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In -Vitro: Evaluation of Corrosion Behavior of Orthodontic Stainless Steel Brackets to Salad Dressing

S.F.Hussain [1]*, K. G. Heah[2],G.R.A. Fromming[3], N.Ibrahim[2],N.Ab.Latif[2],S.A.Sukiman[2] ,S.Mohd.Nazri[2].
[1]*Centre of Comprehensive Care Studies, Faculty of Dentistry, Universiti Teknologi MARA, Malaysia*
[2] *Centre of Preclinical Science Studies Faculty of Dentistry, Universiti Teknologi MARA, Malaysia*
Institute of Pathology, Laboratory Sciences and Forensic Medicine (I-PPerForM) & Faculty of Medicine, Universiti Teknologi MARA, Malaysia

ABSTRACT

The objectives of this study were to investigate the corrosion behavior of conventional and self-ligating stainless steel brackets and the surface structural changes in response to salad dressing. Damon, In-Ovation,Smart clip, Discovery, OMNI and Masel brackets were all included in the study. For the control group, the brackets were placed in Petri dishes with Potassium Ferrocyanide (Fe $[CN]_6K_4$) and distilled water. Whereasas for the experimental group, the brackets were incorporated into the same reagent mixed with Oil-based - Kraft Classic French Oil and Water-based-Salad Magic, Herb and Garlic Dressing. The released ferrous ion concentrations were measured by spectrophotometer after 24 and 48 hours. Scanning electron microscope was used to analyze surface changes of the brackets. All types of brackets demonstrated signs of corrosion. Generally, self-ligating brackets were more susceptible to corrosion than the conventional ones the most extensive corrosion was seen in In-Ovation R™. Meanwhile, Masel was the most corroded brackets for conventional brackets·The oil-based salad dressing illustrated the most extensive corrosion in all brackets. Self-ligating brackets, Inovation R™ showed pitting corrosion on the wings. Smart clip showed surfaces corrosion only. The commonly ingested fluids aggravate the corrosive process, and this is related to sodium chloride content.

Keywords**:** corrosion; orthodontic; brackets; salad dressing

I. INTRODUCTION

The resistance to corrosion of orthodontic brackets is of great importance to prevent release of ions into the oral cavity, which have been associated with allergic, toxic and carcinogenic effects during orthodontic therapy [1,2].Corrosion is an electrochemical reaction between a metallic material and its surrounding environment that takes place by release of positive metal ions such as iron (Fe), chromium (Cr) and nickel (Ni) from alloys to form more stable compounds such as sulfides, oxides and chlorides [3]. Nowadays most of orthodontic brackets used during orthodontic treatment are made of different types of alloys and with different manufacturing processes and microstructures that increases their corrosion potential [4]. These brackets are manufactured by casting and milling. A new method of bracket production is the metal injection molding (MIM) technique, getting more and more important in the last few years [5,6].Stainless steels are protected from corrosion (i.e., passivated) by a thin, hard, and non-reactive surface film of chromium oxides. Because of their availability, strength, and appearance, Stainless steels reign supreme in modern orthodontics. Austenitic steels, lower in strength but corrosion resistant, are being gradually replaced with the mechanically stronger martensitic type. The latter's nonhomogeneous structure, which renders it more prone to chemical attack, is evidenced by its ferromagnetism. Corrosion is an electrochemical reaction of a metal or alloy with different components of surrounding environment (DIN, 2002). Brackets are subject to corrosion in the oral cavity because they are immersed in the patient's saliva, acting as an additive of electrolyte in the oral cavity, corrosion takes place by release of positive metal ions from orthodontic alloys to form stable compound such as chlorides, sulfides and oxides.Most species are of low molecular weight, and their concentrations in the oral cavity is difficult to assess and distinguished from that of similar species derived from food, cooking utensils or the respiratory environment [7]. Additional factors influencing corrosion are varying oral temperatures; the presence of plaque and the daily dietary intake.Oxygen required for corrosion is present in abundance [8].

Two major aspects of corrosion are of importance: First of all, corrosive processes result in the destruction of the surface by a loss of metal ions. In general, surface corrosion acting on the whole metal surface is considered to be less destructive than local corrosion effects, as for example pitting corrosion. Localized corrosive attacks can weaken the structure and result in fracture. Secondly, the problem of ion release into the oral cavity is discussed because of its biological effects. The recent literature shows the wide attention in attributes of dental alloys such as cytotoxicity and allergenicity [7-9]. In direct-bonding brackets, the most common site of corrosion is the interface between the bracket and the mesh pad. In self-ligating brackets, an additional source of corrosion is generated by contact of the body of the bracket with the clip or spring designed to maintain the arch wire at the slot's bottom. While an attack heavy enough to seriously damage the parts is unlikely, it might, nevertheless, significantly interfere with the attachment's sliding mechanism. Among the most aggressively corrosive agents ingested is salad dressing. Using these and a coloring reagent responding to the leached metal, it is possible to disclose attachments that are prone to generate problems and allergies in the patient [10]. It was stated that most of the blame for corrosion process falls on beverages containing phosphoric acid (e.g., Coca-Cola, Diet Coke); salad dressings may be even more aggressive due to their content of table salt. Indeed, Cl- ions are known to dissolve the chromium oxide layer that protects stainless steel, rendering it as susceptible to corrosion as iron or common steel [10]. Although several researches have been conducted on corrosion behavior of orthodontic brackets and the allergic and cytotoxic effects of metal ion release, only few studied their correlation to food and drinks [11, 12].Even though those previous studies did not use sophisticated means such as spectroscopy, but they evaluated the hydrogen volume released by the metal's attack or the aura made around the attachment when using appropriate color changing reagents [13].The purpose of this study was to investigate the corrosion of conventional and self-ligating stainless steel brackets of different manufacturers to salad dressings and evaluate the surface structure changes of brackets by scanning electron microscopy (SEM) before and after the experiment. Furthermore, is to investigate malfunctioning of slot-closing mechanism of self-ligating stainless steel brackets.

II. MATERIALS AND METHODS

Six differentcommercially available orthodontic bracketswere included in this study. The systems chosen for metallic brackets of bicuspids of Roth prescription (slot size: 0.022 inch) made by several manufacturers as listed below:

1. Damon_ 4 Steel, MIM clip, self-ligating Ormco
2. Discovery_ MIM, conventional Dentaurum
3. In-Ovation_ Milled steel, self-ligating Dentsply GAC
4. OMNI conventional clip Dentsply GAC
5. Smart clip^{TM} Milled steel, NiTi clip, self-ligating 3M Unitek
6. Masel, Masel (Conventional)

Two types of salad dressing were selected in the study oil and water based of high sodium chloride contents according to manufacturer label as follow:

1. Oil-based - Kraft Classic French Oil (Na content; 2037 mg/100 ml)
2. Water-based-Salad Magic, Herb and Garlic Dressing (Na content; 1090 mg/100 ml)

2.1. Control group

One set composed of three of each type of brackets were placed into Petri dishes that contain distilled water mixed and stirred with 1:100 Potassium Ferrocyanide (Fe [CN]6K4)* by applicator at room temperature 23°C .

2.2. Experimental group

Two sets of three of each six types of brackets listed in (Table 1) placed into Petri dishes. These Petri dishes contain the selected salad dressings individually mixed with 1:100 Potassium Ferrocyanide (Fe [CN] 6K4)*. Each Petri dish will be was covered by paraffin film to prevent evaporation at room temperature 23°C.

Samples of each resultant fluid in Petri dishes were measured for concentration of Ferrous release at 24 and 48 hours respectively. Optical density (OD) of each fluid measured by using Spectrophotometer (RS 232 PRIM SECOMAM, Germany). (Fe [CN]6K4 is a reagent known to turn dark blue in the presence of Fe2+ ions)

2.3. Scanning electron microscopy

Scanning electron microscopy (FESEM; Field Emission Scanning Electron Microscope; FEI QUANTA 200, Institute Medical Molecular Biotechnology) were used to analyze the bracket surfaces prior and after the test. The brackets were examined as-received to the corrosion state in order to analyze the changes caused by corrosion and to see which structures were the results of the production processes. The brackets were cleansed with 90% ethanol. Each bracket photographed as overview and detailed micrograph from each side of standard magnifications were set to 200·, 500· and 1,000X.

2.4. Statistical analysis:

The collected data analyzed by using student t-test in the SPSS, version 20, with p values < 0.05 were considered to be statistically significance.

III. RESULTS

The results of the present study illustrated in Visual Observations, Spectrophotometer and Field Emission Scanning Electron Microscope (SEM).

3.1. Visual Observations

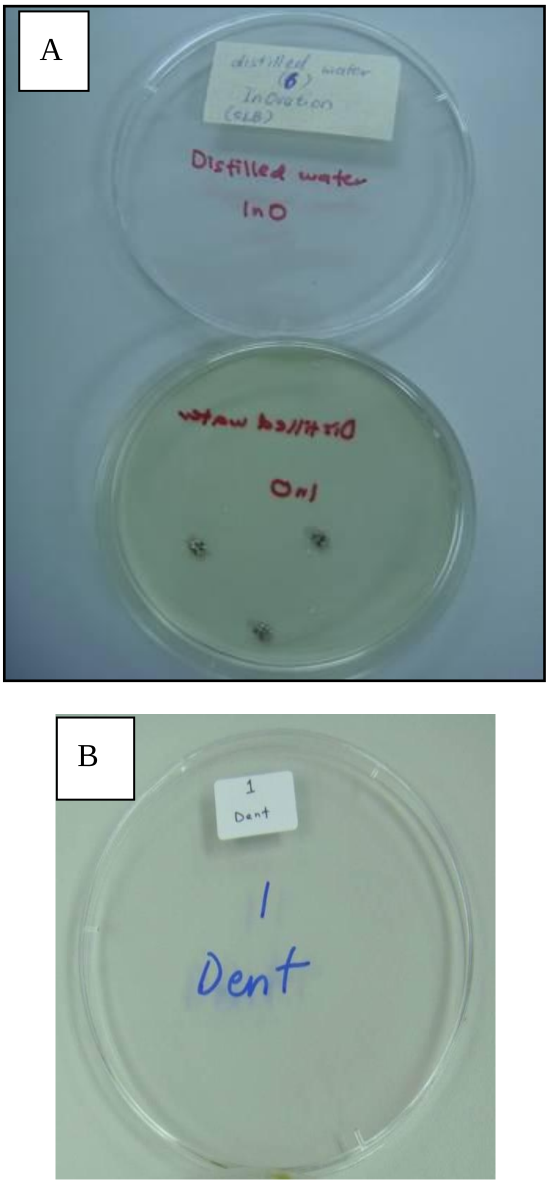
Visual changes are of subjective description. Nevertheless,they do give us the idea of the reactions taking place.

3.1.1. After 24 hours

Visually it was clearly shown there were changes in all of the brackets of all samples with different signs of corrosion for the experimental group. The indicator had changed colour to bluish greenish, and some even exhibited brown bronze colour around the brackets. It can be concluded that there was evidence of changes or in other words, corrosion have taken place (Figure 1).

Figure 1. A: control group of self-ligating innovation R with distilled water showed no color changes after 24

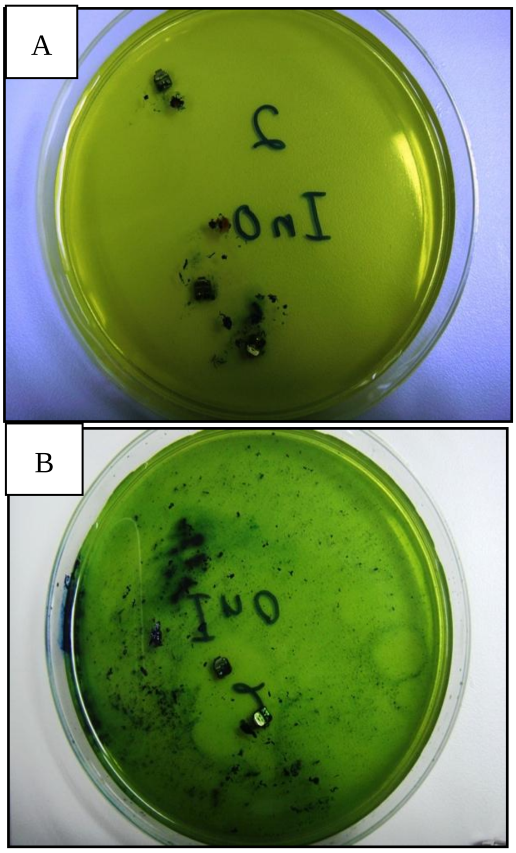
hours. B: experimental group of conventional orthodontic brackets Dentaurum with oil based salad dressing showed colour changes as the colour indicator turned to bluish green after 24 hours.



3.1.2. After 48 hours

A more obvious colour change could be seen, more intense and more in quantity. Elements of rust (brown colour) could be seen around several brackets. Some brackets from each fluid were taken and let to dry on tissue papers after 48 hours (Figure 2).

Figure 2. (A and B) Show the color changes after 24& 48 hours with innovation R self-ligating brackets respectively.



3.2.Spectrophotometer

a. Optical Density (OD) values
b. Difference (24 hrs - 48 hrs) of OD values
c. Ferrous ion concentration

The optical density (OD) of each sample after 24 and 48 hours was obtained by using a range of wavelengths from 450 nm – 700 nm by the spectrophotometer. The OD values were then used to calculate the fluid concentration from the standard curve graphs of each sample. Subsequently, the p value of fluid concentrations from 24 hours and 48 hours of the experimental group was determined.

The results showed that most of the OD values increased after 24 hours. P value was further calculated to prove the increment is statistically significant. The highest values were most notably seen in In-Ovation R™ (self-ligating bracket) and Masel (conventional bracket), indicating more corrosion compared to other brackets that relative to visual observations. The difference of ferrous ion being released between 24 hours and 48 hours is statistically significant with p value = 0.015. The means were calculated from these concentrations and graphed (Figure 3&4).

Figure 3. Mean of OD values after 24 & 48 hours of Test and Control Groups

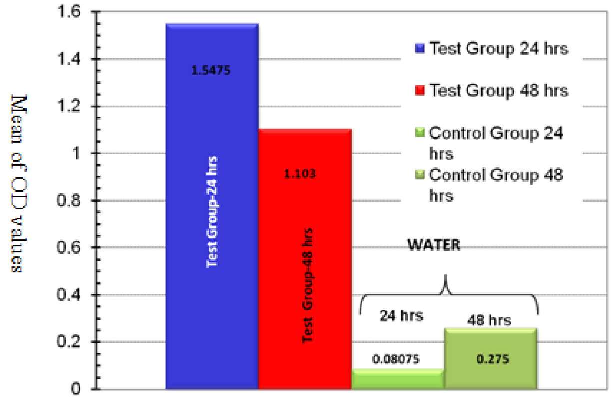
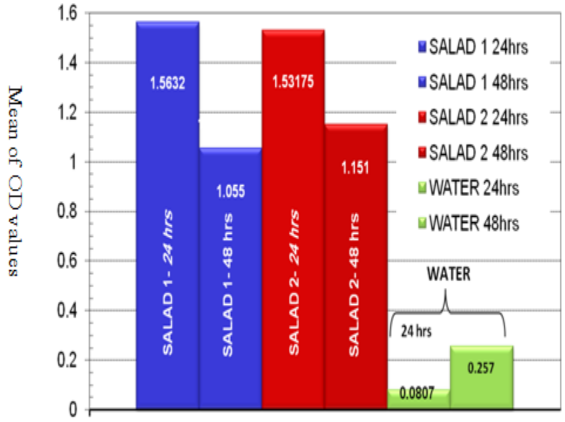


Figure 4. Means of OD values of the two salad dressings used in the study after 24 & 48 hours (salad 1:oil based salad dressing, salad 2: water based salad dressing).



3.3.Field Emission Scanning Electron Microscope

3.3.1. Surface changes (pitting corrosion & surface roughness)

The SEM result demonstrates the surface changes taking place on the brackets. Therefore, the photomicrographs seen verify the OD results with regard to release of ferrous ions. From the photomicrographs, surface roughness and pitting corrosion was seen. Pitting corrosion indicates more ferrous ion release despite a more generalized surface corrosion.

3.3.1.1. Time

The control group show almost no surface changes after 24 hours in all brackets. However, the tested groups of all samples showed different signs of corrosion at various areas of the brackets. The degree of corrosion seen corresponds with the OD result. The highest OD result demonstrates the most destruction.

After 48 hours more surface changes were seen in almost all samples. Therefore, the increase in ferrous ion concentration is verified by SEM. The most corroded brackets seen were in In-Ovation R™ and Masel.

3.3.1.2. Salad dressings

The results showed that all the brackets immersed into both salad dressings surface changes in different manners of 24 hours. However, more surface changes and extensive corrosion were estimated after 48 hours.

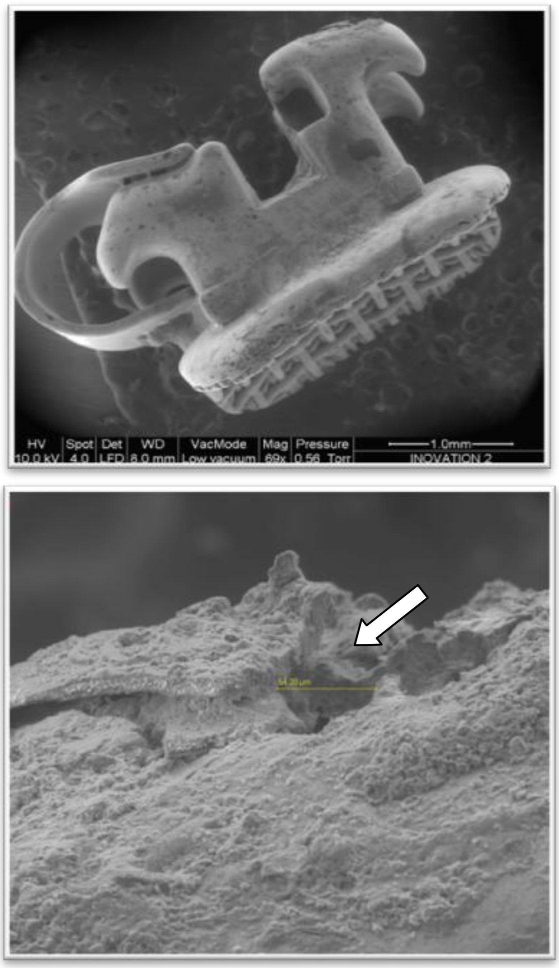
The oil-based salad dressing illustrates the most extensive corrosion in *all* brackets. Meanwhile, the water-based salad dressing demonstrated more corrosion in conventional brackets rather than self-ligating brackets.

3.3.1.3. Self-Ligating Brackets VS Conventional Brackets

Generally, self-ligating brackets were more susceptible to corrosion than the conventional ones, showing more extensive corrosion after 48 hours than 24 hours. For the self-ligating brackets, the most extensive one was seen in In-Ovation R™. Meanwhile, Masel was the most corroded brackets for conventional brackets.

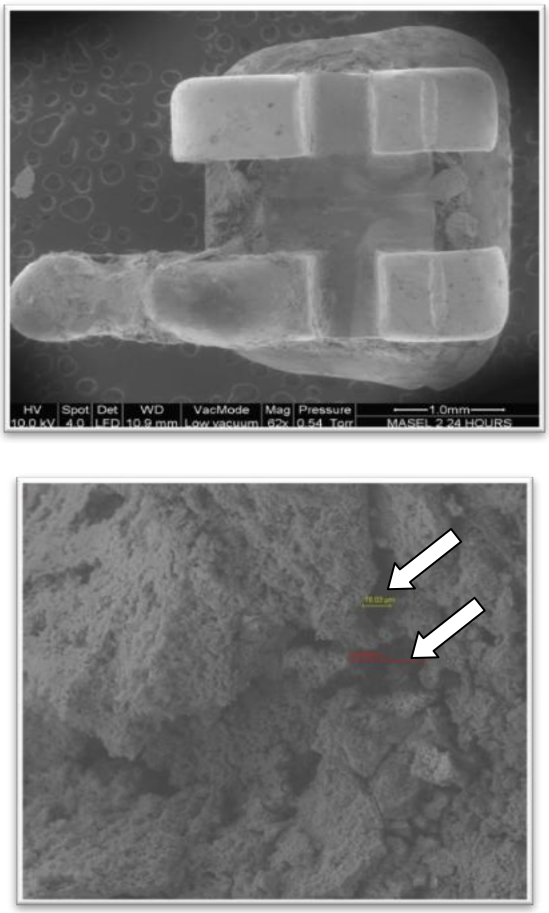
In-Ovation R brackets showed both surface and pitting corrosion at wings, interface of the body and base of bracket, and some at the side of the slot. However, very less corrosion was seen on the clip.

Figure 5. photomicrographs showing surface roughness on body and pitting corrosion on wings of In-Ovation R™ of sample 2 (24 hours).



Masel showed more uniform corrosion of surface roughness demonstrating pitting corrosion in some samples. Pitting corrosion and crevices were discovered on the surface (at areas like the hook, body and connections). Other areas include the base of bracket which constitutes the mesh pad. Discovery® showed the same but being extensive only in oil-based salad dressing (Figure 6).

Figure 6. photomicrographs showing Surface roughness on body and pitting on hook of Masel sample 2 (24 hours) at 60X and 1000 X magnifications



IV. DISCUSSION

The values of optical density (OD) obtained from the spectrophotometer shows that almost all of the OD values increased after 24 hours indicating increased in ferrous ions release. Measuring the release of ferrous ions should give some hints with regard to SEM results and interestingly, the results showed that the OD obtained corresponds with the SEM result. Thus, the increase in ferrous ions was verified by SEM micrographs taken at 48 hours. Both SEM and OD values showed that In-Ovation R™ and Masel brackets were most corroded.

From this study, all of the brackets showed more extensive corrosion in salad dressings; this was compatible with other studies but with a different methodology [10]. It was believed that the most aggressive corrosive agent ingested is salad dressing. The salad dressings may be even more destructive due to their high sodium chloride content i.e the oil-based salad dressing being the highest one. Chloride ions from the table salt are responsible for dissolving the chromium oxide layer, which acts as passivation or protective layer for stainless steel against rust. This layer is also dissolved in a condition of high acidity as in drinks, which caused by the phosphoric acid content though rather to demonstrate less ferrous ion released [10].SEM analysis and OD values showed that the self-ligating brackets were less corrosion resistant than conventional ones. This result was expected because the different brazing alloy in between clip, wings and its base induced galvanic corrosion. It may lead to the progressive dissolution of the metal and may detach the wing from the bracket base during orthodontic therapy or at the debonding stage. In addition, the clip or spring of both type of self-ligating bracket showed less corrosion because it is relatively made of nobler metal alloy than their body. Moreover, further aggravates the attack are the non-homogenous surfaces, the hidden areas of the bracket, the soldered or connecting points. These areas tend to accumulate debris from the salad dressings and buildup oxides. However, the attack to the slot is the most important part at clinical point of view. Metal oxides buildup in this region may cause impairment in the opening-closing mechanism of the slot and thus interrupting the orthodontic therapy. Another study done showed a different result with different methods i.e Smartclip™ was more corrosion susceptible than In-Ovation R™ but with lactic acid as the corrosive agent [14].

Meanwhile, the conventional brackets showed more of uniform corrosion and the most widespread one was Masel brackets than Discovery®; in all salad dressings. The areas included the whole body and quite a destructive one on its base. Destruction of the base causing deformity of the mesh pad may possibly lead to lack of bonding to the tooth surface.In another study, Discovery® and In-Ovation R™ also showed the highest amount of nickel release rather than other conventional and self-ligating brackets; however, the amount were far from the critical concentration for nickel to induce allergic reaction. The same study showed low nickel release for Smartclip[12, 15]. Therefore,the nickel release of those brackets corresponds to the degree of corrosion occurring in this study.

The SEM analysis also showed brackets demonstrating different surface changes or behavior. A localized corrosion or so-called pitting corrosion increases the risk of the bracket to fracture due to localized weakening of the affected area [16]. Pitting and crevices also release more ferrous ions and may cause cytotoxic effects. Pitting corrosion was mostly seen in In-Ovation R™ and Masel. On the other hand, generalized surface corrosion is considered less destructive than the previous one and mostly seen in almost all the brackets.Overall, enhancement of metallic properties can be done to ensure a more effective orthodontic therapy in the future. The passivatingfilms of the most deteriorated metal of certain manufacturers can be upgraded and a new coating from new materials shall be used.Despite material improvements, patients still play the most important role. A good dietary intake (less sodium) ensures good material care, as well as hindering from systemic disease as a whole. More research need to be done to verify these results obtained from this study.

V. CONCLUSIONS

In general, our study has proved that there is a difference in corrosion resistance between self-ligating brackets and conventional brackets. The self-ligating brackets are more corrosion susceptible than the conventional brackets. Also, salad dressings are corrosive to the brackets due to high sodium chloride content. Thus more studies needed to be conducted in future to confirm these results especially with recent development of good biomaterial of orthodontic bracket.

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Conflict of interest:
The authors declare no conflict of interest

REFERENCES

[1] Kim, H., & Johnson, J. W. (1999). Corrosion of stainless steel, nickel-titanium, coated nickel-titanium, and titanium orthodontic wires. *The Angle Orthodontist*, *69*(1), 39-44.

[2] Pereira, M. C., Pereira, M. L., & Sousa, J. P. (1999). Histological effects of iron accumulation on mice liver and spleen after administration of a metallic solution. *Biomaterials*, *20*(22), 2193-2198.

[3] Brantley, W., & Eliades, T. (2000). *Orthodontic materials: scientific and clinical aspects*. TIS.

[4] Matasa, C. G. (2003). Heavy metal release: a do-it-yourself test. *World J Orthod*, *4*, 348-357.

[5] Siargos, B., Bradley, T. G., Darabara, M., Papadimitriou, G., & Zinelis, S. (2007). Galvanic Corrosion of Metal Injection Molded (MIM) and Conventional Brackets with Nickel-Titanium and Copper; chNickel-Titanium Archwires. *The Angle Orthodontist*, *77*(2), 355-360.

[6] Arici, S., & Regan, D. (1997). Alternatives to ceramic brackets: the tensile bond strengths of two aesthetic brackets compared ex vivo with stainless steel foil-mesh bracket bases. *Journal of Orthodontics*, *24*(2), 133-137.

[7] Eliades, T. (2007). Orthodontic materials research and applications: part 2. Current status and projected future developments in materials and biocompatibility. *American Journal of Orthodontics and Dentofacial Orthopedics*, *131*(2), 253-262.

[8] Costa, M. T., Lenza, M. A., Gosch, C. S., Costa, I., & Ribeiro-Dias, F. (2007). In vitro evaluation of corrosion and cytotoxicity of orthodontic brackets. *Journal of dental research*, *86*(5), 441-445.

[9] Eliades, T., Pratsinis, H., Kletsas, D., Eliades, G., & Makou, M. (2004). Characterization and cytotoxicity of ions released from stainless steel and nickel-titanium orthodontic alloys. *American journal of orthodontics and dentofacial orthopedics*, *125*(1), 24-29.

[10] Matasa, CG. (2007). Corrosion and self-ligating brackets. Orthod Materials Insider December; 19: 4.

[11] Kao, C. T., & Huang, T. H. (2010). Variations in surface characteristics and corrosion behaviour of metal brackets and wires in different electrolyte solutions. *The European Journal of Orthodontics*, *32*(5), 555-560.

[12] Luft, S., Keilig, L., Jäger, A., & Bourauel, C. (2009). In-vitro evaluation of the corrosion behavior of orthodontic brackets. *Orthodontics & Craniofacial Research*, *12*(1), 43-51.

[13] Matasa CG. Stainless steels, acids, and salts: friends or foes? Orthod Materials Insider. December 2008, vol. 20, Nr. 4.

[14] Matasa CG. Making Friends of Foes. The Orthodontic Materials Insider, Dec.2008, Vol.20, Nr.4.

[15] Kao, C. T., Ding, S. J., Min, Y., Hsu, T. C., Chou, M. Y., & Huang, T. H. (2007). The cytotoxicity of orthodontic metal bracket immersion media. *The European Journal of Orthodontics*, *29*(2), 198-203.

[16] Matasa, C. G. (2000). Biomaterials in orthodontics. *Graber TM, Vanarsdall RLOrthodontics: current principles and techniques. 3rd ed. St. Louis: Mosby*, 331-332.