Evaluation of nikel release in stainless steel attachments

Claude G. Malasa
Chicago, USA

Summary

Most metallic orthodontic attachments are made of a variety of stainless steels that are put together (soldered, brazed) with the help of other alloys. Aside these variations, several processes methods are currently used for their manufacture and service. While resistant against most corrosive agents, all stainless steel devices are corrosion susceptible, depending from their composition and treatment. As a result, various amounts of nickel, a known allergen, is released in the patient's body. While there are already standardized methods to test the amount leached in vitro, these do not apply to all orthodontic attachments and require sophisticated and expensive means.

To compare attachments, it has been found that it is enough to modify a procedure recommended by ISO for the evaluation of the nickel released from stainless steel samples destined for casting. If the recommended solution is gelled and added with specific ion-detecting reagents, the degree of attack of the attachments immersed can be inferred from the extent of the colored spots generated in time. While only semi-quantitative, the method has been successfully applied to wires, brackets and expansion screws allowing to screen the appliances that have higher chances to endanger the health of the patient.

Introduction

Nickel related problems

"Tin mouths" can host large amount of bands, brackets and wires made of various heavy metals. In some instances, these attachments dissolve in part in the mouth[1-15] , Fig. 1 and 2. Among the metals released, nickel ranks first as importance, as it can lead from allergies to tissue necrosis and hepatic dysfunction. *"In the 1980's, the incidence of allergies to nickel was about 10 percent,"* claims Dr. David Cohen of the New York University School of Medicine. *"By the mid-1990's, that number had increased almost 40 percent to 14.3 percent."*

It is long since the nickel-generated allergy is the most dreaded contact allergies in the industrialized countries. Young people are more frequently affected than the older, and this sensitivity has been found to increase in the younger generations .

The sensitivity to nickel-induced reactions is never inherited; it develops gradually by extensive skin contact with nickel-containing alloys. Once sensitized, a person will normally remain so for the rest of his life. The symptoms developed can affect parts of the body that are away from the nickel contact (knees, buttocks) [16-17] A known carcinogenic agent[18-19] , nickel has been found to lead to tissue necrosis[20-21] altering both internal organs (spleen)[22] and muscles[23]. Cell exposure to carcinogenic nickel compounds induces many genes that are commonly expressed in cancer cells, but not in normal ones, and modify the lymphatic system[24]. Last but not least, nickel has recently been found to contribute to the Chronic Fatigue Syndrome and to immunity in general[25-28], affecting up to 31.9% of females[29].

On a broader plane, the European Union has recommended the restriction for the use of nickel in the manufacture of objects placed in direct and prolonged contact with skin, establishing a threshold of 0.5 microgram of nickel/cm^2/week[30-33]. To implement this Directive, groups of experts are currently at work in order to establish the bases for future European and international standards on tests. Due to such problems, both the European

Community and the Ministry of Health and Welfare of Japan prohibit in the territories they control any dental attachments leaching nickel above pre-established limits.

Fig. 1. Worn and corroded one-piece bracket

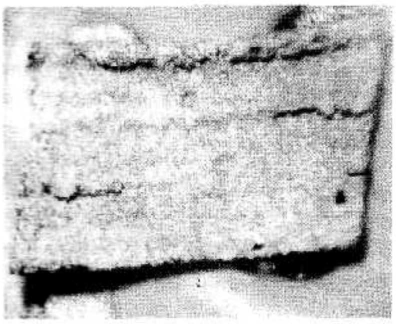
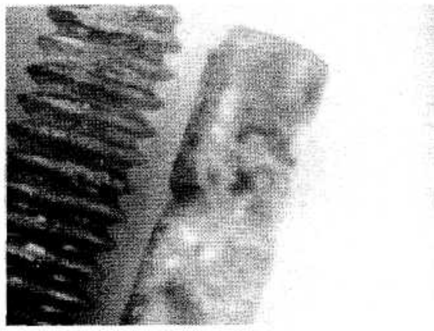


Fig. 2. Worn and corroded part of an expansion screw



Stainless steel alloys

Homogeneous, stainless steel alloys consist of a single phase. Made of several metals (Fe, Cr, Ni, C) that are soluble one in another, these steels are made of tiny unit cells in which these elements coexist in a certain ratio. In other alloys (such as in the system nickel and gold), each of the component metals can be removed separately by chemical attack/dissolution. In stainless steel's solid solutions, the dissolution takes place unit cell by unit cell. In each of these, the elements are found in the proportion shown by the chemical composition of the alloy. As a result, it is not necessary to go to extra lengths to measure the content of the Ni released by a certain stainless steel object: it suffices to measure another component (Fe or Cr) that may be easier to determine. As its leached amount will be proportional with the nickel content of the alloy, as an example it can be inferred that for each ten atoms of Fe dissolved, there should be also one of Ni.

While resistant to many chemicals due to the impervious layer of chromium oxide that coat their surfaces, stainless steels can rust and be attacked whenever the mentioned layer is removed. The main attackers are the chlorides: dissolving the oxide mentioned, these leave the steel exposed to attacks. If a source of oxygen is readily available, the layer is reformed: if not, such as in hidden places or under a plastic layer (crevice corrosion) the corrosion continues. The corrosion is enhanced by the steel's joint with other metals (galvanism). If nobler than stainless steel, the other metal will cause the steels' dissolution. As the environmental conditions to which the stainless steel parts are subjected may vary, it is usual to equalize their protective layer by passivation, a treatment based upon oxidation that refreshes the protective layer mentioned.

In dentistry, accelerated corrosion tests simulating the nickel release that takes place *in vivo* were recommended both by the Japanese government[34] and by ISO. While the first had as purpose to analyze only brackets, the second the stainless steel used for casting[35]: both tests cannot be applied to all orthodontic devices and require a sophisticated and expensive analysis of the resulting solution using flame-photometry and atomic absorption.

The method suggested uses a semi-quantitative method to compare a variety of attachments. The nickel these release is evaluated by measuring/comparing the size of colored stain formed around these while immersed in a specific gel. Its composition is based upon a solution recommended by ISO for the analysis of stainless steel alloys samples cut to specific sizes.

Materials and method

In the aqueous solution recommended by ISO as standard for the accelerated corrosion test of stainless steels containing 0.1 mol/1 of lactic acid 85% (CAS 50-21-5) and 0.1 mol/1 sodium chloride (CAS 7647-14-5), the distilled water is replaced with its 3:1 mixture with glycerol to reduce water evaporation. The solution is then gelled by the adding 50 g Aerosil 200 (Degussa, Cleveland OH) and stirring in an epoxy coated Hobart mixer to prevent both the attack of the stainless steel container and any metal contamination. According to the method of evaluation desired, reagents giving colored complexes have to be added. For nickel, these were dimethylglyoxime and dithiooxamide (or rubeanic acid), and for iron, potassium ferrocyanide, known for similar uses in the metallurgical industry .

An attempt to use dithiooxamide to make directly a gel indicating the amount of leached nickel did not succeed due to the incompatibility of this reagent with the acid environment. A similar situation occurred also with dimethylglyoxime (CAS 95-45-4, from Fisher Scientific, Pittsburgh, PA). This last reagent gives a characteristic pink color in the presence of free ammonia, which added into the gel would interfere with the accelerated corrosion test by neutralizing the acid. To get the color, solutions of the reagent and of ammonium hydroxide had to be sprayed over the attachment-exposed gel. The resulting reddish complex adheres so well to the attachments that it can be freely lifted from the gel and used to indicate the sites where most of the corrosion took place, Fig. 3, 4. The solutions used contained 1 g of dimethylglyoxime in 100 ml 98% alcohol and concentrated, reagent grade ammonium hydroxide (aqua ammonia, CAS 1336-21 -6. Fisher Scientific).

Fig. 3. Complex dimethylglyoxime/nickel coloring the corrosion products in brackets

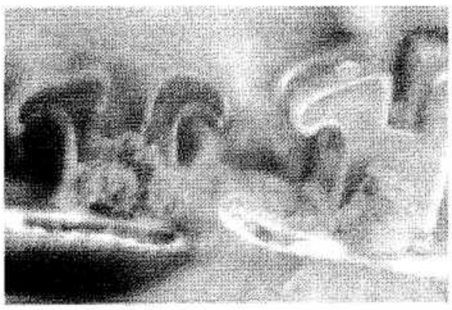
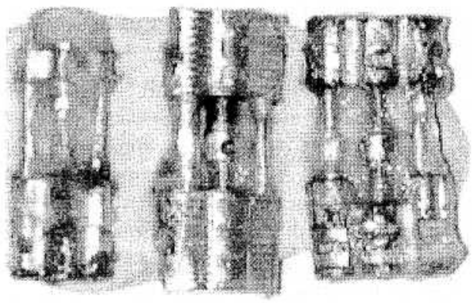


Fig. 4. Complex dimethylglyoxime/nickel coloring the corrosion products in expansion screws



As the last method proved to be difficult, the single phase behavior of stainless steel was exploited as instead of evaluating directly nickel, the test was directed toward iron, the release of which, as shown above, is proportional to nickel and whose ferrocyanide complex is stable in acid environment. Consequently, to the gel were added 10 ml of an aqueous solution 1% of potassium ferrocyanide II trihydrate (CAS 14459-95-1). The corroding gel was placed either in Petri dishes or in plastic drawer organizers (Rubbermaid, 9 x 6 x 2 inch), all free of any metal contamination. The volume of gel poured in each of the first type of containers was 50 ml, while in the second 200 ml.

The attachments tested were single and joined wires, brackets having similar sizes and various expansion screws. As the tested attachments were made at different times and kept in various conditions, these were subjected after degreasing with ethyl acetate to pickling with a 2% aqueous solution of hydrofluoric and nitric acid and the subjected to an equalizing passivation using a 2% solution of chromic anhydride (CAS 1308-38-9) in 63% nitric acid (CAS 7697-37-2), all from Fisher Scientific These were then placed one by one in the gel, taking care to have them properly immersed. To enhance contact, the gel was vibrated for few seconds and then left for two to three days. For direct nickel testing, the containers with exposed gel were sprayed in excess with the solutions of dimethylglyoxime and ammonium hydroxide and left overnight before being photographed with a Nikon Cool Pix 950 digital camera. For iron testing, while the spots start to form around each attachment after few minutes, these were photographed after two days.

Nickel release testing

A headgear and two batches of brackets were tested in Petri dishes according to this procedure. A first batch was made of thirty-nine brands, one-piece, coated, self-engaging as well as retainers and stops, new or used and reconditioned.

The second batch comprised forty brackets with mesh pads (combined). In both cases, five attachments were placed at an almost equal distance in each dish.

Iron release testing

As the direct test for nickel requires some skill when compared with the one for iron (whose direct proportionality with nickel has been discussed), wires, headgears as well as new and used and recycled brackets and expansion screws were treated as shown and immersed in the potassium ferrocyanide containing gel and photographed after two days of exposure.

At the New York University, under the supervision of Prof. Dr. M. M. Kuftinec, Dr. Leticia Boos has tested for iron release, using the ferrocyanide-containing gel, several arch wires having the same size. The diameter of the spots formed was measured with a Boley Gauge and the results statistically processed and compared. The procedure was repeated three times, following the same steps.

Results

Wires: iron and nickel testing

All the arch wires tested at NYU generated stains after 48 h: while the arch wires from the same companies behaved the same way, showing consistency, marked differences were found between the brands. The arch wires from American Orthodontics produced the smallest spots, which lead us to conclude that it leached less iron, and implicitly, less nickel. GAC arch wires produced the second smallest stains, followed by ORMCO, Rocky Mountain, Unitek and Ortho Organizers.

In a separate study, two headgears were tested successively for nickel and iron, as shown in Fig. 5 and 6. While the area of nickel release was diffuse, that of iron was specific, indicating galvanic corrosion where the two wires were joined, i.e. at the steel/brazing interface.

Fig. 5. Headgears after 24 h exposure in a gel reacting to leached nickel. reacting to leached nickel

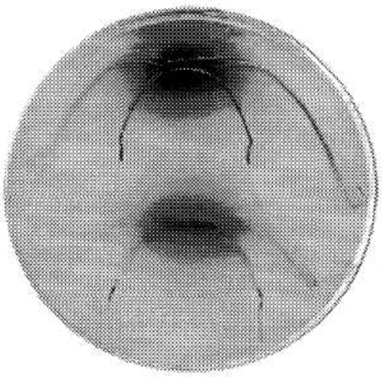
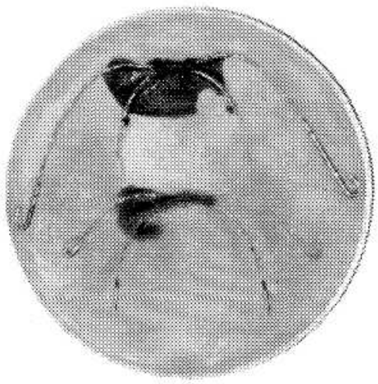


Fig. 6. Same headgears, after a second 24 h exposure to a corrosive gel reacting to leached iron



Brackets: nickel release testing

The new and used one piece, coated and self-engaging brackets subjected to nickel release detection were photographed after a week of exposure as shown in Fig. 7. The brackets tested can be located using the number of the dish where the name of the manufacturer is indicated (other origin than US is also shown). A mark varying from (-) to (++) indicates the degree of attack: a mark (-) shows low corrosion susceptibility, (+) a moderate one, while (++) indicates a high susceptibility.

One piece brackets. 1. Lancer, *Sinterline,* new (-); 2. Adenta, *Econoline,* new (+); 3. Ortho-Organizers, *Single Bracket Bonding System,* used (-); 4. Pyramid Orthod., *Prestige,* used (-); 5. Glenroe, cast (-); 6. Pyramid Orthod., *Prestige,* new (-); 7. Pumpa (Russian), new (-); 8. Unitek, *Glance,* new (-); 9. Technomed (German), new (-); 10. Chinese , new (-); 11. Unitek, *Dynabond III,* new (+); 12. Unitek, *Miniature Twin,* new (-); 13. Lancer, *Elite Opti-Mim,* new (-); 14. Dentaurum, *Discovery,* used (-); 15. CEOS A (Spain), *Low Ni,* new (-); 16. Advanced

Orthodontics, *Integra,* new (-); 17. Unitek, *Mini Unitwin,* used, (+).
Varia. 18.Retainers, used (+); 19. Stops, used (-) **Self-engaging brackets.** 20. Forestadent, *Mobil-Lock,* new (++); 21. Ormco, *Twin Lock,* new (++); 22. Ormco, *Edgelock,* new (++); 23. "A"-Co., *Activa,* new (++); 24. Orec, *Speed,* used (-); 25. American Orthodontics, *Time,* new (+); 26. "A"-Co., *Damon,* used (+). **Coated brackets and controls.** 27. Unitek, *Mini Victory,* control, new (+); 28. Same, gold coated, new (+); 29. Advanced Orthodontics, *Formula,* control, new (+); 30. Same, nickel-palladium coated by Wonder Wire, (P.O. Box 6497, Wyomissing, PA 19610), new (+); 31. Same, recycled (+); 32. Altheis, platinum coated by Line Mechanics (03725 Teulada, Spain), new (++); 33. Same, control, new (++); 34. Ormco, old type, coated by NiCoTef (Nimet Industries, 2424 Foundation Drive, South Bend, IN 46628, new (++); 35. Same (control), new (+); 36. Ormco *Mini Diamond,* gold coated by Line Mechanics, new (++); 37. Same, control, new (+); 38. Ormco *Diamond,* gold coated by Line Mechanics, new (+); 39. Ormco *Diamond,* gold coated by Line Mechanics, new (+) (control).

Fig. 7. One piece, coated and self-engaging brackets after a week of exposure to a corrosive gel reacting to nickel

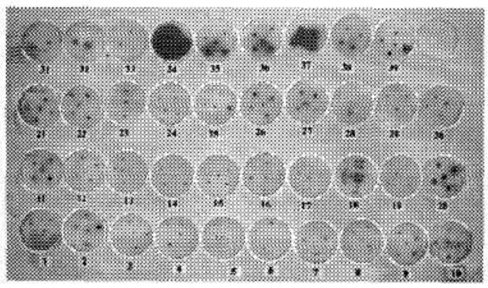
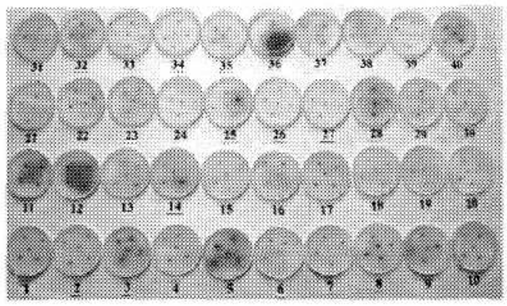


Fig. 8. Combined, mesh-based brackets after a week of exposure to a corrosive gel reacting to nickel



A similar test has been performed on combined, mesh-based brackets, as shown in Fig. 8
Combined brackets (mesh pads) 1. "A"-Co., *Comfort,* used (-); 2. Ormco, *Vari Simplex,* used (-); 3. Ormco, *Mini-Vick,* used (+); 4. Unitek, Chun-Hoon, used (-); 5. Rocky Mountain, *Edgewise regular, medium single,* new (-); 6. American Orthodontics, Mini Tweed, single (-); 7. Unitek, *4-Stage,* used (-); 8. American Orthodontics, *Channel Edge,* used (+); 9. Lancer, *CAT,* used (+); 10. Rocky Mountain, *Edgewise regular, medium single,* used (-); 11. Rocky Mountain, *Synergy,* new (+); 12. Rocky Mountain, *Mini Taurus,* new (++); 13. Unitek, *Unitwin,* used (+); 14. Ortho-Organizers, *Elite,* used (+); 15. Unitek, *Twin Torque,* used (-); 16. Unitek, *Victory Series,* used (++); 17. TP Orthodontics, *Straight Edge,* used (+);18. TP Orthodontics, *Advantage,* used (-); 19. "A"-Co., *Attract,* used (+); 20. "A"-Co., *Standard Edgewise,* used (-); 21. "A"-Co., *Mini Twin,* used (+); 22. Dentaurum, *Ultra Mini Trim,* used (+); 23. Dentaurum, *Ultra Trim,* used (+); 24. American Orthodontics, *Master Series,* used (-); 25. American Orthodontics, *Triple Action,* used (++); 26. GAC, *Omni,* used (-); 27. GAC, *MicroArch,* used (-); 28. Ormco, Diamond, used (+++); 29. Lancer, *Natural Arch,* used (+); 30. Ormco, *Diamond,* used (+); 31. Lancer, *Sinterline,* used (+); 32. Orec, *Aardwark,* used (++); 33. GAC, *Shoulder,* new (-); 34. GAC, *Viazis,* used (-); 35. TP Orthodontics, *Tip Edge,* used (-); 36. American Orthodontics, *Mini Master Series,* vertical slot, used (+++); 37. Forestadent, Mini-Mono, used (+); 38. TP Orthodontics, *Begg, 256 series,* used (+); 39. Unitek, *Light Wire Begg,* used (-); 40. Ormco, *Begg,* used (++).

Brackets: iron release testing

Twenty brackets from nine brands, same type but new and recycled, were tested in parallel in the plastic trays shown joined together in Fig. 9. The new brackets were placed in the left tray, and the recycled ones in the right one.

The degree of attack was deemed as follows, first row: Orec, *Speed;* new and used (-); Ormco, *Mini Diamond,* new (-), used (+);

Unitek, *Unitwin;* new (++), used (+). In the second row, Unitek, *Dynabond II;* new and used (+); American Orthodontics, *Mini Master series;* new and used (-); "A"-Co., *Standard Edgewise,* new and used (-). In the last row, Unitek, *Victory;* new (-), used (+); Rocky Mountain, *Triple Control;* new and used (-); Ormco, *Diamond,* new and used (-)

The brackets which were least attacked, i.e. these which have released the lowest amounts of heavy metals, as evidenced by the smaller spots around them, were Orec, *Speed,* Ormco *Mini Diamond,* American Orthodontics, *Mini Master Series,* and Ormco. *Diamond.* The heaviest attack occurred on Unitek's Unitwin one-piece brackets.

Expansion screws: iron release testing

Some of the expansion screws tested were from *Forestadent, Lewa, Leone, Czech, Dentaurum,* while others were unknown, being sent for the purpose by Prof. Dr. S. Kiliaridis & Dr. F. Pribula, Geneva University as shown in Fig. 10. Their relative position was maintained in the ferrocyanide-containing gel shown in Fig. 11. The two types of Forestadent expansion screws tested, although of about the same size, seemed as not being made of the same alloy. Leone and these marked as Unknown I an II showed a lower release of harmful ions than the others. Despite their bulk and size, Dentaurum's Hyrax exhibited smaller spots than some of their tinier counterparts.

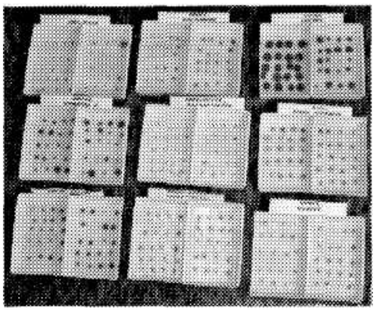


Fig. 9. New (left) and used (right) brackets displayed in parallel, after an exposure of two days to a corrosive gel reacting to iron

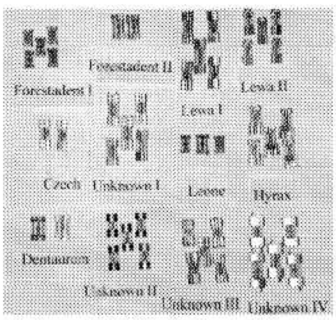


Fig. 10. Expansion screws before being tested

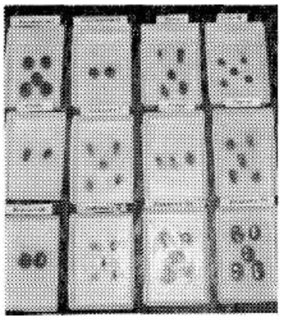


Fig. 11. The same expansion screws, but after an exposure of 24 h to a corrosive gel reacting to iron

Discussion

While the content in nickel of the orthodontic attachments is altogether steadily decreasing, there are also three worrisome trends toward the their decrease in corrosion susceptibility. A first one is miniaturization: corrosion resistant, austenitic steels are replaced with the martensitic and the precipitation-hardened ones, mechanically superior. The second trend is the proliferation of cheaper attachments where the content in expensive metals is reduced. A third one is a manufacturing process, injection molding. While theoretically it allows the use of alloys that are prohibitive in other processes, it often adds porosity and a lower density to poorer alloys.

The resistance to nickel-generated afflictions is decreasing in the newer generations at a time when health caring organizations cannot cope with the multitude of products launched every year. As measures such as Proposition 65 adopted in California (according to which the clinician is responsible with the materials he uses) tend to proliferate, the need for simple, do-it-yourself methods of evaluation grows.

While the conditions encountered in the mouth are different from those existing in the acid gel, the basic formula used for the accelerated corrosion has been recommended by ISO to best duplicate them. While only semi-quantitative, the evaluation of nickel released and that of its indirect counterpart, iron, could allow a clinician to tailor his treatment according to the patient's degree of sensitivity. The indirect procedure is especially easy to perform and uses ingredients readily available.

The test is superior to the one recommended by the ISO standard as it can be applied to any orthodontic attachment, and better that the Japanese one that is designed only for brackets. Instead of using sophisticated and expensive methods such as flame photometry or atomic absorption, it allows the general evaluation and the detection of weak areas of any stainless steel attachment by a simple immersion in an easy to prepare gel. A comparison of the iron released of new vs. recycled brackets of the same type shows little difference, with the exception of Unitek's Unitwin brackets. The maximum release of harmful ions has been described to occur within in the initial stage of wearing the attachments, after which follow a decrease till a plateau is reached[37, 38]. This, can be explained in view of the drop in activity of the crystallites that form the various active sites, phenomenon commonly encountered in heterogeneous catalysis, where the active sites lose a significant portion of their function in time.

The test can be used to assess how a certain attachment, be it arch wire, direct bonding bracket or expansion screw, would behave in the oral environment. While it cannot provide the exact amount of nickel released, it can be used as a tool to compare and rank the orthodontic attachments thus choose the one that would be less likely to produce an allergic reaction in sensitive patients.

Conclusions

The release of nickel is on increased concern in medicine, as the variety and number of items that could release harmful ions is increasing. The organizations that could or should monitor these cannot cope with this avalanche, while the physician starts to be considered liable for the iatrogenic afflictions he may produce.

A simple immersion in a gel made of few, readily available ingredients allows an evaluation of the heavy metals leaching of the various attachments the orthodontist uses. As the authorities rely more and more on the physician to take the necessary measures to protect the patient, the time spent and the materials needed for the testing may be well worthwhile.

References

1. Matasa CG, Direct bonding metallic brackets: Where are they heading? *Am. J. Orthod. Dentofac Orthop* 1992; **102:** 552-560.
2. Matasa CG, Nicht rostende Edelstahle und Direkt - Bonding Brackets. II Chemishes Verhalten (In German: Stainless steels and direct bonding brackets. II Chemical properties) *Infonnationen aus Orthodontie und Kieferorthopadie* (Heidelberg, Germany), 1993; **25(2):** 147-166.
3. Matasa CG, Materiales usados por ortodoncistas. Aceros (In Spanish: Materials used by orthodontists: steels), *Journal of Orthopedics, Orthodontics and Pediatrics* (Caracas, Venezuela) 1996; 1: 27-38.
4. Matasa CG, Nichtrostende Edelstahle und Direkt- Bonding- Brackets. III. Mikrobiologisches Verhalten-auch der Adhasive (In German: Stainless Steels and Direct-bonding Brackets. III. Microbiological properties.) *Informationen aus Orthodontie und Kieferorthopadie* (Heidelberg, Germany), 1993; **25(3):** 269-285.
5. Matasa CG, The wear and corrosion resistance of metal deposits, *The Orthodontic Materials Insider*, 1999; **12** (3): 1-8); Doc, I'm allergic to metals! *Idem*, 1999; **12(4):** 4-8.
6. Matasa CG, It's just up to you to fight nickel allergies... *Idem*, 2000; **13(30):** 1-7.
7. Matasa CG, La corrosion des verrous: un defi pour l'orthodontiste (In French: Attachment corrosion: a chalenge for the orthodontist) *Actualites Odonto-Stomatologiques* (Paris, France) September, 187:401-409,1994.
8. Matasa CG, Orthodontic attachment corrosion susceptibilities. J. *Clin. Orthod.* 1995; **29(1):** 16-23.
9. Matasa CG, Evaluacion de la corrosion en los aditamentos ortodoncicos" (In Spanish: Corrosion testing of orthodontic attachments) *Rev. Venezolana de Ortodoncia* (Caracas), 1998; 15 (1): 437-444.

10. Matasa CG, Corrosion susceptibility of coated stainless steel direct bonding brackets, Poster at the 99th AAO Annual Session in San Diego, May 1999.
11. Matasa CG, Biomaterials in orthodontics, Chapter in *Orthodontics: Current Principles and Techniques*, IIIrd ed., T.M. Graber, R. Vanarsdall, ed., C.V. Mosby, 2000, St. Louis, MO: 305-337.
12. Matasa CG, Doc, I'm allergic to metals, *The Orthod. Materials Insider*, 1999; **12(4):** 4-8
13. Matasa CG, Shiny coatings are in. *Ibidem*, 1999; **12(3):** 1-8.
14. Matasa CG, Trends: Goodbye Ni, welcome Co,Mn. *Ibidem*, 1995; **8(14):** 1-6.
15. Matasa CG, Facts about bracket corrosion. *Ibidem*, 1992; 5(1): 1-6.
16.Gjerdet NR, Clinical and biological aspects of orthodontic materials, In: Dental materials: Biological properties and clinical evaluations, Mjor IA, CRC Press, Boca Raton, FL 1995.
17. Council on Dental Materials, Instruments, and Equipment. Biological effects of Ni-containing, dental alloys. *J Am Dent Assn* 1982; 104:501-5.
18. Covington JS, McBride MA, Siagle WF Disney AL. Quantization of nickel and beryllium leakage from base metal casting alloys. J *Prosthet Dent.* 1985; **54(1):** 127-36.
19. Kelly JR, Rose TC. Non-precious alloys for use in fixed prosthodontics: a literature review. *J Prosthet Dent* .1983; **49** (3): 363-9.
20. Menne I, Brandrup F, Thestrup-Pedersen K et al. *Patch test reactivity to nickel alloys.* Contact Dermatitis 1987; 16: 255-9.
21. Peters KP, Heese A, Allergie gegen Metale in der Zahn-heilkund, *Tagung der DGKMZ* (German Academy for Dentistry), Wiesbaden, 1995.
22. Levy A, Hanau D, Foussereau J, Contact dermatitis in children, *Contact Dermatitis*, 1980: 6: 260-4.
23. Tracana RB, Pereira ML, Abreu AM, Sousa JP, Carvalho GS, Stainless steel corrosion products cause alterations on mouse spleen cellular populations, J. *Mater, Sci., Mater, in Medicine* 1995:56-61.
24. Costa M, Klein CB, Nickel Carcinogenesis, Mutation, Epigenetics, Selection, *Environmental Health Perspectives* 1999; **107(9);** *40-45*.
25. Eggleston DW. Effect of dental amalgam and nickel alloys on T-lymphocytes. *J Prosthet Dent* 1984; **51(5):** 617-23.
26. Sterzl I, Prochazkova J, Hrda P, Bartova J, Matucha P, Stejskal V, Mercury and nickel allergy: risk factors in fatigue and autoimmunity; *Neuroendocrinology Letters*, 1999; 20: 221-228
27. Regland B, Nickel allergy, Second World Congress on Chronic Fatigue Syndrome and Related Disorders held in Brussels, 9-12 September, 1999.
28. Marcusson JA, Lindh G, Evengard B, Chronic fatigue syndrome and nickel allergy, *Contact Dermatitis* 1999 May; **40(5):** 269-72
29. Bass JK, Fine H, Cisneros GJ, Nickel hypersensitivity in the orthodontic patient, *Am J Orthod Dentofac Orthop* 1993; **103:** 280-5.
30. Amendment- Annex 1 to Directive 76/769/EEC.
31. Menne T, Prevention of nickel allergy by regulation of specific exposures. *Ann Clin Lab Sci* 1996; 26: 133-8.
32. Delescluse J, Dinet Y, Nickel allergy in Europe: The new European legislation. *Dermatology* 1994; **189** (suppl. 2): 56-7.
33. Liden C, Menne T, Burrows D, Development of European standards for the prevention of nickel allergy, Second Congress of the European Society of Contact Dermatitis, 6-8 October 1994, Barcelona, Spain.
34. Ministry of Health and Welfare of Japan, Standard 1985.3.30 No. 294
35. International Standards Organization, test #6871-2; 1996.
36. ASTM Method A 380, Section 7.3.4
37. Barret RD, Bishara SE, Quinn JK, Biodegradation of orthodontic appliances. Part I, Am J Orthod Dentofac Orthopl993;103:8-14.
38. Park HY, Shearer TL, In vitro release of nickel and chromium from simulated orthodontic appliances, Am J Orthod Dentofac Orthop 1983; **84:** 156-9.

Correspondence to: Claude G. Matasa, DCE, DSc, Adj. Professor, U. of Illinois, Chicago, USA, President, Ortho-Cycle Co., 2026 Scott St., Hollywood, FL 33020, Ph.: 954/920-9074; 800/ 8229253, www.Matasa.net, e-mail: Matasa@aol.com