

Influence of Temperature and pH on Corrosion Resistance of Ni-Cr and Co-Cr Dental Alloys on Oral Environment

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Abstract

The aim: The study was to evaluate the influence of temperature and pH on corrosion resistance of Ni-Cr and Co-Cr dental alloys, in order to characterize the physical and mechanical properties of corrosion resistance property of the Ni-Cr and Co-Cr and investigate the correlations between corrosion and biocompatibility of dental alloys and to interpret the results by comparison with ion concentrations found in necessary food.

Methods: In this work, the corrosion behavior of three different dental alloys, namely PD CASTA H, CERACAST NB Beryllium Free, and PD 2000 alloys were tested in Ringer's solution, artificial saliva at different pH values and temperature. The dental alloys were immersed in the Ringer's solution for 14 days. The surface analysis was by scanning electron microscopy (SEM) and Energy dispersive spectrometry (EDS). The electrochemical characteristics of individual metal components was also investigated using cyclic voltammetry methods.

Results: On the basis of the results obtained it has been shown that the corrosion behavior of PD CASTA H and PD 2000 alloys, which contain Co and a high Cr content, shows the best corrosion resistance compared with that of CERACAST NB alloy in Ringer's solution artificial saliva. And the influence in temperature, acidity and alkalinity of solution effects on the properties of dental alloys in the oral cavity.

Conclusions and recommendations for further work: On the basis of the results obtained, our advice would be to recommend to avoid an increase in the oral temperature and avoid the taking of acid food which are probably to lower the pH of the oral cavity and increase the corrosion of the alloys when the removable or fixed partial dentures treatment.

Keywords: Artificial saliva, Biocompatibility, Chromium-cobalt alloys, Corrosion, Cyclic voltammetry, Electrochemical measurement, Nickel-chromium alloys, Organic acids, pH, Resistance, Scanning electron microscopy, Temperature

Introduction

Dental alloys are widely used in dentistry, especially in contact with oral tissues for many years. It is of paramount importance to understand and get familiar with biocompatibility of alloys for their long term success in rendering successful treatment for the patients. One of the most relevant properties of a casting alloy to its biologic safety is its corrosion resistance [1]. A biomaterial can be defined as a material which is used to restore or replace function to a body tissue and is continuously and intermittently in contact with body fluids [2].

The three main classes of biomaterials include metals, polymers and ceramics. Along with these, biomaterials are also composed of certain natural materials like collagen and they also play a significant role in the multidisciplinary field of tissue engineering [3,4]. The choice of an alloy is based on several factors. Cost is a serious consideration due to the high price of gold. These factors in particular limit the use of alloys for dental prostheses, and the choice of a specific application is primarily determined by their mechanical properties, such as hardness, mechanical strength and ductility [5]. The choice of a prosthetic laboratory and technician by the dental practitioner is important for the casting quality. In 1972 the American Dental Association [6], proposed a program for acceptance of Metal Alloys, aiming at evaluating all metal alloys for cast restorations, including those not included in its specifications, all alternative alloys to the gold-based alloys and those which apart from their composition, demonstrated biological compatibility and adequate physical, chemical and mechanical properties [7].

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High noble alloys have successful clinical use but as the price of gold increased, alternative cheaper based alloys (Ni-Cr, Co-Cr) were developed [8]. Alloys such as (Ni-Cr, Co-Cr) have been used in the fabrication of removable and fixed partial dentures for their excellent mechanical properties corrosion resistance. In dentistry, the most important factors affecting the choice of dental alloys are biocompatibility, mechanical properties and resistance to tarnish and corrosion [9]. When selecting a dental casting alloy for a clinical situation, the first decision will be the physical properties of the alloys, biocompatibility, and good mechanical properties, such as high hardness, strength, resistance to tarnish and high temperature and also resistance to corrosion. The humid, warm oral cavity offers ideal conditions for corrosion of the metal surface and its dissolving. Foods and drinks are usually very acid or alkaline. Different organic acids, such as lactic and piruvic acid are created after disintegration of rests of food [10]. Organic acids decrease pH value inside the oral cavity and may have a negative effect on ions release from dental alloys. Metal ions which are released from dental alloys in the oral cavity can lead to either toxic or allergic responses [11].

Furthermore, they can be transferred to distant organs, thereby causing different changes. There are studies examined ion release from dental alloys which appeared on the market as a result of the high price of gold in different conditions, release much more ions than the conventional alloys with a high share of gold [12]. They also proved that ion release from different dental alloys was not directly proportional to ion concentration in the alloy, some elements are much more unstable than others and this phenomenon is known as "selective dissolving" [13]. In general, corrosion rates of metals and alloys can be determined using chemical and electrochemical methods. Chemical methods for finding the corrosion tendency of alloys can be done by determining the mass loss of corroding metal and alloy, the amount of corrosion products in the corrosive media or the amount of gas produced during the corrosion reaction [14]. The purpose of the present study was to evaluate the influence of temperature and pH on corrosion resistance of Ni-Cr and Co-Cr dental alloys. To characterize the physical and mechanical properties of Ni-Cr and Co-Cr alloys on corrosion resistance after being immersed on artificial saliva. To investigate the correlations between corrosion and biocompatibility of dental alloys and to interpret the results by comparison with ion concentrations found in food. To determine the influence of fluoride and an acidic environment on the mechanical properties of dental alloys.

Experimental

Materials

Three different dental materials PD CASTA H, and CERACAST NB Beryllium Free, all supplied by Mountain Medico. Composition of cobalt and nickel based alloys are as given in Table 1. Materials were purchased in the form of a cylinder of diameter 7 mm and 15 mm length.

Samples preparation: The dental alloys (Ni-Cr) and (Co-Cr) alloys of 7 mm diameter and 15 mm length as cylinders, were cut into small pieces and to reduced in size (7 mm diameter and 1 mm length), using a Colchester 5x20 Chipmaster Machine provided at the Material Research Department (MRD), iThemba LABS, Western Cape, South Africa. The original and reduced sizes of dental alloys is shown in Figures 1 and 2 below:

Alloys	Composition (wt%)
PD CASTA H	Co: 60%, Cr: 29%, Mo: 6.2%, Ni :2.0%, F: 2.0%, C, Si, Mg: <1%
CERACAST NB	Ni: 61.0%, Cr: 25.0%, Mo: 10.5%, Si: 1.5%, Ti: <1%, F, Co, Ag: <1%.
PD 2000	Co: 63.0%, Cr: 28.5%, Mo: 6.0%, Si <1%, C: <1%, Mg : <1%

Table 1. Origin and Composition of materials.

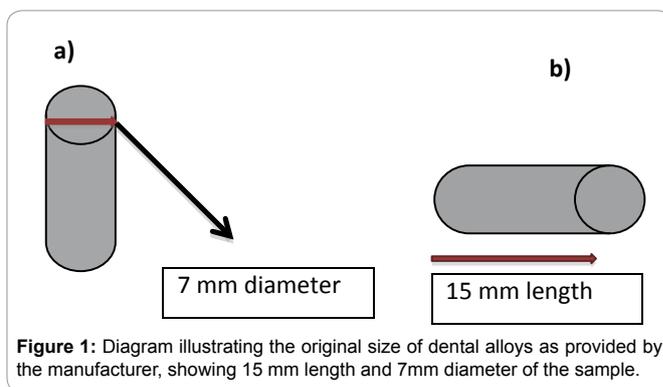


Figure 1: Diagram illustrating the original size of dental alloys as provided by the manufacturer, showing 15 mm length and 7mm diameter of the sample.

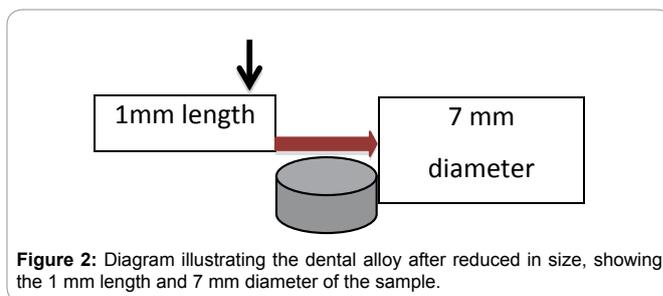


Figure 2: Diagram illustrating the dental alloy after reduced in size, showing the 1 mm length and 7 mm diameter of the sample.

Components	(g/L)
Sodium chloride NaCl	9.000
Calcium chloride CaCl ₂	0.240
Potassium chloride KCl	0.430
Sodium bicarbonate NaHCO ₃	0.200

Table 2: Composition of Ringer's solution.

Preparation of test solution: The Ringer's solution consists of several salts dissolved in water. The solution typically contains sodium chloride (NaCl), calcium chloride (CaCl₂), potassium chloride (KCl), and sodium bicarbonate (NaHCO₃). The chemical composition of the Ringer's solution is given in Table 2 [15]. Ringer's solution is frequently used in human medicine in the form of lactated Ringer's solution which is frequently used in human medicine in the form of lactated Ringer's solution.

All samples from each group were tested in artificial saliva solution for 14 days.

Experimental procedure: The alloys were divided into 6 groups, as shown in Table 3. Each group contains three different alloys from each type. All samples from each group were tested in artificial saliva solution, for 14 days. The composition of the solution is given in the Table 2.

The pH of the solution was measured before the experiment using a glass electrode (Model pH 25, Manusl, Spain) pH meter. The pH of the solution was reduced by adding lactic acid. This acid was chosen in order to obtain conditions that were as close

Solutions	Samples	The test groups	Days of immersion	pH	Temperatures
Ringer's solution	Dental alloys in each group: I. PD CASTA H II. CERACAST NB III. PD 2000	Group 1	14 days	2.5	28°C
		Group 2	14 days	2.5	37°C
		Group 3	14 days	2.5	40°C
		Group 4	14 days	6.7	28°C
		Group 5	14 days	6.7	37°C
		Group 6	14 days	6.7	40°C

Table 3: Design of the study groups showing different samples (dental alloys) and the solution at different pH and temperatures

as possible to the clinical reality, since this acid is naturally released by the bacteria in the oral cavity [16,17].

All the samples were kept at fixed temperatures (28°C, 37°C) inside the Incubator (Scientific- series 2000) for 14 days. However, for higher temperature the samples were kept in the Oven (Labotec-term-o-Mat30-250°C) set at 40°C.

Characterization

Electrochemical measurements: The electrochemical technique employed in this study was the cyclic voltammetry (CV). In this technique a time dependent potential was applied to an electrochemical cell and then the current flowing through the cell was measured as a function of that potential. A plot of current, which is directly proportional to the concentration of an electro active species, versus the applied potential is called a voltammogram, with quantitative and qualitative information about the species involved in the oxidation or reduction reaction at the working electrode [18]. The cell was a three-electrode all-glass double jacket cell, with a platinum counter electrode and saturated calomel reference electrode (SCE) and the working electrode was the alloys which placed in the centre of the cell and embedded with an area of 0.780 cm² exposed to the Ringer's solution and used as the working electrode. For the investigation the effect of temperature on the corrosion cell and the electrochemical process, the cell was connected with constant-temperature water circulator and control it at 37 ± 0.1°C.

Cyclic voltammetry (CV): The CV is a type of voltammetric techniques which uses to analyze new processes that take place at the surface of the electrode giving indications on the reversibility, the kinetics, and the different thermodynamic parameters of the process [19]. The CV uses to study of redox processes, for understanding reaction intermediates and for obtaining stability of reaction products. The potential can be cycled between the two switching potential for several cycles before the experiment is ended at the final potential [20]. The corrosion test cell was used in located in the Chemistry Department, University of the Western Cape, South Africa. The dental alloys were cleaned for two minutes by using distilled water. One litter of Ringer's solution, pH = 2.5, 6.5, and the temperature 37 ± 1°C was used. The alloys were placed in the cell, the open circuit potential (E_r) was monitored for 1 hour. All the cyclic voltammetry measurements in this study were carried out using a scan rate of 5 mV s⁻¹.

Surface analysis: SEM uses a focused electron beam to image the surface. The image is obtained by scanning the focused electron probe across the surface and collecting the resulting image signal from the surface. The signal is collected from the specimen surface and the electron beam loses energy by inelastic scattering as the electrons penetrate beneath the sample surface.

Most of the electron current from an excited sample is due to the release of secondary electrons from the sample surface [21]. SEM Images are produced by scanning the beam while displaying the signal from an electron mode. In many applications, the large depth of field in SEM images, typically at least 100 times greater than for a comparable optical microscope, is more relevant than the high resolution. An important factor in the success of SEM is that images of three-dimensional can be generated.

Three of the alloys, of PD CASTA H, and CERACAST NB Beryllium Free, were observed using scanning electron microscopy (SEM) (Auriga Carl Zeiss, Germany). The three samples (alloys) were carefully cleaned with alcohol, and then dried by the air drier before SEM analysis. The determination of the surface topography was done before and after the immersion in the solution at different pH values, and temperatures ranges. Elemental mapping and atomic composition of the alloys were performed using Energy Dispersive X-ray Spectroscopy (EDS). Which is interfaced with SEM. The samples were subjected to immersion for 14 days in Ringer's solution artificial saliva.

Elemental mapping and atomic composition of the alloys were performed using Energy Dispersive X-ray Spectroscopy (EDS). Which is interfaced with SEM.

Results

Cyclic voltammetry (CV)

The CV was performed on three dental alloys: PD CASTA H (Cr-Co), CERACAST NB (Ni-Cr) and PD 2000. The corrosion resistance for each alloy was evaluated in Ringer's solution at (pH= 6.5 and

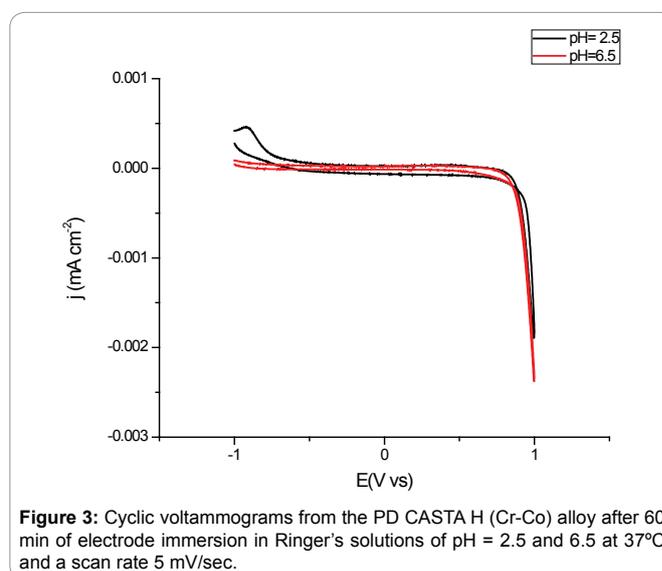
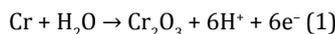


Figure 3: Cyclic voltammograms from the PD CASTA H (Cr-Co) alloy after 60 min of electrode immersion in Ringer's solutions of pH = 2.5 and 6.5 at 37°C and a scan rate 5 mV/sec.

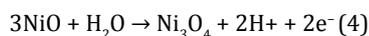
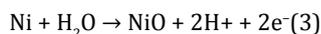
2.5). Cyclic voltammograms were performed from -1000 mV/SCE to +1000 mV/SCE at scanning rate of 5 mV/s. Figure 3 presents the cyclic voltammograms of PD CASTA H (Cr-Co) alloys recorded at a scan rate of 5 mV s⁻¹ and 37°C in Ringer's solution at pH=2.5 and 6.5. The potential scan was initiated at -1 V. In the presence of air, chromium metal spontaneously forms a layer of passive oxide layer of Cr₂O₃. The formation of Cr₂O₃ at the electrode surface and its further oxidation to Cr₂O₃ at higher potentials leading to the recorded anodic peak, can be represented by the following reactions [22].



There was no varying significance in the voltammograms shapes with pH values. The current density with the passive range is higher at pH 2.5 and decreases at higher pH 6.5 (Figure 3).

A cyclic voltammograms for CERACAST NB (Ni-Cr) alloys were recorded in potential range from - 0.1V to 0.1 V (Figure 4). In the anodic range there were peak A1 and A2, is related to the formation of NiO on the surface. In the reverse scan, at 0.5V, there was small cathodic peak K1 appears, which is related to the reduction of Ni (VI) to Ni (III).

The cathodic and anodic peaks can be represented by the following reactions [22].



From the results in Figure 4 the anodic peaks A1 at pH 2.5 appeared at - 0.4 V where the pH value was lower. The second anodic peak A2 appears at - 0.3 V in the solution at pH 2.5. It is most probably related to the oxidation of Ni (II) oxide to Ni (III) (equations 4 and 5). At higher alkali concentration, this is electrochemically-formed NiO is because the OH⁻ ions activate the Ni-Cr surface confirmed by the increase of the anodic current density as the peak height when the concentration of alkali

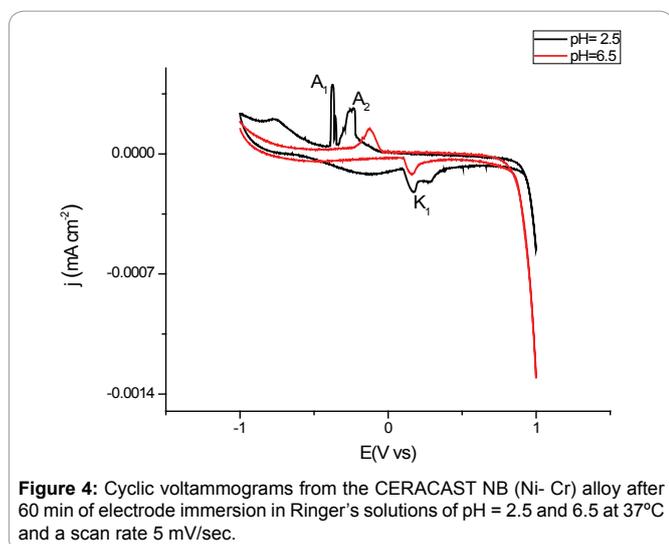


Figure 4: Cyclic voltammograms from the CERACAST NB (Ni- Cr) alloy after 60 min of electrode immersion in Ringer's solutions of pH = 2.5 and 6.5 at 37°C and a scan rate 5 mV/sec.

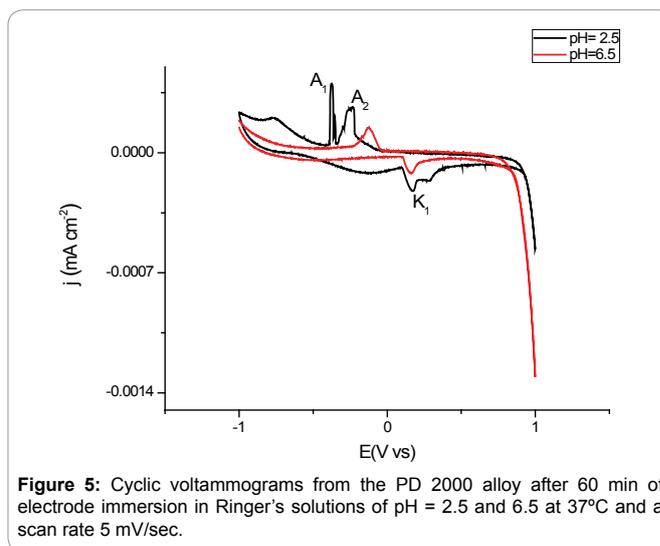


Figure 5: Cyclic voltammograms from the PD 2000 alloy after 60 min of electrode immersion in Ringer's solutions of pH = 2.5 and 6.5 at 37°C and a scan rate 5 mV/sec.

(NaOH) increases. Generally, there was trend of decreasing current density with increasing pH value due to the formation of more stable oxide layers at neutral and slightly alkaline solutions.

In PD 2000 free Ni alloys, the cyclic voltammograms were recorded in the potential range from - 1V to 1V (Figure 5). The electrochemical behaviour of this alloy is very similar to that of PD CASTA H (Cr-Co) alloys, with an anodic peak A1, which may release to the formation of Cr₂O₃ at the electrode surface and its further oxidation to Cr₂O₃ at higher potentials leading to the recorded anodic peak as for PD CASTA H alloy. The change in pH value of the solution does not significantly affect the electrochemical behaviour of Cr-Co alloys.

Surface morphology of the alloys

The determination of the surface topography was done before the immersion in the solution using SEM (Carl Zeiss Auriga, Germany). The three samples (alloys) were carefully cleaned with alcohol, and then dried by the air drier before SEM analysis. (Figure 6 a, b and c) shown the surface morphology of the alloys, there is no corrosion on the surface of the alloys in initial state.

The Ringer's solution was used at different pH value and different temperature. The surface topography of the samples were determined using SEM. The micrographs have shown that pitting corrosion at different areas on the surface of PD CASTA H, CERACAST NB and PD 2000 (Figures 7 a, b and c). The corrosion results indicate that the surface morphology of alloys that has a high Co and Cr content shows the best corrosion resistance compared with CERACAST NB alloys. Due to ability of Cr to form a passive Cr₂O₃ film on the surface.

Chemical composition microanalysis by Energy dispersive spectrometry (EDS)

The chemical composition of the tested alloys as given by the manufacturer are presented in Table 4. In this research, the EDS which were interfaced with SEM were used for the composition analysis of the alloys. Figure 8 shows different peaks of the elements contained in the alloys such as Co, Cr, C, Mo, Si, Al, and O. The sharp peak of the Co, showed that the sample has a higher content of Co and Cr, compared to another elements.

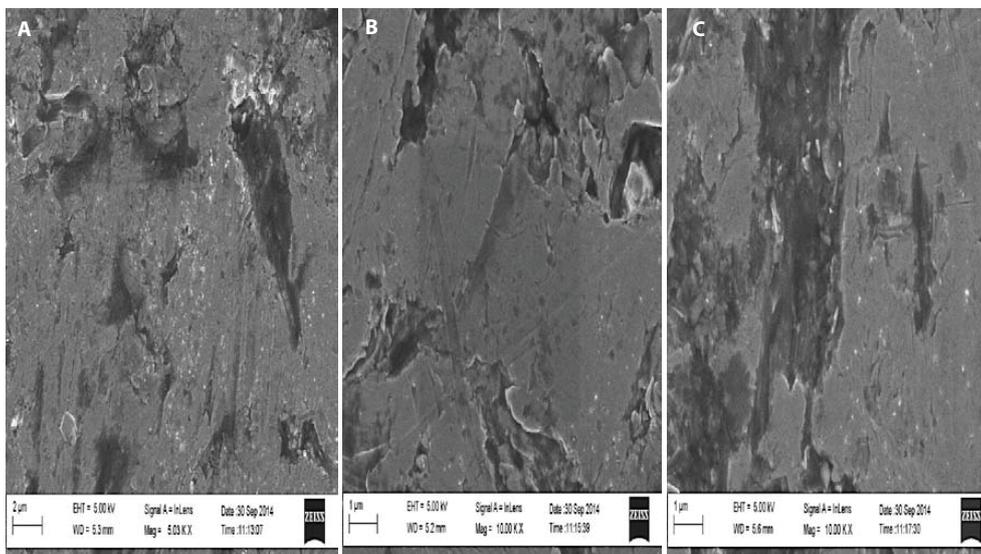


Figure 6: Surface analysis of (a) Co-Cr-Ni alloy, (b) Ni-Cr alloy, (c) Co-Cr free Ni alloy, by SEM before the test solution.

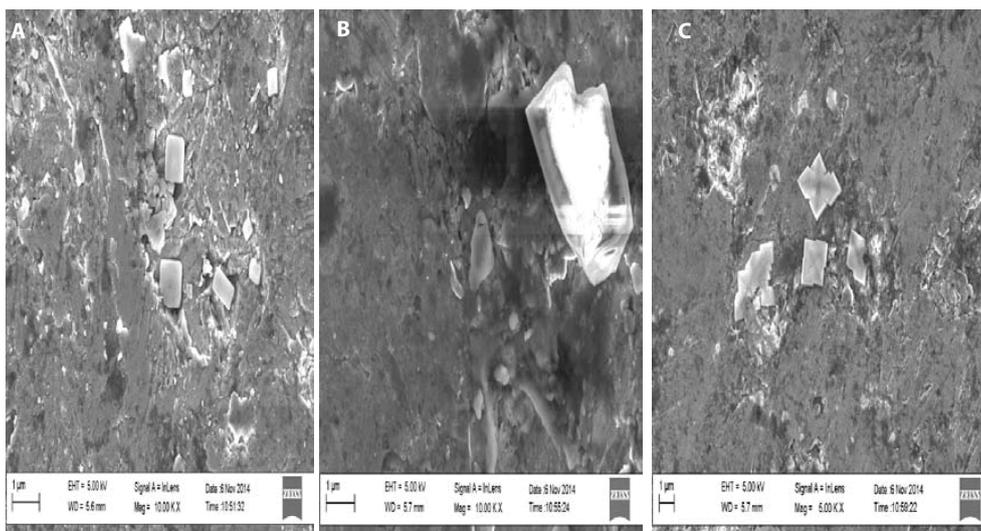


Figure 7: Surface analysis of (a) Co-Cr-Ni alloy, (b) Ni-Cr alloy, (c) Co-Cr free Ni alloy by SEM, after test solution.

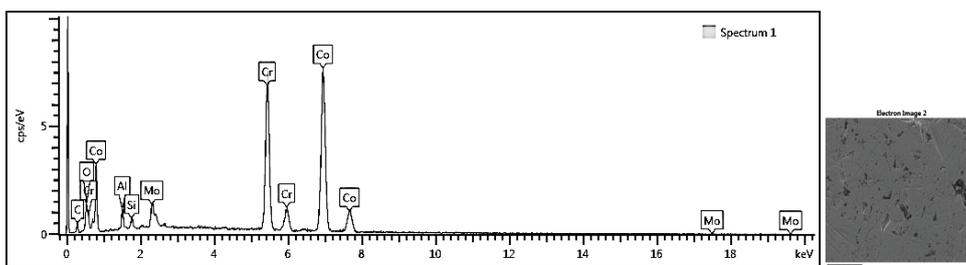


Figure 8: The EDS spectrum of PD CASTA H (Co-Cr) alloy.

The EDS spectrogram in Figure 9 shown that the sample has a higher content of Ni and Cr, but with lower content of Al, Mo, Si.

The EDS spectrogram of PD 2000 (Co-Cr free Ni) alloy showed

the higher peaks of Co and Cr, with no peak to Ni, which indicate free Ni. The elements with lower content are Mo, Si, O, and C, as shown in Figure 10.

Alloys	Chemical composition, %wt, given by the manufacturers									
	Cr	Co	Ni	C	Si	Mg	O	Al	Fe	Mo
PD CASTA H	29.0	60.0	2.0		< 1%		----	----	2.0	6.2
CERACAST NB	25.0	<1%	61.0	---	1.5	---	---		< 1%	10.5
PD 2000	28.5	63.0	---	<1%	<1%	<1%	----	----	----	6.0
Alloys	Chemical composition, %wt, which obtained from EDS spectrogram									
PD CASTA H	20.82	37.04	----	12.94	1.39	----	8.49	3.28	----	2.04
CERACAST NB	26.71	----	57.23	----	4.48	----	----	5.99	----	5.6
PD 2000	22.35	39.72	----	10.96	1.55	----	10.13	3.13	----	2.16

Table 4: Comparison of chemical composition for the alloys given by the manufacturers and the chemical composition of the alloys obtained from EDS spectrogram after corrosion test.

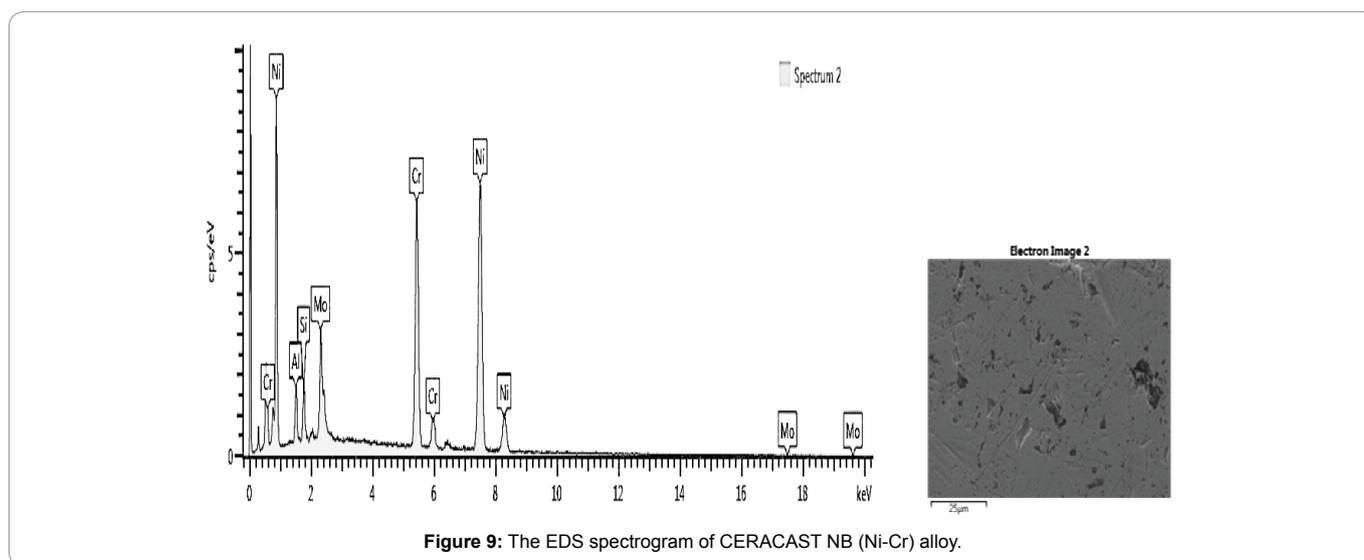


Figure 9: The EDS spectrogram of CERACAST NB (Ni-Cr) alloy.

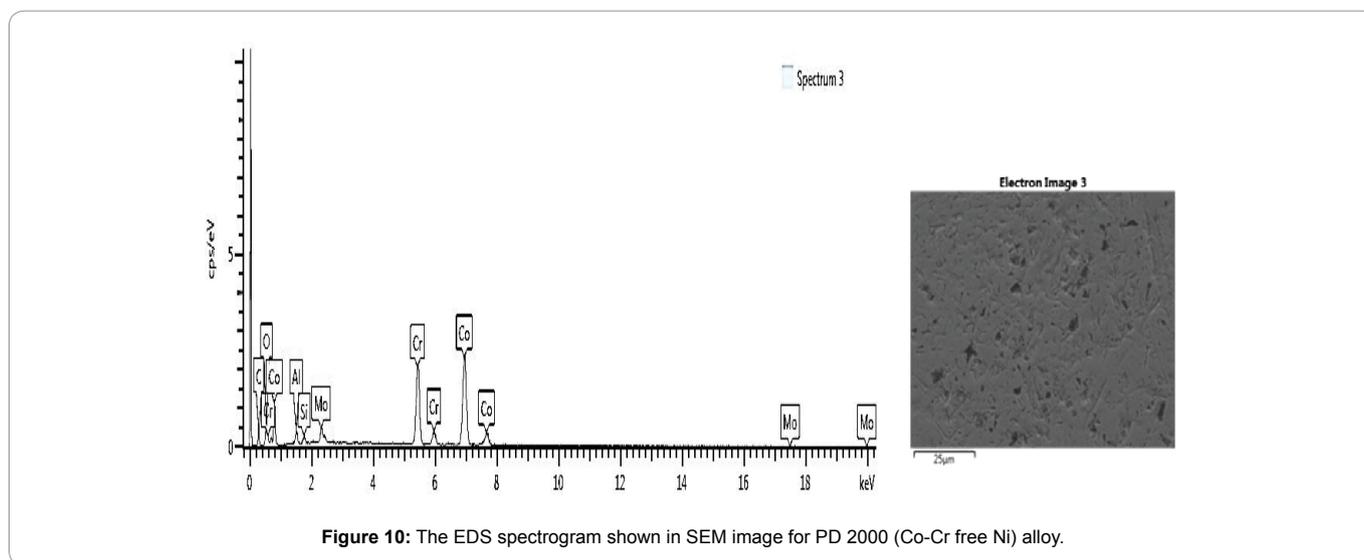


Figure 10: The EDS spectrogram shown in SEM image for PD 2000 (Co-Cr free Ni) alloy.

There were significant difference in the percentages of the constituent elements of alloys that have been studied before the immersion test compared with the results obtained from EDS spectrogram after the test solution, perhaps this is due to the interplay between the ions of elements in the alloy and the ions of elements in the solutions during immersion period, or the effects of the pH and temperature of the solutions (Table 4) below.

Discussion

Dental alloys must be more resilient to withstand the effects of most severe environment. Variations in the temperature, acidity or alkalinity value and high stresses all have an effect on the properties of materials. Normal temperature in the oral cavity is between 32°C and 37°C. However the acidity or alkalinity of fluids measured in the oral cavity by pH varies from around (4 to

8.5), while the intake of acid fruit juices or alkaline medicaments can extend this range from pH 2 to 11.

The non-precious alloys react easily with the biochemical medium from the oral cavity due to their complex composition, and are especially degraded by electrochemical corrosion the selection of dental alloys depending on the mechanical and biocompatibility properties. Also on the corrosion resistance. In order to realise certain prostheses the choice of dental alloy is very important, because inadequate material may lead to mechanical, chemical or biological failures that have undesirable consequences in time for the patient's general state of health [23]. The purpose of this study was to compare and examine how the dental alloys which contains Co, Cr, and Ni behaves in artificial saliva of different pH value and temperatures. This study was also envisaged to evaluate the roles of dental alloys elements and passive film homogeneity on the corrosion resistance of Co-Cr and Ni-Cr alloys.

Since the price of gold rose significantly in the 1930s, a large number of new non-noble alloys were developed for use in dentistry apart from the Au-Pt alloys. The Au-Pt alloy is a high noble alloy, while the Co-Cr-Mo alloy used for fabrication of casting alloy (metal framework) dentures or the Ni-Cr alloys used for dental metal ceramic appliances are base metals or non-noble alloys [24].

Base metal casting alloys (nickel-chromium, cobalt-chromium and cobalt-chromium-nickel) are popular for fabricating the metallic frameworks for removable partial dentures because of their lower cost [25,26]. Nickel-chrome casting alloys were developed as an alternate, because of their superior properties in relation to porcelain-fused-to-metal (PFM) applications, high strength for crowns and fixed partial denture, better elongation percentage and high elastic modulus for removable partial denture [27]. Nickel is considered to be the most common allergen in dental alloys [28,29]. Chromium and nickel impart corrosion resistance and mechanical strength to non-precious alloys. It has been observed that in nickel alloys with a chromium content of over 20% and a molybdenum content of greater than 4% can ensure adequate corrosion resistance [30,31]. The presence of Cr improves the corrosion resistance of alloys in a corrosive environment due to the formation of a Cr rich, passive oxide film which is highly resistant to acid [32]. Molybdenum in the Ni-Cr based alloy increases the resistance to localized corrosion in the chloride containing environment [16]. Therefore, for based dental alloys, the addition of 12% Cr (minimum value) and 2-5% Mo to the alloy bulk is recommended from the corrosion resistance point of view [33].

There is much literature on corrosion studies of dental alloys in natural or artificial saliva media. However only a few studies of dental materials in saline solutions to emulate aggressive corrosion conditions in the oral cavity have been reported [31]. In one study Sun et al. [34]. have used 0.9% and 0.09% NaCl solutions in simulated environments for corrosion studies of various non-precious and noble dental alloys using open circuit potential (OCP) and cyclic polarization measurements was made. Lucas et al. [35] have used 0.9% NaCl medium as an in vitro medium for studying Co-Cr and Ni-Cr alloys using electrochemical techniques. Dong et al. [36] examined corrosion resistance behaviour of Co-Cr and Ti using immersion tests in various types of electrolyzed water [37].

Johanson et al. (1989b); have studied corrosion of copper-nickel alloys in saline solutions using electrochemical techniques. Geis-Gerstorfer et al. [38] analyzed corrosion of various Ni-Cr-Mo and Co-Cr-Mo alloys in 0.1 M NaCl solution by weight loss over a 5 week duration. Huang has used 1% NaCl in the halide solutions for the study of corrosion resistance of cp. Ti [39].

In this study, SEM was used to characterize the surface morphology and the corrosion attack of the three dental alloys before and after the immersion period in artificial saliva. The SEM results for the three tested alloys in initial state showed that there is no corrosion on the surface and each sample have a different morphology. SEM showed differences in the growth of a passive oxide layer of Cr_2O_3 , with small mounts of Co_3O_4 , CoO and CoCr_2O_4 on the surfaces especially with the higher presence of Cr in the alloy.

Therefore the oxide layer growth decelerates with increasing oxidation time because outward diffusion of cobalt ions is hindered by a thick, compact, and adherent oxide layer on the metal surface. The oxidation time and the oxidation temperature have many effects in the corrosion rate, there are a higher rate constant of oxide layer when the temperatures were around 40°C , compared to oxide layer form on other alloys at lower temperatures. The influence of different alloying elements have many affects in the oxidation process due to the variety of alloying elements which have different affinities to oxygen [40].

The results showed that the corrosion resistance of the Ni-Cr alloys is related to the formation of passive film containing $\text{Ni}(\text{OH})_2$, NiO , Cr_2O_3 and MoO_3 on the surface. The presence of Ni in the oxide film is also important in metal protection. In most Cr-Co alloys, which has a maximum of about 20 to 25 weight percent of Cr, a layer of Cr_2O_3 forms on the alloy surface. The Cr content is the key alloying addition determining passive film stability, which improve hot corrosion properties. The presence of a substantial Mo content (>9 wt%) is required to achieve maximum film stability. A higher content of Cr_2O_3 and MoO_3 in the passive film could lead to a higher resistance to metal ion transfer through the passive film. The homogeneous distribution of Cr is critical especially in low-Cr nickel-based alloys for better corrosion resistance compared with Cr_2O_3 . The oxide of nickel is more porous and has less protective ability to corrosion. Hence, the passive film zones, which are rich in NiO, will act as weak regions for localized corrosion, which can cause localized dissolution of Ni-rich phases [41]. In contrast, silicon enhances the oxidation resistance not only because of SiO_2 formation but also due to the beneficial effect of silicon on the formation of protective Al_2O_3 [42].

Lactic acid will ionize to lactate (L^-) and (H^+) ion, when this acid added to the Ringer's solution. The ionization process of lactic acid is due to a decrease in the pH value on the solution. Therefore the corrosion resistance decrease when the lactic acid addition on the solution. On other hand the pH also decrease with increasing the amount of lactic acid. The corrosion rate is therefore aggravated with an increase in lactic acid.

Summary and Conclusions

From the obtained results the specific conclusions showed the following:

- From the results obtained in this study there were change

observed on the surface of dental alloys due to change in temperatures and pH of the solution.

- The corrosion resistance of the alloys was decrease when the pH of the solution was lowered to pH 2.5 as well as the temperatures raised to 40°C.
- The overall corrosion resistance were observed to the alloys with content of Co and Cr. This is due to the passivation phenomenon attributed to formation of a protective layer of chromium oxide, thus inhibiting the corrosion process.
- In general. The good corrosion resistance of the Cr-Co, and Ni-Cr alloys in Ringer's solution is due to the highly protective passive oxide film that is the key factor for its compatibility. This concluded that the good corrosion resistance of Cr-Co and Ni-Cr alloys in Ringer's solution was due to the higher protective passive oxide film that was the key factor for their compatibility.
- The metal and different alloys have thermal microbiological and enzymatic properties. A metal in aqueous solution will be thermodynamically unstable and there is a tendency to pass from a solid state to anionic form which is associated with a decrease in energy. The direction of energy changes is influenced by factors such as surface morphology, salivary composition, pH and temperatures. An unstable metal may corrode, releasing metal ions in to a solution and may have adverse biological, aesthetic and functional effects.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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