STRUCTURAL ANALYSIS AND CORROSION RESISTANCE OF DENTAL BRACKETS

Daniela Alina NECSULESCU[11], Iulian ANTONIAC[2], Claudia MILEA[3], Mariana CIURDAS[4*]

The paper represents an analysis regarding the corrosion behavior of stainless-steel dental brackets. They can be made from stainless steel, ceramic, composite or plated with noble metals. Through their chemical composition, mechanical properties, and corrosion resistance they offer the best performance at relatively low costs. The surface of the brackets was sandblasted with alumina particles to remove any impurities. The investigations on the sandblasted brackets were achieved through SEM-EDX analyzes. The corrosion resistance evaluation tests were performed in artificial saliva. Following the analyses, it was observed that the behavior in the corrosive environment of the samples was adequate.

Keywords: Brackets, stainless steel, sanding, structure, corrosion test

1. Introduction

The metallic orthodontic device is the most common type of dental device, and new technologies have made wearing the device much more comfortable today than it was in past years [1]. Patients can choose between stainless steel dental brackets, noble metal plated and ceramic or composite brackets, depending on the costs, quality, and biocompatibility of these [2, 3].

Metallic brackets have good mechanical and corrosion resistance properties at relatively low cost [4].

Corrosion is the process of chemical and electrochemical reactions between a metal/ alloy and its environment, resulting in damage to the material and its properties [5].

It is very important to study the corrosion of metal alloys in the oral cavitation, as this process can adversely affect the biocompatibility and mechanical integrity of prosthetic restorations and lead to treatment failure [6].

[1] Lecturer, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Spl. Independentei 313, Bucharest, Romania, e-mail: alinanecsulescu@yahoo.com

2 Prof., Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Spl. Independentei 313, Bucharest, Romania, e-mail: antoniac.iulian@gmail.com

3 PhD. Student, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Spl. Independentei 313, Bucharest, Romania, e-mail: milea.claudia12@yahoo.com

4 Lecturer, Faculty of Materials Science and Engineering, University POLITEHNICA of Bucharest, Spl. Independentei 313, Bucharest, Romania, e-mail: ciurdasmariana@yahoo.com, *corresponding author

Corrosion in the oral cavity is mainly a type of electrochemical corrosion, manifested on the surface of the material in the form of electrochemical reactions. These reactions lead to the continuous dissolution of the metal. This is the main cause for which corrosion is described as damage to the material under the aggressive action of the medium (in this case oral fluid) [7]. Therefore, metals and alloys intended for use in the oral cavity should withstand degradation caused by moisture, aggressive substances from which saliva is made, in particular chlorine ions, temperature and pH changes [8]. Corrosion in the oral cavity is a permanent process because the ions on the layer of the oral metal-fluid interface are removed by abrasion of food, liquids and toothbrush.

The corrosion behavior of a dental alloy may be influenced by the oral cavity (containing saliva, dental plaque, bacteria, and gastric acid reflux), as well as by the acidity and oxygen level [9]. Human saliva is an important tool for corrosion analysis and plays a major role in the oral health of humans, being the first biological fluid to deal with microorganisms, food, and medicinal substances [10]. Its composition consists of approximately 99% water, with different electrolytes (sodium, potassium, calcium, chlorine, phosphate, magnesium, bicarbonate) and proteins, represented by enzymes, immunoglobulins and antimicrobial agents, mucous glycoproteins, albumin, polypeptides, and oligopeptides [11].

The purpose of this work is to evaluate the structure and corrosion resistance of some dental brackets used in orthodontics in an artificial saliva.

2. Materials and methods

The standardized commercial chemical composition of the brackets under study is:

Tabel 1

Chemical composition of brackets

Name	Stainless steel 316L
Code UNS	S31603
Fe (Wt%)	59.8-72%
Cr (Wt%)	16-18%
Mn (Wt%)	<2.0%
Mo (Wt%)	2-3%
Ni (Wt%)	10-14%
P (Wt%)	<0.045%
S (Wt%)	<0.030%
Si (Wt%)	<0.75%
C (Wt%)	<0.030%

In this paper, a study was conducted on the influence of the corrosion resistance, in artificial saliva type Fusayama Meyer on stainless steel dental brackets. As a preliminary stage to the corrosion tests, the surfaces were cleaned by sandblasting. It can be seen in Figs. 1 and 2 that the stainless-steel sample, before sandblasting, has a opaque appearance, without metallic gloss.

Fig. 1. Base of the unsandblasted sample

Fig. 2. Unsandblasted sample slot

The surface preparation of a dental bracket shall comprise all methods to obtain a degree of cleanliness and adhesion necessary and appropriate for subsequent operations. The experimental sample was first sandblasted to remove possible residues, thus obtaining a much sharper macroscopic structure for analysis and to remove any possible oxides from the sample to determine the chemical composition as accurately as possible. Surface morphology is observed using SEM scanning electron microscopy images [12]. Further corrosion analysis was carried out in the chosen medium, namely The Fusayama Meyer artificial saliva on stainless steel samples and finally the corrosion rates were calculated.

3. Results and discussion

After the sandblasting process brackets have a glossy, clean appearance, as can be seen in Figs. 3 and 4.

Fig. 3. Base (heel) of the sandblasted sample

Fig. 4. Slot of sandblasted sample

Determination of the chemical composition of brackets after blasting was carried out by EDS analysis.

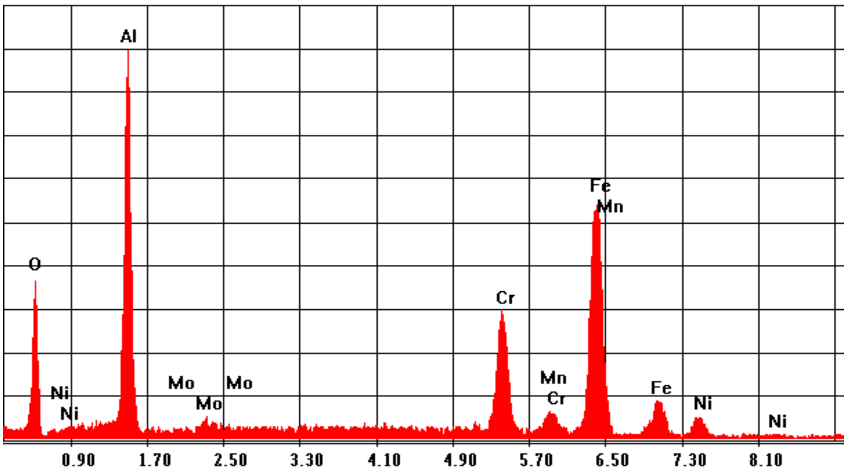

Fig.5 Chemical composition of brackets after sandblasting

Tabel 2

Chemical composition (EDS) corresponding to the experimental sample

Element Symbol	Weight concentration, (Wt%)
Fe	Matrix
Cr	16.51%
Mn	0.78%
Mo	1.13%
Ni	9.34%
P	0%
S	0%
Si	0.342%
Al	23.73%
O	31.85%
C	0%

It was observed the presence of aluminum and oxygen in the composition of the material, in different percentages, arising due to alumina sandblasting.

Following analysis of scanning electron microscopy, an image of the morphological structure of unsandblasted bracket can be observed in Fig. 6. It has a vague macroscopic appearance at the superior part, the grid shapes being covered by the adhesive used for its application. Fig. 7 shows small crowded areas of adhesive present on the surface of the bracket, before sandblasting.

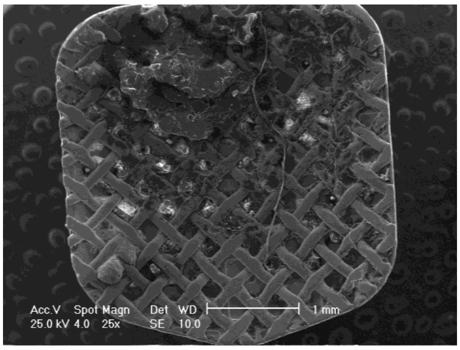

Fig. 6 SEM image of unsandblasted bracket

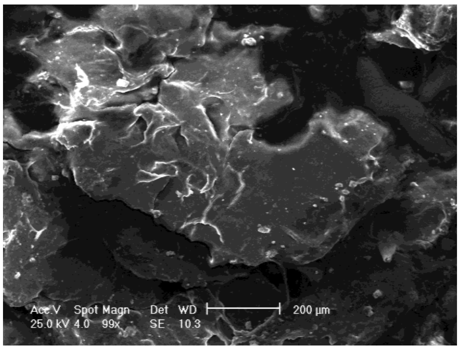

Fig. 7. SEM image of unsandblasted bracket

After sandblasting of the bracket, the SEM images obtained are conclusive, the macroscopic aspect being clearer, the grid shapes appear firmer, better contoured (Fig. 8). In detail (Fig. 9) we observe a degradation of the grid shapes structure of the sandblasted brackets.

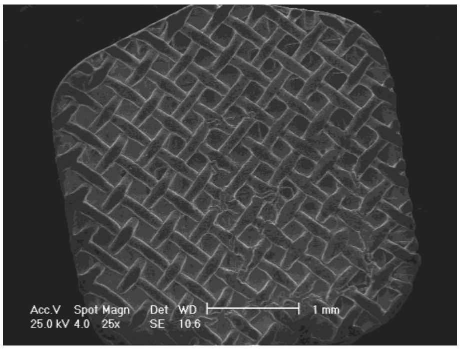

Fig. 7. SEM image of sandblasted bracket

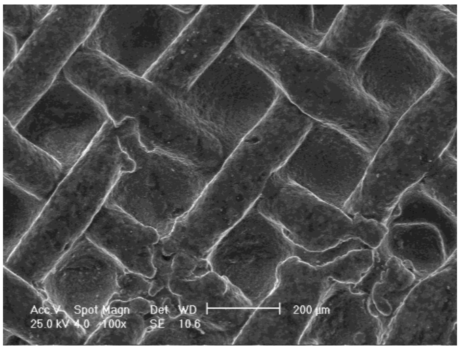

Fig. 8. SEM image of unsandblasted bracket, X100

Corrosion resistance was determined by the technique of linear polarization [5]. This technique consists of tracing linear polarization curves involving the following steps:

- - Time required to measure open circuit potential (EOC): 1 hour
- - Parameters of the trace of potential-dynamic polarization curves and scanning rate: from -0,1 V (vs OC) to +0,6 V (vs OC), with a scanning rate of 0,33 mV/s.

The corrosion cell consists of the following elements:

- Reference electrode (RE): calomel oversaturated electrode
- (SCE) recording electrode (CE): platinum electrode
- working electrode (WE): investigated samples (i. e. metal brackets)

- Test medium: Fusayama Meyer artificial saliva
- The corrosion test was carried out at the temperature of the human body: 37±1°C.

The corrosion resistance assessment was carried out according to ASTM G15 97 standard, and the composition of the Fusayama Meyer artificial saliva can be found in Table 3.

Tabel 3.

Composition of Fusayama Meyer artificial saliva

Solution	**NaCl**	**KCl**	**Uree**	**NaH_2PO_4**	**$CaCl*2H_2O$**
Quantity (ml)	0,4	0,9	1	0,69	0,795

Prior to corrosion tests, the brackets were incorporated into an acrylic resin (Duracryl) after an electrical conductor had been previously glued to them and then sanded on metallographic papers of type 200, 600, 800 and 1200.

After recording the open circuit potential, in order to find out the potential of Eoc, the potential dynamic curves from the -0,1 V (vs Eoc) to +0,6 V (vs Eoc) was registered. The potential-dynamic curves for metal brackets studied according to the pH of artificial saliva are shown in Fig. 9.

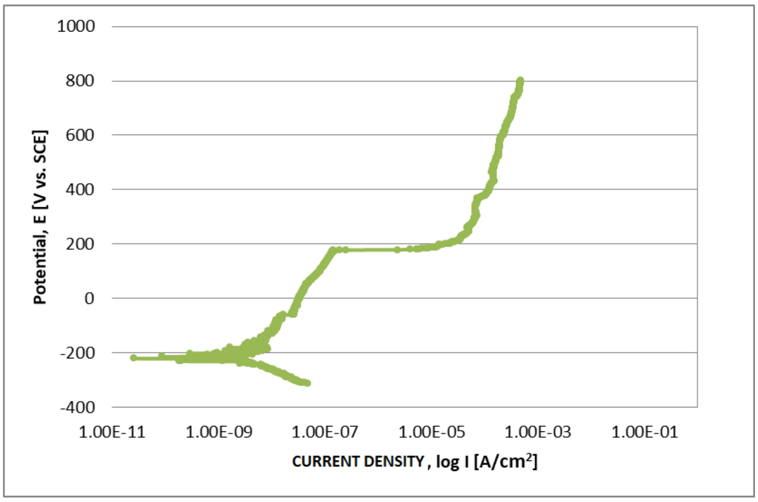

Fig.9. Potential-dynamic curve in artificial saliva pH=7

Using the parameters identified from the potential-dynamic curves and using the characteristics of the material used to make brackets, corrosion rates (according to ASTM G102-89 (2004)) corresponding to artificial saliva were calculated:

$$CR = K_i \frac{I_{cor}}{\rho} EW \qquad (1)$$

where: CR – corrosion rate
K_i – $3.27x10^{-3}$
ρ – material density
i_{cor} – corrosion current density
EW – equivalent weight

Table 4

Corrosion parameter values

Artificial saliva	E_{oc}	E_{cor} (mV)	i_{cor} (nA)	CR (mmpy)
Experimental sample	-211,934	-215,808	5,339	0,000755

4. Conclusions

In this paper, a study was carried out on the influence of the corrosion environment, using artificial saliva Fusayama Meyer on stainless steel dental brackets.

In the first stage, the surfaces were sandblasted to remove adhesive and other impurities. Comparable differences between the morphological structure before sandblasting are observed with the help of SEM images, being a opaque and non-glossy one and the surface after sandblasting becoming well contoured and easy to identify.

Using the parameters identified from the potential-dynamic curves, as well as the characteristics of the material used in the development of the brackets, the corrosion rates corresponding to the artificial saliva were calculated, resulting in the experimental sample to have a good corrosion resistance.

In conclusion, 316L stainless steel brackets are indicated in the manufacture of orthodontic devices that are used for a longer period in the oral cavity.

R E F E R E N C E S

[1] *L.Boboc, D.Stanciu, A.Temelcea, R.Stanciu*, Ortodonție practică, Aparatele ortodontice (Practical orthodontics, Orthodontic appliances), Editura Medicală, București, 2011. (in Romanian)
[2] *I.Pătraşcu, s.a*, Materiale dentare (Dental materials), Editura Horanda Press, Bucureşti, 2002. (in Romanian)
[3] Brantley, W.A., Eliades, T., Orthodontic Materials: Scientific and Clinical Aspects, Thieme, 2001.
[4] *C. Pumnea, I.Dima, F.Sorescu, M. Dumitru, T. Niculescu*, Tehnici speciale de analiza fizico-chimica a materialelor metalice (Special techniques for physico-chemical analysis of metallic materials), Ed. Tehnica, Bucuresti, 1988. (in Romanian)

[5] *St. John K.R.* ASM Handbook, Corrosion: Environments and Industries, ASM International, **vol. 13C**, 2006, pp. 820-825.

[6] *Mohamed-NurAbdallah*, *TiantongLou*, *Jean-MarcRetrouvey*, *SunjaySuri*, Biomaterials used in orthodontics: brackets, archwires, and clear aligners, Advanced Dental Biomaterials, 2019, pp 541-579

[7] *S.A Iacoban*, Cercetări asupra caracteristicilor mecanice și fizico-chimice a unor biomateriale multicomponente utilizate în stomatology (Research on the mechanical and physico-chemical characteristics of multicomponent biomaterials used in dentistry), PhD Thesis, Universitatea Tehnică "Gheorghe Asachi", 2018. 9in Romanian)

[8] *A.Houb-Dine, L.Bahije, Y.Oualalou, H.Benyahia, F.Zaoui*, Topographic and chemical surface modifications to metal brackets after a period in the mouth, International Orthodontics, **vol. 15**, issue 3, 2017, pp. 515-528.

[9] *O.Luca, Ş.Lăcătuşu, C.Mocanu, D.Aelenei*, Study regarding corrosion processes of some alloys used for dental restorations, Journal of Romanian Dentistry, **vol. 10**, issue 1, 2006, pp. 17-21.

[10] *TP Chaturvedi*, Indian Journal of Dental Research, Corrosion of orthodontic brackets in different spices:In vitro study, **vol.** 25, issue 5, 2014, pp. 630-634.

[11] *N.Schiff, F.Dalard, M.Lissac, L.Morgon, B.Grosgogeat*, Corrosion resistance of three orthodontic brackets: a comparative study of three fluoride mouthwashes, European Journal of Orthodontics, **vol. 27**, issue 6, 2005, pp. 541–549.

[12] *D.Bojin, D.Bunea, F.Miculescu, M.Miculescu*, Microscopie electronica de baleiaj si aplicatii",(Scanning electron microscopy and applications) Editura Agir, Bucuresti, 2005. (in Romanian)