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Thermo Active Ni-Ti Super Elastic Shape Memory Alloy *vs.* 22 K Gold Alloy which is More Corrosion Resistant in Artificial Saliva in Presence of Jamun (*Naaval pazham* or *Syzygium cumini*) Fruit Juice?

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ABSTRACT

Orthodontic wire of many alloys and metals are used by dentists. These wires may undergo corrosion in the oral environment and in presence of food items we take orally. The corrosion resistance of thermo active Ni-Ti Super elastic shape memory alloy vs. 22 K Gold alloy in Artificial Saliva (AS) in presence of Jamun (Naaval pazham or Syzygium cumini) Fruit Extract (FE) has been evaluated by Polarisation study. When corrosion resistance increases linear polarization resistance value increases and corrosion current decreases. It is observed that for thermoactive alloy, the LPR value decreases in the following order: AS>AS+FE (10 ml)>AS+FE (20 ml)>FE. For 22 K Gold system, the LPR value decreases in the following order: AS+FE (20 ml)>FE>AS+FE (10 ml)>AS. In Artificial Saliva Thermoactive alloy is more corrosion resistant than 22 K Gold. In FE 22 K Gold is more corrosion resistant than Thermoactive alloy. In AS+FE (10 ml) 22 K Gold is more corrosion resistant than thermoactive alloy. In AS+FE (20 ml) 22 K Gold is more corrosion resistant than thermoactive alloy.

Keywords: 22 K gold alloy, Borrosion resistance, *Syzygium cumini*, Polarization study

INTRODUCTION

Orthodontic wires made of several metals alloys are used by dentists to regulate the growth of teeth. Many types of implants are also introduced in the oral environment, which mainly consists of saliva. It has been observed that these materials may undergo corrosion in the oral environment, which mainly consists of saliva [1-20]. When food items and fruit juices are orally in taken, they will also corrode the implants. Kang et al., have investigated the fretting wear behaviour of various arch wire-bracket contacts [1]. Orthodontic wires such as Ni-Ti, stainless steel [2,3], nickel titanium nitride [4,5], SS 316 L [6], titanium [7,9], Ni-Co based alloys [8], commercial metals (CrNi, NiTi and CuNiTi wires) [10], multi-layered Ti/TiN [11], silver binary alloy [12], dental amalgam [13,14], titanium and titanium alloy [15] and metallic biomaterials (CrNi, NiTi and CuNiTi) [10] and mild steel coated with zinc have been used in the presence of saliva. The corrosion resistances of orthodontic wires have been investigated in artificial saliva in presence of various additives such as a Tablet Ciprofloxacin Hydrochloride IP [6], citric acid [7], eugenol [9], iodine glycerine [16], copper ion and aroma compounds [17], Spirulina [18], D-Glucose [19] and electoral [20]. The present work is under taken to investigate the corrosion resistance of thermo active Ni-Ti Super elastic shape memory alloy and 22 K Gold alloy in artificial saliva in presence of an aqueous extract of Jamun (*Naval pazham* or *Syzygium cumini*) fruit juice, by polarization study.

MATERIALS AND METHODS

Preparation of artificial saliva solution

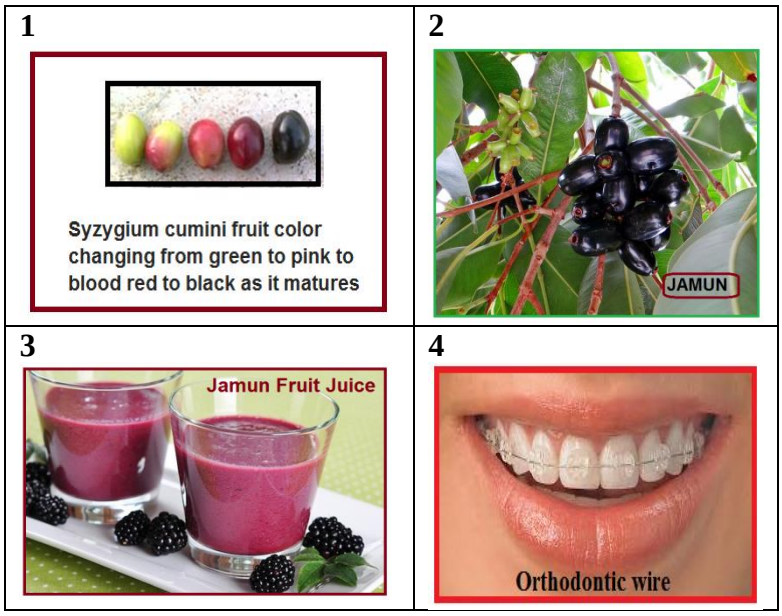
Composition of artificial saliva is given in Table 1.

Table 1: Composition of artificial saliva

Chemical	Amount (g/l)
KCl	0.4
NaCl	0.4
$CaCl_2.2H_2O$	0.906
$NaH_2PO_4.2H_2O$	0.690
$Na_2S.9H_2O$	0.005
Urea	1

Preparation of *Syzygium cumini* extract

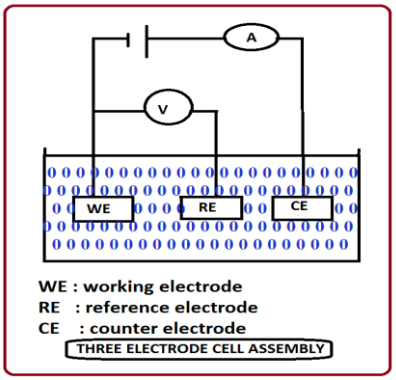
It has been found that *Syzygium cumini* (Schemes 1-3) has cardiometabolic properties which have been attributed to a limited amount of phytochemicals, particularly flavonoids, phenolic acids and tannins. An aqueous extract of *S. cumini* (naval fruit) was prepared by adding 10 g of *S. cumini*, with distilled water and boiled the water for 15 min filtering the suspending impurities and making up to 100 ml. The extract was used as corrosion inhibitor in the present study, to evaluate the corrosion resistance of orthodontic wires (Scheme 1).



Scheme 1: (1) *Syzygium cumini* (naval fruit), (2) In the tree, (3) Fruit juice, (4) Orthodontic wire

Potentiodynamic polarization study

Potentiostatic polarization studies were carried out using a CHI electrochemical impedance analyzer, model 660 A. A three-electrode cell assembly was used (Scheme 2). The working electrode was thermo active Ni-Ti super elastic shape memory alloy/22 K Gold alloy. A Saturated Calomel Electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode. Polarization curves were recorded using iR compensation. Corrosion parameters such as Tafel slopes and $I_{corr,}$ E_{corr} and LPR values were calculated. During the polarization study, the scan rate (v/s) was 0.01; hold time at Ef(s) was zero and quit time(s) was 2.



Scheme 2: Three electrode cell assembly

RESULTS AND DISCUSSION

Polarisation study

Polarisation study has been used to derive corrosion parameters such as Corrosion Potential (E_{corr}), Tafel slopes (b_c and b_a), Linear Polarisation Resistance value (LPR) and Corrosion Current (I_{corr}). When corrosion resistance of a metal in a medium increases, LPR value increases but corrosion current value decreases [21-28]. This is due to the formation of a protective film on the metal surface which prevents the electron transfer from the metal to the medium. Since the loss of electrons is prevented, the anodic reaction of metal dissolution is prevented. Hence the current density also decreases so corrosion resistance of the metal increases.

Polarisaion study of thermo active Ni-Ti super elastic shape memory alloy system

Corrosion parameters of Thermo active Ni-Ti Super elastic shape memory alloy immersed in Artificial Saliva (AS) in the absence and presence of Fruit Extract (FE), obtained from polarization study are given in Table 2. A careful analysis of the various parameters reveals that when thermo active Ni-Ti super elastic shape memory alloy is immersed in AS, the corrosion potential is -456 mV vs SCE. The LPR value is 12899312 ohm/cm^2. The corrosion current is 4.471 × 10^{-9} A/cm^2. When the alloy is immersed in FE the corrosion resistance of the alloy decreases. This is revealed by the fact that the LPR value decreases from 12899312-2975480 ohm/cm^2 and the corrosion current increases from 4.471 × 10^{-9}-11.55 × 10^{-9} A/cm^2 (Figures 1 and 2).

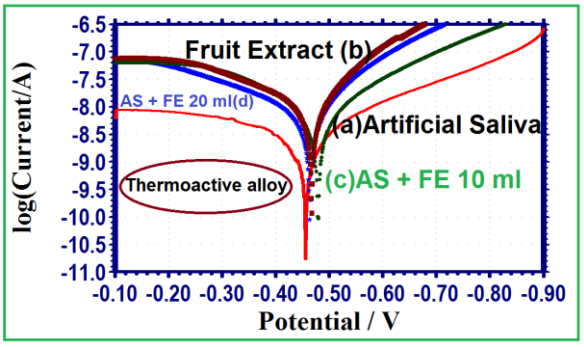


Figure 1: Polarisation curves of thermo active Ni-Ti super elastic shape memory alloy immersed in various test solutions (a) Artificial saliva, (b) Fruit extract, (c) AS+FE (10 ml), (d) AS+FE (20 ml)

Table 2: Corrosion parameters of thermo active Ni-Ti super elastic shape memory alloy immersed in artificial saliva in the absence and presence of fruit extract, obtained from polarization study

System	E_{corr} mV vs SCE	b_c mV/decade	b_a mV/decade	LPR Ohm/cm^2	I_{corr} A/cm^2
Artificial saliva	-456	205	374	12899312	4.471 × 10^{-9}
Fruit extract	-468	115	251	2975480	11.55 × 10^{-9}
AS+FE 10 ml	-480	162	175	5218368	7.032 × 10^{-9}
AS+FE 20 ml	-463	124	262	4280591	8.569 × 10^{-9}

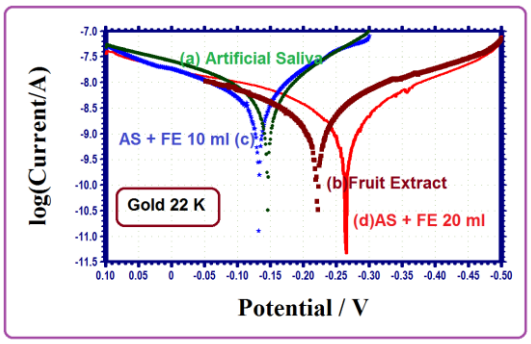


Figure 2: Polarisation curves of Gold 22 K immersed in various test solutions (a) Artificial saliva, (b) Fruit extract, (c) AS+FE (10 ml), (d) AS+FE (20 ml)

When 10 ml of fruit extract is added to artificial saliva, the corrosion resistance of the alloy increases. This is revealed by the fact that the LPR value increases from 4880930-5302673 ohm/cm^2 and the corrosion current decreases from 6.898 × 10^{-9}-7.569 × 10^{-9}A/cm^2. When, 20 ml of FE is added to AS, the corrosion resistance of the alloy decreases. This is revealed by the fact that the LPR value increases from 4880930-17408728 ohm/cm^2 and the corrosion current decreases from 6.898 × 10^{-9}-2.182 × 10^{-9}A/cm^2 (Table 3).

Table 3: Corrosion parameters of 22 K Gold alloy immersed in artificial saliva in the absence and presence of fruit extract, obtained from polarization study

System	E_{corr} mV vs SCE	b_c mV/decade	b_a mV/decade	LPR Ohm/cm^2	I_{corr} A/cm^2
Artificial saliva	-146	123	209	4880930	6.898×10^{-9}
Fruit extract	-222	167	253	14335705	3.045×10^{-9}
AS+FE 10 ml	-132	141	269	5302673	7.569×10^{-9}
AS+FE 20 ml	-265	157	198	17408728	2.182×10^{-9}

Polarization study leads to the following conclusions

- 22 K Gold alloy is more corrosion resistant in fruit extract than in AS.
- Corrosion resistance of 22 K Gold alloy increases in presence of AS+FE.

Implication

People implanted with orthodontic wires made of 22 K Gold alloy need not hesitate to take this fruit juice orally.

Comparison of LPR values of the two systems

- The LPR values of thermoactive alloy and 22 K Gold in various systems are compared in Figures 3-5.
- For thermoactive alloy, the LPR value decreases in the following order:

AS>AS+FE (10 ml)>AS+FE (20 ml)>FE

- For 22 K Gold system, the LPR value decreases in the following order:

AS+FE (20 ml)>FE>AS+FE (10 ml)>AS

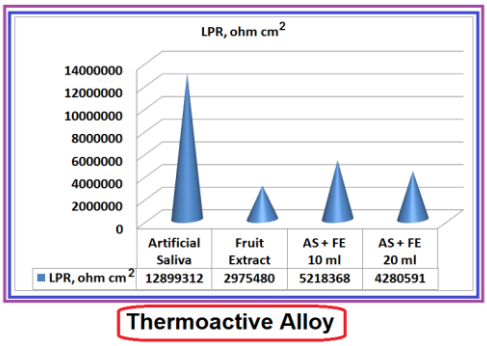


Figure 3: LPR values of thermoactive alloy in various systems

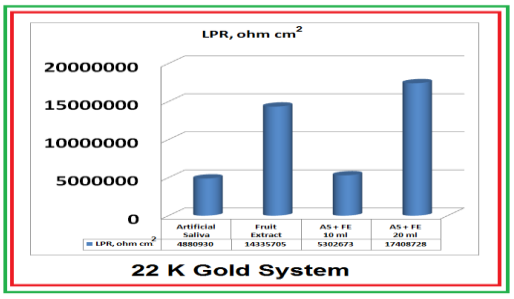


Figure 4: LPR values of 22 K Gold in various systems

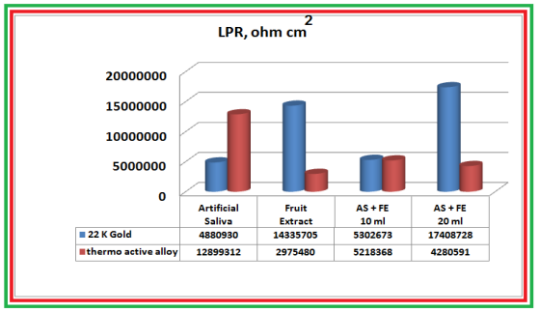


Figure 5: LPR values of thermoactive alloy and 22 K Gold in various systems

Comparison of corrosion resistance of two alloys in various systems

It is seen from Figure 5 that:

- In AS thermoactive alloy is more corrosion resistant than 22 K Gold.
- In FE 22 K Gold is more corrosion resistant than thermoactive alloy.
- In AS+FE (10 ml), 22 K Gold is more corrosion resistant than thermoactive alloy.
- In AS+FE (20 ml), 22 K Gold is more corrosion resistant than thermoactive alloy.

CONCLUSIONS

- The corrosion resistance of thermo active Ni-Ti super elastic shape memory alloy vs 22 K Gold alloy in AS in presence of Jamun (*N. pazham* or *S. cumini*) FE has been evaluated by polarisation study.
- It is observed that for thermoactive alloy, the LPR value decreases in the following order:
- AS>AS+FE (10 ml)>AS+FE (20 ml)>FE.
- For 22 K Gold system, the LPR value decreases in the following order:
- AS+FE (20 ml)>FE>AS+FE (10 ml)>AS.
- In AS thermoactive alloy is more corrosion resistant than 22 K Gold.
- In FE 22 K Gold is more corrosion resistant than thermoactive alloy.
- In AS+FE (10 ml) 22 K Gold is more corrosion resistant than thermoactive alloy.
- In AS+FE (20 ml) 22 K Gold is more corrosion resistant than thermoactive alloy.

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