Orthodontic wires of Ni-Cr and Ni-Ti alloys and its corrosion resistance in the absence and presence of Ciprofloxacin Hydrochloride tablet 500mg in artificial saliva

V.Agnes Brigitta [1] , C.Thangavelu[2], S.Rajendran[3,]
[1] Department of Chemistry, SBM college of Engineering and Technology, Thamaraipadi, Dindigul , Tamil Nadu, India.
[2]P.G& Research department of chemistry, Periyar E.V.R. College(Autonomous), Trichirappalli,Tamil Nadu, India.
[3]Research Center, Department of Chemistry, St. Antony's College of Arts and Science For Women, Thamaraipadi, Dindigul,Tamil Nadu, India.

ABSTRACT

Orthodontic wires of Ni-Cr and Ni-Ti alloys and its corrosion resistance in the absence and presence of Ciprofloxacin Hydrochloride tablet 500mg in artificial saliva has been evaluated by electrochemical study such as AC impedance spectroscopy. This electrochemical study has been used to investigate the corrosion behaviour of these alloys. The analysis of the protective film formed on the metal surface was done using AC impedance spectra. In presence of Ciprofloxacin Hydrochloride tablet in Artificial saliva, the corrosion resistance of Ni-Ti alloy is increases and Ni-Cr alloy is decreases. This is Evidenced by increases of Charge transfer resistance (R_{ct}),decreases of double layer capacitance (C_{dl}) in Ni-Ti alloy and decreases of Charge transfer resistance (R_{ct}),increases of double layer capacitance (C_{dl}) in Ni-Cr alloy. The high corrosion resistance of Ni-Ti alloy is due to the formation of a protective film on the metal surface. This protective film confirmed that the active principles of the tablet ingredients have co-ordinated with the Ni-Ti metal ions through their polar atoms to form a complex. The low corrosion resistance of Ni-Cr alloy is due to the absence of the protective film on the metal surface. Hence these electro chemical studies conclude that people clipped with orthodontic wire made of Ni-Ti alloy can take Ciprofloxacin Hydrochloride (500mg) tablet orally without any hesitation. But in the case of Ni-Cr alloy, People should avoid taking Ciprofloxacin Hydrochloride tablet orally while they are clipping the orthodontic wire made of Ni-Cr alloy.

Keyword : Corrosion resistance, AC impedance spectra, orthodontic wire, Ciprofloxacin Hydrochloride, Ni-Cr and Ni-Ti alloys.

1. INTRODUCTON

On the dental market there are a variety of dental alloys used in dentistry for manufacturing of fixed and removable prostheses. In the oral cavity, these structures are exposed to a chemically adverse environment, with saliva being the most corrosive agent, due to the high concentration of chloride ions that are causing

localized corrosion. One of the most important factors determining the use of a metal alloy for making prosthesis is its resistance to corrosion [1,2]. Non-precious metal alloys are being used due to their low cost and adequate mechanical properties. In the '60s, basic alloys such as nickel-chromium were developed. These alloys are basically composed of Ni (68% to 80%) and Cr (12% to 27%) [3], Chromium enhances the resistance of nickel to oxidizing acids by encouraging the formation of passive films [4]. Nitinol is regarded as alloy with excellent corrosion resistant, but its corrosion and electrochemical behaviour requires careful examination. The excellent corrosion of NiTi results from the formation resistance of very stable, continuous adherent and protective oxide film on its surface [5]. As titanium has high affinity for oxygen, TiO2 based oxides form spontaneously by exposing the fresh metal surface to the air or moisture. Various types of metal alloys are being used for the orthodontic treatment, which undergo chemical or electrochemical reaction with the oral environment. The oral environment is highly aggressive under several situations and leads to corrosion. various metals and alloys such as Ti-Co alloy [6], Ti30Ta alloy [7],Ti-6Al-4V alloy [8], Ti-6Al-7Nb alloy [9], Co-Cr alloy [10-14],CP-Ti and Ni-Cr-Ti alloy [15], Co-Cr-Mo alloy[16,17], Ni-Cr alloy [14,18,19], Ti- Cu [20],Ti-20Zr alloy [21], Ti12Mo and Ti60Ta [22], Ni-Ti shape memory alloy and stainless steel wire [23], and Ti-Mo [24] were used for many studies. The present work is undertaken to study the Orthodontic wires of Ni-Cr and Ni-Ti alloys and its corrosion resistance in the absence and presence of ciprofloxacin tablet 500mg in artificial saliva has been evaluated by electrochemical study such as AC impedance Spectra,

2. MATERIALS AND METHODS

Orthodontic wire made of Ni-Cr and Ni-Ti alloys were chosen for present study. The composition of Ni-Cr alloy is Ni(75%), Fe(12%), Cr(11%), Mn(2%). And the composition Ni-Ti alloy is Ni(49.16%) and Ti(49.75%).The metal specimens were immersed in Fusayama Meyer Artificial Saliva (AS) (Kinani, 2007) containing Ciprofloxacin Hydrochloride tablet system, The composition of Artificial Saliva (AS) was KCl (0.4g/l), NaCl (0.4g/l),$CaCl_2.2H_2O$(0.906g/l), $NaH_2PO_4.2H_2O$ (0.690g/l),$Na_2S.9H_2O$ (0.005g/l) Urea(1g/l). The ingredients of Ciprofloxacin Hydrochloride tablet is Ciprofloxacin (500mg), Tinidazole (600mg).

2.1. AC Impedance spectra

The measure of the ability of a circuit to resist the flow of electrical current is known as impedance. By applying an AC potential to an electrochemical cell and then measuring the current through the cell, the electrochemical impedance is usually measured using a small excitation signal. The instrument used for the polarization study was also used to record AC impedance spectra. The cell setup was also the same. The real part (Z') and imaginary part (Z") of the cell impedance were measured in Ohms at various frequencies. Values of the charge transfer resistance (Rt) and double layer capacitance (Cdl) were calculated from the Nyquist plot and the impedance; log (z/Ohm) value was calculated from Bode plots. During AC, impedance

spectra were recorded: the scan rate (V/s) was 0.005; hold time at Ef(s) was zero and quite time (s) was 2. The value of charge transfer resistance (Rt) and double layer capacitance (Cdl) were calculated from Nyquist plot.

3. RESULT AND DISCUSSION

3.1. AC Impedance spectra

AC impedance parameters such as charge transfer resistance (R_t), double layer capacitance (C_{dl}) (derived from Nyquist plots), and impedance value log(z/ohm) (derived from Bode plots) of various metals immersed in artificial saliva and artificial saliva containing Ciprofloxacin Hydrochloride tablet are given in Table 1.Nyquist plots are shown in Figures 1,2 and 5. Bode plots in Figures 3,4,6 and 7.

Table 1: Corrosion parameters of metals immersed in Artificial Saliva (AS) in the absence and presence of Ciprofloxacin Hydrochloride tablet 500 mg obtained by AC impedance Spectra.

Metal	System	Nyquist plot		Bode plot
		R_t ohm cm^2	C_{dl} F/cm^2	Impedance log(z/ohm)
Ni-Cr alloy	Artificial Saliva (AS)	8761.7	$5.82x10^{-10}$	4.102
	Artificial Saliva + Ciprofloxacin Hydrochloride	3795	1.34×10^{-9}	3.236
Ni-Ti alloy	Artificial Saliva (AS)	13547	3.76×10^{-10}	4.397
	Artificial Saliva + Ciprofloxacin Hydrochloride	22805	$2.23x\ 10^{-10}$	4.586

Ni-Cr alloy

The AC impedance spectra of Ni-Cr alloy was immersed in Artificial Saliva (AS), The charge transfer resistance was 8761.7ohm cm^2 (Figure 1) the double layer Capacitance was 5.82 x $10^{-10}F/cm^2$.The impedance value [(log (z/ohm)] was 4.102. In presence of Ciprofloxacin Hydrochloride tablet (Figure 2), R_t value decreased from 8761.7 to 3795 ohm cm^2 and C_{dl} value increased from 5.82 x 10^{-10} to 1.34 x 10^{-9} F/0.00785 cm^2. There was decreased in the value of impedance [(log(z/ohm)] from 4.102 to 3.236 (Figure 3 and 4).These observation indicates that in the presence of Ciprofloxacin Hydrochloride tablet in artificial saliva, the corrosion rate of Ni-Cr alloy was increased, due to the absence of the protective film on the metal surface. Because of the absence of protective film on the metal surface, the electron transfer from the metal surface to the bulk of the solution was not restricted [25]. This results in decrease of charge transfer resistance and increase in double layer capacitance, since they are related to each other inversely. Hence people clipped with orthodontic wire made of Ni-Cr alloy should avoid taking Ciprofloxacin Hydrochloride tablet orally.

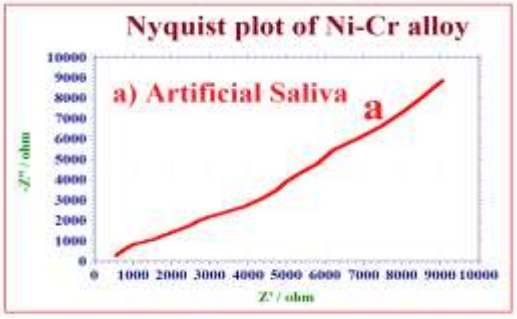

Figure 1

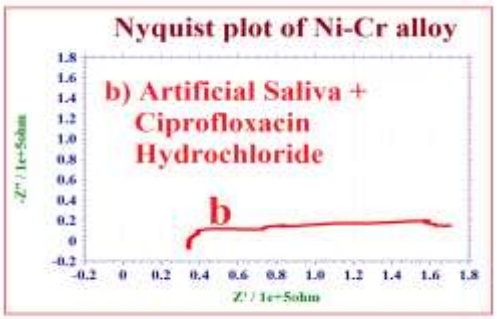

Figure 2

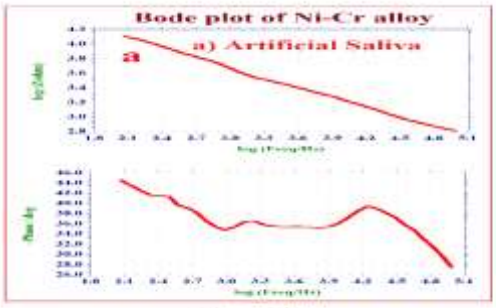

Figure 3

Figure 4

Figure 1. AC impedance spectra (Nyquist plot) of Ni-Cr alloy immersed in various test solutions.
a) Artificial Saliva (AS)

Figure 2. AC impedance spectra (Nyquist plot) of Ni-Cr alloy immersed in various test solutions.
b) Artificial Saliva (AS) + Ciprofloxacin Hydrochloride

Figure 3. AC impedance spectra (Bode plot) of Ni-Cr alloy immersed in various test solutions.
a) Artificial Saliva (AS)

Figure 4. AC impedance spectra (Bode plot) of Ni-Cr alloy immersed in various test solutions.
b) Artificial Saliva (AS) + Ciprofloxacin Hydrochloride

Ni-Ti alloy

The AC impedance spectra of Ni-Ti alloy was immersed in Artificial Saliva, The charge transfer resistance was 13547 ohm cm^2 (Figure 5) the double layer Capacitance was 3.76 x 10^{-10}F/cm^2. The impedance value [(log (z/ohm)] was 4.397. When these values are compared with the values of Ni-Cr alloy, it was observed that Ni-Cr alloy was less corrosion resistant (in artificial saliva) than Ni-Ti alloy. That is the protective film formed on the metal (Ni-Cr) surface was less stable and easily disrupted by the ions present in Artificial Saliva. The AC impedance spectra of Ni-Ti alloy was immersed in Artificial Saliva containing Ciprofloxacin Hydrochloride tablet, the R_t value increased from 13547 to 22805ohm cm^2 and C_{dl} value decreased from 3.76x 10^{-10} to 2.23x 10^{-10} cm^2. There was increased in the value of impedance [(log(z/ohm)] from 4.397 to 4.586 (Figure 6 and 7). It was inferred that a protective film formed on the metal surface in the presence of Ciprofloxacin Hydrochloride tablet. It prevents the corrosion of metal in artificial saliva [26]. It was interesting to note that in the presence of Ciprofloxacin Hydrochloride tablet, the corrosion rate of Ni-Ti alloy in artificial saliva decreased. Hence people clipped with orthodontic wire made of Ni-Ti alloy can take Ciprofloxacin Hydrochloride tablet orally without any hesitation.

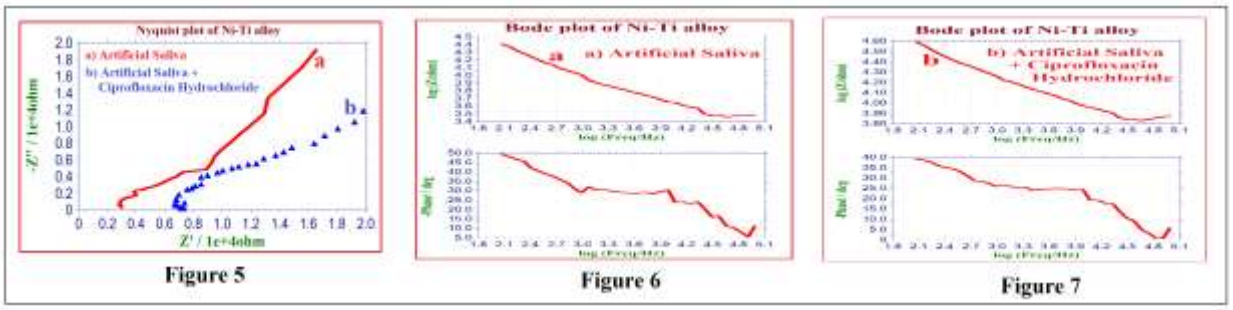

Figure 5 Figure 6 Figure 7

Figure 5. AC impedance spectra (Nyquist plot) of Ni-Ti alloy immersed in various test solutions.
a) Artificial Saliva (AS) b) Artificial Saliva (AS)+ Ciprofloxacin Hydrochloride

Figure 6. AC impedance spectra (Bode plot) of Ni-Ti alloy immersed in various test solutions.
a) Artificial Saliva (AS)

Figure 7. AC impedance spectra (Bode plot) of Ni-Ti alloy immersed in various test solutions.
b) Artificial Saliva (AS) + Ciprofloxacin Hydrochloride

4. CONCLUSION

From the electro chemical study of AC impedance spectra concluded that, In presence of Ciprofloxacin Hydrochloride tablet in Artificial Saliva, the corrosion resistance of Ni-Cr alloy decreases. Hence, it is advised that people clipped with orthodontic wire made of Ni-Cr alloy should avoid taking Ciprofloxacin Hydrochloride tablet (500mg) orally. But in the case of Ni-Ti alloy, in presence of Ciprofloxacin Hydrochloride tablet in Artificial Saliva, the corrosion resistance of Ni-Ti alloy increases. Hence, it is recommended that people clipped with orthodontic wire made of Ni-Ti alloy can take Ciprofloxacin Hydrochloride tablet (500mg) orally without any hesitation. When compared to these two orthodontic wires (Ni-Cr and Ni-Ti) Ni-Ti is the best candidate.So, dentists can recommend this tablet to their patients while they are clipping with orthodontic wire made of Ni-Ti alloy on their teeth.

5. AKNOWLEDGEMENT

The authors are thankful to their respective managements, for their constant help and encouragement and motivation.

6. REFERENCES

[1] A. C. Fraker, “Corrosion of Metallic Implants and Pros-Thesis Devices,” In: ASTM International, Ed., ASTM Metals Handbook, Metals Park, Ohio, Vol. 13, 1987, pp. 1324-1335.

[2] M. F. Leclerc, “Surgical Implants,” In: ASTM Interna-tional, Ed., ASTM Metals Handbook, Metals Park, Ohio, Vol. 02, 1987, pp.164-180.

[3] G. R. Baran, “The Metallurgy of Ni-Cr Alloys for Fixed Pros-Thodontics,” Journal of Prosthetics Dentistry, Vol. 50, No. 5, 1983, pp. 639-650

[4] Paul Crook orrosion resistant nickel alloys Haynes International Inc.Kokomo, Indiana

[5] L. Tan, R.A. Dodd, W.C. Crone, Corrosion and wear-corrosion behaviour of NiTi modified by plasma source ion implementation, Biomaterials 24 (2003) 3931-3939.

[6] I. Mutlu, Synthesis and characterization of Ti-Co alloy foam for biomedical applications, Transactions of Nonferrous Metals Society of China (English Edition), (2016), 26(1): 126-137.

[7] R. Chelariu, D. Mareci, C. Munteanu, C. Crimu, I. Zetu, Electrochemical behavior of experimental Ti30ta alloy in the presence of fluoride and albumin protein, Digest Journal of Nanomaterials and Biostructures, (2014), 9(4): 1349-1358.

[8] E. M. Anwar, L. S. Kheiralla, R. H. Tammam, Effect of fluoride on the corrosion behavior of Ti and ti6al4v dental implants coupled with different superstructures, Journal of Oral Implantology, (2011),37(3): 309-317.

[9] F. Rosalbino, S. Delsante, G. Borzone, G. Scavino, Influence of noble metals alloying additions on the corrosion behavior of titanium in a fluoride-containing environment, Journal of Materials Science: Materials in Medicine, (2012),23(5): 1129-1137.

[10] W. Cheng, H. Yu, X. Lin, T. Ding, P. Ji, The effect of fluoride on dental alloys in different concentrations of fluoride artificial saliva, West China Journal of Stomatology, (2012), 30(1): 18-21.

[11] D. I. Baila, C. V. Doicin, C. M. Cotrut, I. G. Ghionea, C. I. Tarba, Sintering the beaks of the elevator manufactured by direct metal laser sintering (DMLS) process from Co-Cr alloy, Metalurgija (Open Access), (2016),55(4): 663-666.

[12] X. Z. Xin, J. Chen, N. Xiang, Y. Gong, B. Wei, (2014) Surface characteristics and corrosion properties of selective laser melted Co-Cr dental alloy after porcelain firing, Dental Materials, 30(3): 263-270.

[13] F. Alifui-segbaya, P. Foley, R. J. Williams, The corrosive effects of artificial saliva on cast and rapid manufacture-produced cobalt chromium alloys, Rapid Prototyping Journal, (2013), 19(2): 95-99.

[14] Y. Ge, X. He, F. L. Zhang, Z. Y. Chen, X. WangEvaluation on corrosion resistance of dental prosthetic materials Ni-Cr alloy, Co-Cr alloy and pure Ti in Cola, Journal of Jilin University Medicine Edition, , (2013),39(2): 335-338.

[15] B. G. Liang, X. T. Shen, L. Liu, Y. X. Lu, Z. D. Yu, C. X. Yang, Y. Z. Zhang, Effect of pH value and fluoride ions on corrosion resistance of pure Ti and Ni-Cr-Ti alloy in artificial saliva, Journal of Zhejiang University Medical Sciences, (2010), 39(4): 399-403.

[16] S. R. M. De Aguiar, M. Nicoai, M. Almeida, A. Gomes, (2015) Electrochemical behaviour of a cobalt-chromium-molybdenum dental alloy in artificial salivas, Bio-Medical Materials and Engineering, , (2015), 25(1): 53-56.

[17] T. Puskar, D. Jevremovic, R. J. Williams, D. Vukelic, I. Budak, A comparative analysis of the corrosive effect of artificial saliva of variable pH on DMLS and cast Co-Cr-Mo, Dental Alloy Materials (Open Access), (2014), 6(9): 6486-6501.

[18] I. C. Matos, I. N. Bastos, M. G. Diniz, M. S. De Miranda, Corrosion in artificial saliva of a Ni-Cr-based dental alloy joined by TIG welding and conventional brazing, Journal of Prosthetic Dentistry, (2015), 114(2): 278-285.

[19] J. Wan, G. Qiao, The effect of hydrogen peroxide on the electrochemical corrosion properties and metal ions release of nickel-chromium dental alloys, Shanghai Journal of Stomatology, (2013), 22(2): 137-141.

[20] I. Mutlu, Electrochemical corrosion behavior of TiN-coated biomedical Ti-Cu alloy foam in fluoride containing artificial saliva, Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science, (2014), 45(8): 3640-3644.

[21] J. M. Calderon Moreno, M. Popa, S. Ivanescu, E. I. Neacsu, M. V. Popa, Microstructure, mechanical properties, and corrosion resistance of Ti-20Zr alloy in undoped and NaF doped artificial saliva, Metals and Materials International, (2014),20(1): 177-187.

[22] D. Mareci, R. Chelariu, G. Bolat, V. Grancea, D. Sutiman, Electrochemical behavior of Ti alloys containing Mo and Ta as β-stabilizer elements for dental application, Transactions of Nonferrous Metals Society of China (English Edition), (2013), 23(12): 3829-3836.

[23] C. Zhang, X. Sun, X. Hou, H. Li, D. Sun,The corrosion resistance of composite arch wire laser-welded by NiTi shape memory alloy and stainless steel wires with Cu interlayer in artificial saliva with protein, International Journal of Medical Sciences Open Access, ,(2013), 10(8): Indian Journal of Advances in Chemical Science 4(4) (2016) 478-483 482 1068- 1072.

[24] D. Mareci, R. Chelariu, D. M. Gordin, D. Sutiman, T. Gloriant, Effect of Mo content on electrochemical behavior of TiMo alloys for dental applications, Materials and Corrosion, (2010), 61(10): 829-837.