 2009. A 10-year retrospective study on palladium sensitivity. *Dermatitis*, 20(4), pp.208-213.

<https://www.medscape.com/viewarticle/717741>

- Of the patients who were sensitized to palladium, 107 were also tested with nickel and cobalt; 61 (57.0%) of these 107 patients were sensitized to both palladium and nickel, and 33 (30.8%) were sensitized to palladium, nickel, and cobalt.

Hegewald, J. et al., 2005. A multifactorial analysis of concurrent patch-test reactions to nickel, cobalt, and chromate. *Allergy*, 60(3), pp.372-378.

Access via <https://uni-erlangen.academia.edu/WolfgangUter>

- Out of 7232 who tested positive to nickel, 1437 were also allergic to cobalt, or about 20%, and 697 were also allergic to chromate, or about 10%.
- The authors state that the results strongly suggest that some people are more susceptible to contact sensitizations in general, and these people are also more likely to test positive to nickel, cobalt, and chromate.

11. Surveillance and Legislation

Lagrelius, M., 2019. Contact allergy in Swedish adolescents: results from the BAMSE cohort study. (Doctoral thesis).

https://openarchive.ki.se/xmlui/bitstream/handle/10616/46643/Thesis_Maria_Lagrelius.pdf?sequence=3&isAllowed=y

- Among 2,285 adolescents in Sweden, average age 16.6 years, nickel was the most frequent cause of contact allergy (7.5%), followed by fragrance mix I (FM I) (2.1%). Nickel allergy was more common among girls (9.8% versus 4.9%). Piercing and skin reactions to metal items increased the odds of having a nickel allergy.

Warshaw, E.M. et al., 2019. Epidemiology of nickel sensitivity: Retrospective cross-sectional analysis of North American Contact Dermatitis Group data 1994-2014. *Journal of the American Academy of Dermatology*, 80(3), pp.701-713.

Abstract at <https://www.sciencedirect.com/science/article/abs/pii/S0190962218327415>

- “Clinicians should be aware of a significant increase in nickel sensitivity over time (from 14.3% to 20.1% from 1994 to 2014) and a significant increase in the clinical relevance of reactions over time (from 44.1% to 51.6% from 1994 to 2014).”

Schuttelaar, M.L. et al., 2018. Prevalence of contact allergy to metals in the European general population with a focus on nickel and piercings: The EDEN Fragrance Study. *Contact dermatitis*, 79(1), pp.1-9.

<https://onlinelibrary.wiley.com/doi/pdf/10.1111/cod.12983>

- In 5 European countries, the age-standardized prevalences of sensitization to nickel, cobalt and chromium were, respectively, 14.5%, 2.1%, and 0.8%. The highest prevalence of nickel sensitization was seen in Portugal (18.5%) and the lowest (8.3%) in Sweden.
- Significant associations were observed between nickel allergy and being female and having piercings (currently or in the past). More piercings correlate with a higher sensitization rate.

Ahlström, M.G. et al., 2017. Prevalence of nickel allergy in Europe following the EU Nickel Directive – A review. *Contact Dermatitis*, 77, pp.193–200.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/28730624>

- Nickel allergy remains a substantial problem in the population despite the EU Nickel Directive. Steps should be taken for better prevention of nickel allergy, as the prevalence remains unacceptably high in EU countries.

Schnuch, A. et al., 2012. Surveillance of contact allergies: methods and results of the Information Network of Departments of Dermatology (IVDK). *Allergy*, 67(7), pp.847-857.

http://ivdk.org/images/stories/medien/mitteilungen/Pub_397.pdf

- German ACD surveillance showing prevalence of nickel sulphate sensitization at 13-15% of patients who saw a dermatologist for standard patch testing (the highest rate of all).
- Statistics show that reduction of exposure via the EU directive reduces the sensitization rate for nickel, particularly dramatically in children. Other substances show similar trends.
- Notes a plateau in the rate decrease due to a failure of the EU directive to regulate imported costume jewelry. The problem persists.

Jacob, S.E. et al., 2009. Nickel allergy in the United States: A public health issue in need of a “nickel directive”. *Journal of the American Academy of Dermatology*, 60(6), pp.1067-1069.

[https://www.jaad.org/article/S0190-9622\(08\)02464-X/fulltext](https://www.jaad.org/article/S0190-9622(08)02464-X/fulltext)

- Letter to the editor advocating for a US nickel directive, based on the EU directive, and for a public awareness campaign to prevent nickel sensitization in children.

Rietschel, R.L. et al., 2008. Detection of nickel sensitivity has increased in North American patch-test patients. *Dermatitis*, 19(1), pp. 16-19.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/18346391/>

Available (with free registration) at <https://www.medscape.com/viewarticle/572961>

- In North America, nickel sensitivity has increased over the last 12 years and most of this increase is due to the prevalence in women.
- The data show a steady increase in nickel sensitivity from 14.5% in 1992 to 18.8% in 2004.

Basketter, D.A. et al., 2003. Nickel, chromium and cobalt in consumer products: Revisiting safe levels in the new millennium. *Contact Dermatitis*, 49(1), pp.1-7.

<https://onlinelibrary.wiley.com/doi/full/10.1111/j.0105-1873.2003.00149.x>

- “Dose–response studies using 48 h occlusive patch test conditions in sensitized individuals show that ≥90% of sensitized patients fail to react below 1 p.p.m., even on irritated skin. Assessment under more realistic exposure conditions has shown that in the presence of irritants and/or following repeated exposures, such individuals rarely react to levels below 10 p.p.m. On the basis of this information, it was recommended a decade ago that household (and other consumer) products should not contain more than 5 p.p.m. of each of Ni, Cr or Co and that, for an even greater degree of protection, the ultimate target level should be 1 p.p.m. The data generated since the original recommendations were made serve to reinforce the validity of these recommendations. Indeed, it is our view that typically the level of each of these transition metals should not normally exceed 1 p.p.m.”

12. Immunology of SNAS

Bechara, R. et al., 2017. Nickel sulfate promotes IL-17A producing CD4+ T cells by an IL-23-dependent mechanism regulated by TLR4 and Jak-STAT pathways. *Journal of Investigative Dermatology*, 137(10), pp.2140-2148.

<https://www.sciencedirect.com/science/article/pii/S0022202X17316494>

- “Ni-ACD is a complex immunologic disease involving not only a cell-mediated Th1 response but also Th17 cell development with alterations in IFN- γ levels and TLR4, Jak-STAT, p38MAPK, and NF- κ B immunologic pathways.” - <https://www.dermatitisacademy.com/nickel-allergy-pathways/>

Borghini, R. et al., 2017. Nickel allergic contact mucositis: Duodenal histological, immunohistochemical and cultural characterization of an emerging clinicopathologic entity. *Gastroenterology*, 152(5), p.S813.

Abstract at

https://www.researchgate.net/publication/316374102_Nickel_Allergic_Contact_Mucositis_Duodenal_Histological_Immunohistochemical_and_Cultural_Characterization_of_an_Emerging_Clinicopathologic_Entity

- In samples of the duodenum taken from patients with a positive nickel oral mucosa patch test, higher levels of IFN- γ and decreased IL-10 were found after exposure to nickel.

Di Tola, M. et al., 2014. Immunological characterization of the allergic contact mucositis related to the ingestion of nickel-rich foods. *Immunobiology*, 219(7), pp.522-530.

https://www.academia.edu/19113390/Immunological_characterization_of_the_allergic_contact_mucositis_related_to_the_ingestion_of_nickel-rich_foods

- An oral mucosa patch test (omPT) was positive in 25 patients and negative in 12 controls who had been referred to a gastroenterology unit.
- After omPT, serum and urine Ni concentrations increased significantly in all patients, while a significant increment of circulating lymphocytes and neutrophils was highlighted, respectively, in Ni-sensitive and control patients.
- Consistently, the Th and Tc circulating lymphocytes, as well as the Th/Tc ratio increased significantly in Ni-sensitive patients after omPT. The presence of CD3+, CD4+, and CD8+ cells was highlighted on the oral mucosa biopsy samples taken from Ni-sensitive patients after omPT.
- No noteworthy increment in serum concentrations of total IgE, IL-2, IL-4, IL-12, IL-15, IFN- γ , and TNF- α was observed in any patient after omPT.

de Mello, L.M. et al., 2009. TH1/TH2 balance in concomitant immediate and delayed-type hypersensitivity diseases. *Immunology Letters*, 124(2), pp.88-94.

https://www.academia.edu/6626628/TH1_TH2_balance_in_concomitant_immediate_and_delayed-type_hypersensitivity_diseases

- Nickel allergy involves TH1 cells. Dust mite allergy involves TH2 cells. However, the Th1-derived cytokine IFN-gamma inhibits the proliferation of Th2 lymphocytes, so how can the two types of allergy coexist?
- Patients presenting with IgE and cell-mediated allergies were analyzed for cytokine production. The level of IFN-gamma was lower in the group that had both types of allergy.

Sosroseno, W., 1995. The immunology of nickel-induced allergic contact dermatitis. *Asian Pacific Journal of Allergy and Immunology*, 13(2), p.173.

<https://pdfs.semanticscholar.org/3c1a/1feb505b351ca91b878fd19bd186e67bbfb2.pdf>

- A discussion of the mechanisms behind nickel ACD, which includes mast cell involvement.

Type 1 (IgE) Reactions

#IgE #histamine

Saluja, S.S. et al., 2016. Contact urticaria to nickel: A series of 11 patients who were prick test positive and patch test negative to nickel sulfate 2.5% and 5.0%. *Dermatitis*, 27(5), pp.282-287.

Abstract at <https://www.ncbi.nlm.nih.gov/pubmed/27649351>

- Presents a series of 11 patients who tested positive to a nickel prick test but negative to a patch. The authors suggest that IgE allergy to nickel may be far more common than once thought.

Büyüköztürk, S. et al., 2015. Oral nickel exposure may induce Type I hypersensitivity reaction in nickel-sensitized subjects. *International Immunopharmacology*, 26(1), pp.92-96.

https://www.researchgate.net/publication/273792884_Oral_nickel_exposure_may_induce_Type_I_hypersensitivity_reaction_in_nickel-sensitized_subjects

- This study finds the presence of Type I hypersensitivity in addition to a Type IV immune reaction in patients with chronic systemic symptoms related to nickel. Nickel containing dental alloys and oral nickel intake seem to trigger systemic symptoms in previously nickel sensitized patients.
- Of 39 patients with a positive patch test, 27 had a positive skin prick test (70%).

Walsh, M.L., Smith, V.H. and King, C.M., 2010. Type 1 and type IV hypersensitivity to nickel. *Australasian Journal of Dermatology*, 51(4), pp.285-286.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/21198528/>

- "We report a case of type 1 and type IV contact hypersensitivity to nickel."

- When patch tested, the patient complained of discomfort at the site within seconds, and developed erythema and oedema was visible in 20 minutes, consistent with an urticarial type of reaction. After 96 hours, there was evidence of residual eczema.

Estlander, T., et al., 1993. Immediate and delayed allergy to nickel with contact urticaria, rhinitis, asthma and contact dermatitis. *Clinical & Experimental Allergy*, 23(4), pp.306-310.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/8319128/>

- Case study of a patient with nickel ACD who developed asthma, rhinitis and contact urticaria. Patch testing was positive. Scratch chamber tests, open tests, specific IgE determinations (RAST), and RAST-inhibition test indicated that she had developed an IgE-mediated allergy to nickel; the bronchial provocation reaction with NiSO₄ was, however, a late one.

Osmundsen, P.E., 1980. Contact urticaria from nickel and plastic additives (butylhydroxytoluene, oleylamide). *Contact Dermatitis*, 6(7), pp.452-454.

Abstract at <https://pubmed.ncbi.nlm.nih.gov/7214887/>

- Chamber-prick test with nickel sulfate 2.5% in pet. evoked a strong urticarial reaction in both patients. Both patients were patch test negative.