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CORROSION RESISTANCE OF SS18/8 ALLOY, GOLD 18CARAT, GOLD 22 CARAT AND SS316L ALLOY, IN ARTIFICIAL SALIVA IN THE ABSENCE AND PRESENCE OF VITAVION FORT (VITAMIN B COMPLEX) TABLET 500MG

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ABSTRACT
Corrosion resistance of orthodontic wire made of SS18/8 alloy, Gold 18 carat, Gold 22 carat and SS316L alloy in artificial saliva (AS) in the absence and presence of Vitavion Fort tablet 500 mg has been evaluated by electrochemical study such as polarization study. Polarization study leads to the conclusion that corrosion resistance of Gold 18 carat and Gold 22 carat decreases in the order: AS + Vitavion Fort > AS. Hence, people clipped with orthodontic wire made of Gold 18 carat and Gold 22 carat can take Vitavion Fort tablet orally without any hesitation. For SS18/8 alloy and SS316L alloy polarization study leads to the conclusion that corrosion resistance of SS18/8 alloy and SS316L alloy decreases in the order: AS > AS + Vitavion Fort. So, people clipped with an orthodontic wire made of SS18/8, SS316L alloys should avoid taking Vitavion Fort tablet orally.

KEYWORD: Corrosion resistance, polarization study, orthodontic wire, SS18/8 alloy, SS316L alloy, Gold 18 and 22 carat, Vitavion Fort.

1. INTRODUCTON
In the past decades, a variety of wire alloys was introduced into orthodontics, leading to improvement of treatments. The major process of degradation of alloy is corrosion. Orthodontic wires must be biocompatible with oral tissues.[1] Stainless steel is notable for its corrosion resistance and it is widely used for food handling and cutlery among many other applications. Stainless steel does not readily corrode, rust or stain with water as ordinary steel does. However, it is not fully stain-proof in low-oxygen, high-salinity, or poor air-circulation environments.[2] stainless steel used for implants contained ~18wt% Cr and ~8wt% Ni, which made it stronger than steel and more resistant to corrosion. stainless steels contain sufficient chromium to undergo passivation, forming an inert film of chromium oxide on the surface. This layer prevents further corrosion by blocking oxygen diffusion to the steel surface and stops corrosion from spreading into the bulk of the metal.[3] Metallic materials such as Ti, Ti-alloy, Co–Cr alloy and stainless steel–AISI (American Iron and Steel Institute) 316L are used as biomaterials due to their superior tensile and fatigue strength and fracture toughness as compared to nonmetals such as polymeric and ceramic. However, metallic materials – 16 The stability of the surface oxide layer is one of the most important requirements of a biomaterial. For untreated 316L SS, the stability of the surface oxide layer is not very high and the possibility of metal ions being released is greater in comparison to Co-Cr and Ti-6Al-4V alloys.[4] After electrolytic polishing, 316L stainless steel forms a very thin, of a few nanometer, compact oxide film resistant against corrosion in the presence of physiological human body fluids environments.[5] Among the metallic materials, AISI 316L stainless steel is most commonly employed for temporary devices such as fracture plates, bone screws and hip nails due to its low cost and acceptable biocompatibility.[3,6,7] It also has good ductility and possesses good biocompatibility.[7,8] However, it has been often reported to suffer from severe crevice and galvanic corrosion, primarily due to the presence of occluded sites and high chloride concentration in physiological fluids. The corrosion of the stainless steel implant releases metal ions such as Fe, Ni and Cr, which produce local systematic effects and thereby plays a role in prosthetic loosening.[3] In the dental industry, the metallic alloys are mainly used for crown, bridges, prostheses, supra constructions and

implants. They need to fulfill important requirements such as ease and reliability of handling and treatment, toughness appropriate to the situation of application, good biocompatibility and aesthetic properties. These materials are confronted with extreme environmental conditions in the mouth, as the temperature can vary between 5 and 55°C the composition and the pH of the saliva varies depending on the nutrition.[9] The interactions between saliva and these foreign materials can affect the corrosion and tribo corrosion performance of 316L stainless steel prostheses.[10] The original artificial saliva solution was introduced by Takao Fusayama[10], but the chemical composition of artificial saliva has changed in time. In recent years, there has been a significant increase in the number of studies examining the corrosion properties of 316L stainless steel used in medical/dental applications. In some recent studies the corrosion mechanisms of 316L stainless steel in various solutions, including different artificial saliva have been examined.[11-13] The Corrosion resistance of 18 carat gold in artificial saliva in presence of D-Glucose have been investigated by Saranya et al.[14] Corrosion resistance of SS316L Alloy in artificial saliva in presence of a Sparkle Toothpaste, have been investigated by Renita Souza et al.[15] Electrochemical Corrosion Behaviour of Dental/ Implant Alloys in Artificial Saliva have been investigated by Mohit Sharma et.al.[16] Corrosion Behavior of Metals in Artificial Saliva in Presence of Spirulina Powder and electrol have been investigated by S.Rajendran et.al.[17,18] Corrosion behaviour of 18 carat gold with artificial saliva in presence of brufen 400mg tablet and ciprofloxacin Hydrochloride IP have been investigated by Mohamed Kasim Sheit et.a.[19,20] corrosion resistance of super elastic Ni-Ti alloy in artificial saliva, in the absence and presence of Almox 250mg has been evaluated by Rajendran et. Al. [21] Inhibition evaluation of mango juice extracts, cashew juice extract, fruit peel aqueous extracts, Carica papaya extracts, Garlic and Ginger extract on the corrosion of mild steel in HCl have been evaluated by Loto, Rocha, Okaufor, Priya, Bouyanzen and Singh et al.[22-28] The present work is undertaken to study the Corrosion resistance of SS18/8 alloy, SS316L alloy, Gold 18carat and Gold 22 carat in artificial saliva in the absence and presence of vitavion Fort tablet 500mg. By a polarization study, corrosion parameters such as Corrosion potential $E_{(Corr)}$, Linear polarization Resistance(LPR), Corrosion current(I_{Corr}) and Tafel slopes (anodic= b_a and cathodic= b_c) were calculated.

2. MATERIALS AND METHODS

Orthodontic wire made of Stainless Steel18/8 (SS18/8),Gold18carat, Gold 22carat, and Stainless Steel 316L(SS316L) were chosen for present study. The composition of SS18/8, Gold 18 carat, Gold 22 carat and SS316L are given below the tables 1&2.

Table 1: Composition of SS316L and SS18/8 alloys.

Composition of SS316L alloy		Composition of SS18/8 alloy
Carbon	0.3%	.08%
Manganese	2%	2%
Chromium	16-8%	18-20%
Molybdenum	2-3	-
Nickel	10-14%	8-10.5%
Iron	Bal	Bal
Silicon	1%	1%
Phosphorous	.045%	.045%
Sulfur	.03%	.03%
others	-	

Table 2: Composition of Gold 22 carat and Gold18 carat.

Metals	Gold 22carat	Gold 18carat
Gold	91.6%	75%
Silver	5%	10-205
Copper	2%	5-15%
Zinc	1.33%	----

The metal specimens were immersed in Fusayama Meyer artificial saliva (AS) (Kinani, 2007) containing Ecosprin 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).

2.1 Polarization Study

Polarization Studies were carried out in a CHI-Electrochemical work station with impedance. A three electrode cell assemblies were used. The working electrode was one of the four metal alloys. A saturated Calomel electrode [SCE] was the reference electrode and platinum electrode was the counter electrode. From the polarization study corrosion parameters such as Corrosion Potential(E_{Corr}), Linear polarization Resistance (LPR), Corrosion Current(I_{Corr}) and Tafel slopes (anodic= ba and cathodic= bc) were calculated.

3. RESULTS AND DISCUSSION

3.1 Analysis of Potentiodynamic polarization curves

Corrosion resistance of SS18/8 alloy, Gold18carat, Gold 22 carat and SS316L alloy immersed in various test solutions are given in Table 3. The potentiodynamic polarization curves are shown in Figure1-4. When corrosion resistance increases Linear Polarization Resistance (LPR) increases; Corrosion current (I_{corr}) decreases.

Table 3: Corrosion parameters of metals immersed in Artificial Saliva(AS) in the absence and presence of Vitavion Fort tablets, obtained by polarization study.

Metal	System	E_{crro} mVvs SCE	b_c mV/ decade	b_a mV/decade	LPR Ohmcm^2	I_{corr} A/ cm^2
SS18/8	AS	-501	0.182	0.245	1604576.8	$2.834X10^{-8}$
	AS+ Vitavion Fort	-671	0.163	0.244	925696.8	$4.601 X10^{-8}$
Gold 18 carat	AS	-113	0.160	0.215	2118899	$1.889X10^{-8}$
	AS+ Vitavion Fort	-113	0.152	0.164	3499522.8	$9.824 X10^{-9}$
Gold 22 carat	AS	-057	0.103	0.287	5935387	$5.594X10^{-9}$
	AS+ Vitavion Fort	-098	0.101	0.236	7449597	$4.337 X10^{-9}$
SS316L	AS	-472	0.159	0.301	1010745.6	$4.490X10^{-8}$
	AS+ Vitavion Fort	-501	0.186	0.251	976036.2	$4.771 X10^{-8}$

3.1.1 SS18/8 alloy

The polarization curve of SS18/8 alloy immersed in various test solutions are shown in figure 1. The corrosion parameters namely Corrosion Potential(Ec orr), Tafel slopes (b_c= cathodic; b_a=anodic) Linear Polarization Resistance (LPR) and Corrosion current(I_{corr}) are given in table 3. It is observed from Table 3 that, when SS18/8 immersed in Artificial Saliva (AS), Linear Polarization Resistance (LPR) value is 1604576.8 ohmcm^2. The Corrosion current (I_{corr}) is $2.834X10^{-8}$A/ cm^2. The Corrosion Potential (E_{corr}) is -501mV vs SCE.

When SS18/8 immersed in AS in presence of Vitavion Fort tablet system, Linear Polarization Resistance (LPR) value decreases from 1604576.8 to 925696.8 ohm cm^2. The Corrosion current (I_{corr}) increases from $2.834X10^{-8}$ to $4.601X10^{-8}$ A/ cm^2. These values indicate that the corrosion resistance of SS18/8 alloy is less in AS containing Vitavion Fort tablet system than in AS alone. Further the Corrosion Potential (E_{corr}) value shifts from -501 to -671mV vs SCE. This value indicates that, there is no effective protective film formed on the metal surface. Due to this, oxygen diffused to the steel surface and undergo further corrosion from spreading into the bulk of the metal.[29] Hence corrosion resistance of SS18/8 alloy is less in AS containing Vitavion Fort tablet system than AS (in absence of Vitavion Fort tablet) alone. Thus the polarization study leads to the conclusion that when SS18/8 alloy is immersed in various test solutions, the decreasing order of corrosion resistance is as follows:

AS > AS + Vitavion Fort

This study reveals that people should not prefer to take Vitavion Fort tablet orally while clipping with an orthodontic wire made of SS18/8 alloy. Because its corrosion resistance is very less than AS containing Vitavion Fort tablet system.

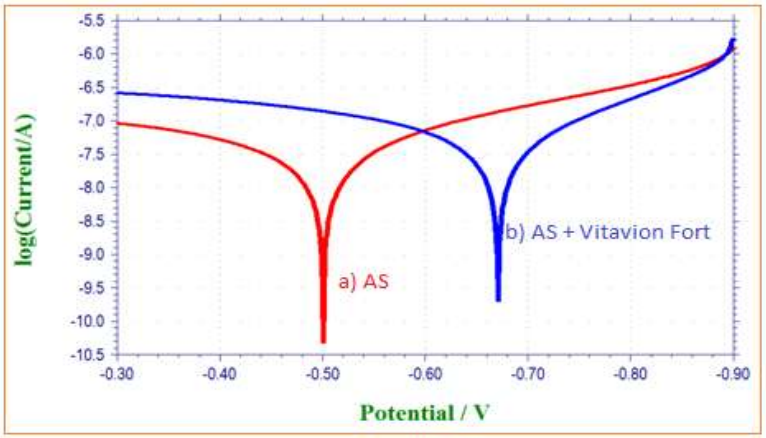

Figure 1: Polarization curves of SS18/8 alloy immersed in various test solutions.
a) AS b) AS + vitavion Fort

3.1.2 Gold 18 carat

The polarization curve of Gold 18 carat immersed in Artificial Saliva (AS) system are shown in Figure 2. Linear Polarization Resistance (LPR) value is 2118899ohm cm^2. The Corrosion current (I_{corr}) value is $1.889X10^{-8}$A/ cm^2. The Corrosion Potential(E_{corr}) is -113mV vs SCE.

The polarization curve of Gold 18 carat immersed in AS in presence of Vitavion Fort tablet system is shown in Figure 2. Linear Polarization Resistance (LPR) value increases from 2118899 to 3499522.8 ohm cm^2. The

Corrosion current (I_{corr}) decreases from $1.889X10^{-8}$ to $9.824X10^{-9}$ A/ cm^2. These values suggest that gold 18 carat is more corrosion resistant in AS containing Vitavion Fort tablet system than in AS alone. Further there is no any change in the Corrosion Potential (E_{corr}) value from -113mV vs SCE. These values suggest that an effective protective film formed on the metal surface, which controlled the rate of corrosion of the metal alloy in AS containing Vitavion Fort tablet system. Thus the polarization study leads to the conclusion that when Gold18 carat is immersed in various test solutions, the decreasing order of corrosion resistance of Gold18 carat is as follows:

AS + Vitavion Fort > AS

This study reveals that people clipped with an orthodontic wires made of Gold18 carat can take Vitavion Fort tablet orally without any hesitation. Because in this medium (AS + Vitavion Fort system) the corrosion resistance of Gold18 carat is high.

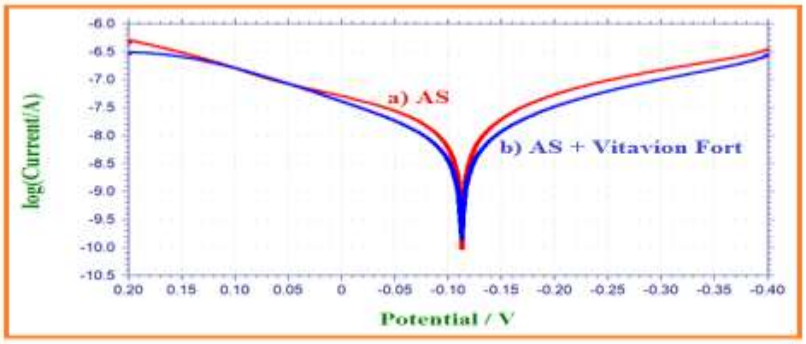

Figure 2: Polarization curves of Gold18 carat immersed in various test solutions.
a) AS b) AS + vitavion Fort

3.1.3 Gold 22 carat

The polarization curve of Gold 22 carat immersed in Artificial Saliva (AS) is shown in Figure 3. Linear Polarization Resistance (LPR) value is 5935387ohm cm^2. The Corrosion current(I_{corr}) $5.594X10^{-9}$A/ cm2. The Corrosion Potential (E_{corr}) is -057mV vs SCE.

The polarization curve of Gold 22 carat immersed in AS in the presence of Vitavion Fort tablet is shown in Figure 3. The Linear Polarization Resistance (LPR) values increases from 5935387 to 7449597 ohmcm^2. The Corrosion current (I_{corr}) decreases from $5.594X10^{-9}$ to $4.337\ X10^{-9}$A/ cm^2. These values suggest that Gold 22 carat is more corrosion resistant in AS in the presence of Vitavion Fort tablet than in the absence of Vitavion Fort tablet in AS. The Corrosion Potential (E_{corr}) value shifts from -057mV vs SCE to -098 mV vs SCE. A protective film is formed on the metal surface. Due to the formation of the protective film, corrosion resistance of Gold 22 carat increases in AS presence of Vitavion Fort tablet. Thus the polarization study leads to the conclusion that when Gold 22 carat is immersed in various test solutions, the decreasing order of corrosion resistance of Gold22 carat is as follows:

AS + Vitavion Fort > AS

This study reveals that the people clipped with an orthodontic wires made of Gold 22 carat can take Vitavion Fort tablet orally without any fear. Because in this medium (AS + Vitavion Fort) the corrosion resistance of Gold 22 carat is increases.

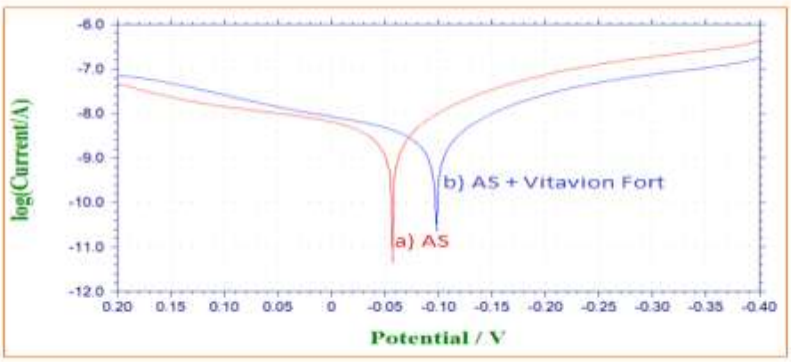

Figure 3: Polarization curves of Gold 22 carat immersed in various test solutions.

a) AS b) AS + vitavion Fort

3.1.4 SS316L alloy

The polarization curve of SS316L immersed in Artificial Saliva (AS) is shown in Figure 4. Linear Polarization Resistance (LPR) value is 1010745.6 ohm cm^2. The Corrosion current (I_{corr}) is 4.490 $X10^{-8}A/cm^2$. The Corrosion Potential (E_{corr}) is -472 mV vs SCE.

The polarization curve of SS316L immersed in AS containing Vitavion Fort tablet is shown in Figure 4. It is interesting to note that the Linear Polarization Resistance (LPR) value decreases from 1010745.6 to 976036.2ohm cm^2. The Corrosion current (I_{corr}) increases from $4.490X10^{-8}$ to 4.771 $X10^{-8}$ A/ cm^2. This indicates that SS316L is less corrosion resistant in the presence of Vitavion Fort tablet in AS than in AS alone. Further the Corrosion Potential (E_{corr}) value shifts from -472 mV vs SCE to -501mV vs SCE. This is due to, there is no effective protective film formed on the metal surface. Due to this, oxygen diffused to the steel surface and undergo further corrosion from spreading into the bulk of the metal.[29] Hence, the corrosion resistance of SS316L decreases in the presence of Vitavion Fort tablet in AS than in AS alone. Thus the polarization study leads to the conclusion that when SS316L alloy is immersed in various test solutions, the decreasing order of corrosion resistance of SS316L alloy is as follows:

AS > AS + Vitavion Fort

This study suggests that the people clipped with an orthodontic wire made of SS316L alloy, cannot take Vitavion Fort tablet orally. Because, in this medium (AS + Vitavion Fort) the corrosion resistance of SS316L alloy is decreases.

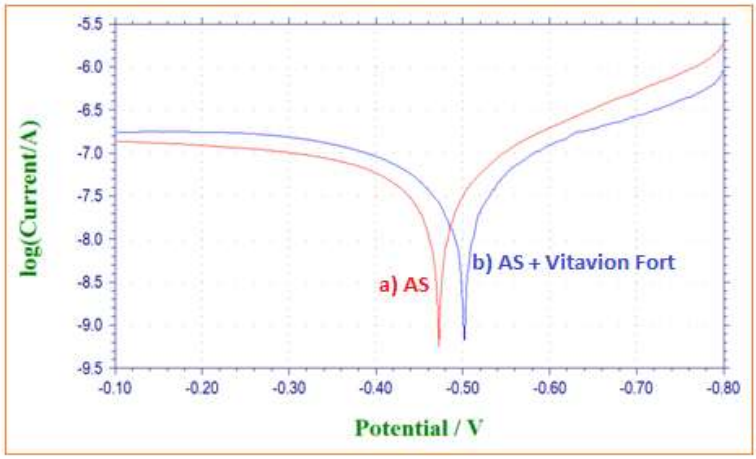

Figure 4: Polarization curves of SS316L alloy immersed in various test solutions.
a) AS b) AS + vitavion Fort

4. The corrosion resistance of metals and alloys in AS system and also in AS + Vitavion Fort tablet system are compared in Figures 5 and 6.

Corrosion parameters of metals immersed in Artificial Saliva(AS) in the absence and presence of Vitavion Fort tablets, obtained by polarization study

Metal	System	E_{corr} mV vs SCE	b_cmV/ decade	b_amV/decade	LPR Ohmcm^2	I_{corr}A/ cm^2
SS18/8	AS	-501	0.182	0.245	1604576.8	$2.834X10^{-8}$
	AS+ Vitavion Fort	-671	0.163	0.244	925696.8	$4.601 X10^{-8}$
Gold 18 carat	AS	-113	0.160	0.215	2118899	$1.889X10^{-8}$
	AS+ Vitavion Fort	-113	0.152	0.164	3499522.8	$9.824 X10^{-9}$
Gold 22 carat	AS	-057	0.103	0.287	5935387	$5.594X10^{-9}$
	AS+ Vitavion Fort	-098	0.101	0.236	7449597	$4.337 X10^{-9}$
SS316L	AS	-472	0.159	0.301	1010745.6	$4.490X10^{-8}$
	AS+ Vitavion Fort	-501	0.186	0.251	976036.2	$4.771 X10^{-8}$

Table 4: LPR Values of AS + Vitavion Fort tablet.

Alloys	LPR, Ohmcm^2
SS18/8	925696.8
Gold 18 carat	3499522.8
Gold 22 carat	7449597
SS316L	976036.2

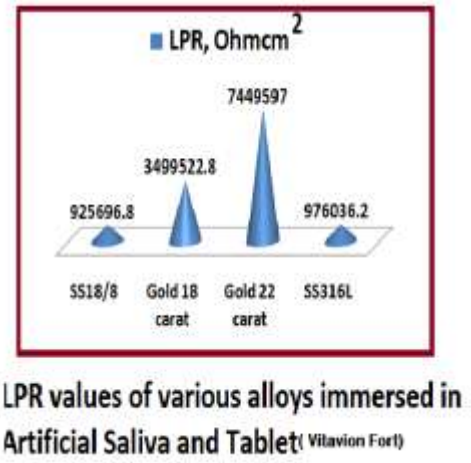

Figure 5: LPR values of various alloys immersed in Artificial Saliva and Vitavion Fort table.

Table 5: LPR Values of AS only.

Alloys	LPR, Ohmcm^2
SS18/8	1604576.8
Gold 18 carat	2118899
Gold 22 carat	5935387
SS316L	1010745.6

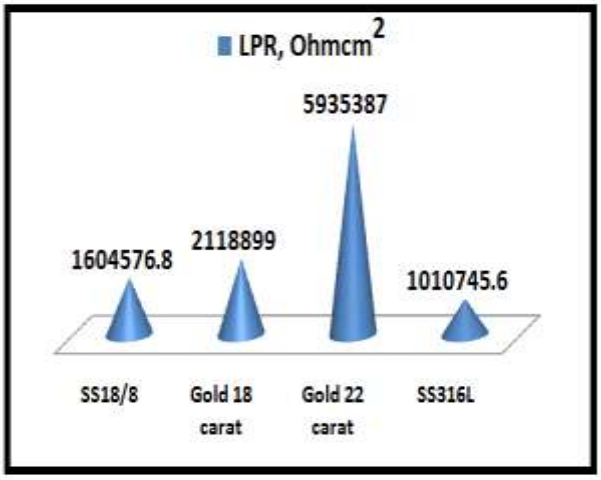

Figure 6: LPR values of various alloys immersed in Artificial Saliva (AS).

5. CONCLUSION

Corrosion resistance of orthodontic wire made of SS18/8 alloy, Gold 18 carat and Gold 22 carat and SS316L alloy in artificial saliva (AS) in the absence and presence of Vitavion Fort tablet 500 mg has been evaluated by electrochemical study such as polarization study. This study leads to the following conclusions.

SS18/8 alloy system

- For SS18/8 alloy, the polarization study leads to the conclusion that when SS18/8 alloy is immersed in various test solutions, the decreasing order of corrosion resistance is as follows:

AS >AS + Vitavion Fort

- This study reveals that people should not take Vitavion Fort tablet orally while clipping with an orthodontic wires made of SS18/8 alloy. Because its corrosion resistant is very less in this medium of AS + Vitavion Fort system.

Gold 18 carat system

- For Gold 18 carat, the polarization study leads to the conclusion that when Gold18 carat is immersed in various test solutions, the decreasing order of corrosion resistance of Gold18 carat is as follows:

AS + Vitavion Fort >AS

- This study reveals that people can take Vitavion Fort tablet orally while clipping with an orthodontic wires made of Gold18 carat. Because in this medium (AS + Vitavion Fort system) the corrosion resistance of Gold18 carat increases.

Gold 22 carat system

- For Gold 22 carat, the polarization study leads to the conclusion that when Gold 22 carat is immersed in various test solutions, the decreasing order of corrosion resistance of Gold22 carat is as follows:

AS + Vitavion Fort >AS

- This study reveals that people can take Vitavion Fort tablet orally without any hesitation while clipping with an orthodontic wires made of Gold 22 carat. Because in this medium of AS + Vitavion Fort tablet system the corrosion resistance of Gold 22 carat increases.

SS316L alloy system

- For SS316L alloy, the polarization study leads to the conclusion that when SS316L alloy is immersed in various test solutions, the decreasing order of corrosion resistance of SS316L alloy is as follows:

AS > AS + Vitavion Fort

- This study suggests that the people clipped with an orthodontic wires made of SS316L alloy, should not take Vitavion Fort tablet orally. Because, in this medium (AS + Vitavion Fort) the corrosion resistance of SS316L alloy decreases.
- This study further suggests that in AS system, among the four orthodontic wires, Gold 22 carat is the most preferable orthodontic wire while taking Vitavion Fort tablet orally. Because its corrosion resistance is higher than that of other three orthodontic wires.
- In AS containing Vitavion Fort tablet system, the polarization study leads to the conclusion that among the four orthodontic wires, Gold 22 carat is also the most preferable orthodontic wire while taking Vitavion Fort tablet orally. Because its corrosion resistance is higher than that of other three orthodontic wires.

- Hence the polarization study leads to the conclusion that the decreasing order of corrosion resistance of these four orthodontic wire in AS containing Vitavion Fort tablet system is as follows:
  Gold 22 carat > Gold 18 carat > SS316L > SS18/8.

5.1 Further, the study reveals the following facts
In AS system

- Gold 18 carat is more corrosion resistant than SS18/8 alloy.
- Gold 22 carat is more corrosion resistant than Gold 18 carat.
- Gold 22carat is more corrosion resistant than SS316L alloy.
- SS18/8alloy is more corrosion resistant than SS316Lalloy.
- Gold 18 carat is more corrosion resistant than SS316Lalloy.
- Gold 22 carat is more corrosion resistant than SS18/8alloy.

In AS containing Vitavion Fort tablet system

- Gold 18 carat is more corrosion resistant than SS18/8 alloy.
- Gold 22 carat is more corrosion resistant than Gold 18 carat.
- Gold 22 carat is more corrosion resistant than SS316 Lalloy.
- SS18/8alloy is more corrosion resistant than SS316L.
- Gold 18 carat is more corrosion resistant than SS316L alloy.
- Gold 22 carat is more corrosion resistant than SS18/8 alloy.

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