HENDESE TEKNİK BİLİMLER ve MÜHENDİSLİK DERGİSİ
JOURNAL of HENDESE TECHNICAL SCIENCES and ENGINEERING
RESEARCH ARTICLE

Investigation of Microstructure and Mechanical Properties (Ni-Cr-Mo) Dental Prosthesis

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(**Received:** 07.03.2024, **Accepted:** 11.10.2024, **Published Online:** 27.10.2024)

Keywords
Dental prosthesis,
Microstructure,
Ni-Cr-Mo.

ABSTRACT

Ni63.4-Cr23.6-Si1.4-Mo11 metal ceramic (CERMET) dental alloy is widely used in dentistry applications instead of expensive alloys. The biocompatibility of the Ni63.4-Cr23.6-Si1.4-Mo11 alloy may pose a problem due to the metals present in the alloy as a result of corrosion activity, so examining its microstructure and mechanical properties is quite important. 11mm diameter Ni63,4-Cr23,6-Si1,4-Mo11 alloy disc was produced using the standard casting method for analyzing. Scanning Electron Microscope (SEM), X-ray Diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDX), Electrochemical Corrosion (Tafel extrapolation) and Micro Hardness test methods were used to examine the microstructure and mechanical properties of the alloy produced. According to the findings obtained from the results, the corrosion rate of the sample was measured as (940,3 x 10-3mpy) and the average Vickers hardness value was (366,54 kg x mm-2). It was seen that the alloy was in dendritic structure from SEM analysis, and Ni dominant XRD phase was detected in XRD tester. It was seen in SEM mapping that all the elements used in the alloy showed a homogeneous structure.

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Volume: 1 **Issue:** 2

Cite as: Aygul, E., "Investigation of microstructure and mechanical properties (Ni-Cr-Mo) dental prosthesis", Hendese, Vol. 1, Issue 2, Pages 62-66, 2024.

Doi: 10.5281/zenodo.13996483

1. INTRODUCTION

The use of metal alloys in dental prostheses is associated with good mechanical properties, biocompatibility, high corrosion immunity and good casting properties. The most popular dental alloys are nickel, titanium and cobalt [1,2] based alloys, where permanent prostheses-bridges, crowns and implants covered with polymer, composite or ceramic are realized [3,4].

Recently, Nickel-Chromium-Molybdenum (Ni-Cr-Mo) based alloys have begun to be widely used instead of expensive precious metal alloys used in dental applications. The use of Ni-Cr-Mo based alloys in dentistry is increasing, especially in the production of fixed dental prostheses [5]. Although there are doubts about the biocompatibility of this alloy (Ni-Cr-Mo), is still chosen as the base metal because of its higher elastic modulus than the noble, offering the advantage of retaining hardness with less bulk. The electrochemical corrosion behavior of Ni-Cr-Mo metal ceramic dental alloy primarily in tandem the Cr and Mo grades in an alloy [6]. Chromium is the basis alloying element in Ni-base alloys and is added to support the consist of a decisive passive oxide layer that is quite corrosion resistant. Molybdenum is often added to increase corrosion immunity [7].

The chemical composition of Ni-Cr-Mo casting alloys mainly comprise of 65-80% Ni and 8-22% Cr as well as Mo 3.8or4%, W 4% or (more rarely) Be, Si [8]. Total Ni + Cr + Mo content should be equal to a minimum of 85% by weight. A direct correlation has been established between cast alloy structures and polarization immunity behavior [8]. Although casting of Ni-Cr-Mo metal ceramic dental alloy is difficult, it is still the traditional method of preparing the metal substrate for economic concerns, due to its high melting range and oxidation potential during casting [9].

With the development of dental technology, many attentions have focused on methods of appropriately fabricating Ni-Cr-Mo dental alloy and facilitating the finishing process [10]. Biocompatibility of the material in biomaterials, especially in alloys used in dental applications, is directly related to the corrosion properties of the material [11,12]. Biomaterials corrode with the effect of acidic and basic inhibitors in the aggressive tissue fluid occasion of the human body. Especially for dental alloys, it can be given as a cause of sudden changes in salivary fluid and food temperature in addition to tissue fluid [13]. The electrochemical corrosion test was performed for the corrosion test of Ni-Cr-Mo alloy. Ringer's solution was used for the aqueous occasion of the electrochemical corrosion test.

The hardness of the Ni-Cr-Mo metal ceramic alloy is such that it allows easy mechanical work. The micro hardness value of the alloy (Ni-Cr-Mo) was obtained with the Vickers hardness tester. After the electrochemical and mechanical tests, microstructure and surface morphology examinations of the alloy (Ni-Cr-Mo) were carried out by means of an X-ray micro analyzer and a scanning electron microscope. The purpose of the tests are to examine the behavior of a commercial Ni-Cr-Mo alloy in an organic solution by comparing its microstructural, X-ray diffraction and corrosion immunity properties.

2. MATERIALS AND METHODS

One of the test samples was the mercantile Ni63,4-Cr-23,6-Si-1,4-Mo11 metal ceramic (CERMET) dental alloy Provided by the company (MESA/ITALY- 9 mm in diameter and 12 mm high). The chemical composition of the prospect alloys is presented in Table 1. The physicochemical and mechanical properties of the Ni-Cr-Mo metal ceramic alloy declared by the producer are compiled in Table 2.

Table 1. Chemical composition of tested alloy Ni-Cr-Mo metal ceramic alloy.

Metal Ceramic Dental Alloy	**Ni** *(%)*	**Cr** *(%)*	**Mo** *(%)*	**Si** *(%)*	**Rest** *(%)*
Ni63,4-Cr 23,6-Si 1,4-Mo11	63,4	23,6	11	1,4	0,6

XRD analysis for Ni63,4-Cr-23,6-Si-1,4-Mo11 metal ceramic dental alloy was performed using XRD-6100 Shimadzu device. XRD measurement details are as follows; Cu X-Ray tube, Voltage = 40.0 (kV), and current = 30.0 (mA). FEI XL30 Sirion scanning electron microscope was used to determine the surface morphology of the alloy. Micro hardness values of the samples were obtained with the FM-310 Vickers hardness tester. Finally, the corrosion rates of the samples were decisive by electrochemical corrosion test.

Gamry company's interface-1000 serial electrochemical analyzer was used for corrosion measurements of the samples. Electrochemical Tafel curve analyses were obtained using Gamry Echem Analyst software. Ringer's solution was chosen for the aqueous environment of the electrochemical corrosion test as an element of the in vivo study of the alloys. To form the solution, one Ringer's tablet was calcined in 500 ml distilled water at 121 °C for 15 minutes. Typical chemical composition of the tablet used; Ammonium Chloride 0,00525; Sodium Hydrogen Carbonate 0,005; Calcium chloride-2-hydrate 0,04; potassium chloride 0,00525; sodium chloride 1,125.

Table 2. Mechanical and physical properties of Ni-Cr-Mo metal ceramic alloy according to producer

Mechanical properties		**Physical properties**	
Hardness (HV)	350-400	Density *(g/cm^3)*	8,3-8,4
Elasticity Mod. (Gpa)	200-230	Casting Temp. *(^0C)*	1270-1395
Tensile st. (Mpa/mm^2)	800	Sol & Liq. *(^0C)*	1309-1417

3. RESULT AND DISCUSSIONS

Figure 1 indicate the XRD pattern of Ni-Cr-Mo metal ceramic alloy with lattice parameter which related peaks degree. The lattice crystal structures obtained were found to be in concert with the available literature data (reference below and Mehta et al., 2015a, 2015b). There is an increase in the main peaks due to the presence of nickel present, but the differences in the value of the increase seen in the peaks vary depending on the content of the alloy and the atomic radius.

The atomic radius of the elements was found Ni, Cr, Mo and Si 1,62 Å, 1,85 Å, 2,01 Å and 2,1 Å respectively. In the results obtained, the dominant Ni peak in the main phase and Ni, Cr peaks respectively are remarked in figure 2 [14-16]. Figures 2a and 2b show SEM (SE) micrographs of Ni-Cr-Mo cermet dental material obtained at 800 X and 1600 X magnification. As a result of the SEM (SE) examinations, surface structure of the alloy has been revealed. The morphological structure of the alloy is typically consisting of intermetallic dendritic, as seen in existing cast materials. In pursuant of the literature (reference below and Perricone at al., Augustyn at all), in the structure of Ni-Cr-Mo metal ceramic alloy, dendrites mainly consist of intermetallic phases [8,17].

SEM mapping according to K and L energy shells of the alloy formed with Ni-Cr and Mo element additives is given in Figures 2c, 2d and 2e. The samples produced are CrK, Mo and NiK from left to right according to the energy shell mapping given. These metals generally show up as small precipitates in the SEM pictures of the alloy. The general result of the SEM mapping is that the Cr, Mo and Ni elements in the alloy have a homogeneous distribution. Measurement can be performed for this alloy to investigate how it will behave. Figure 3b shows the graphical data resulting from the Tafel analysis. It is seen that Ni-Cr-Mo metal ceramic alloy is close to show passivation feature. It is seen that the protective layer formed on its surface has a strong adhesion and reaction to the electrolytic solution. It is seen that it exhibits a behavior close to passivation feature.

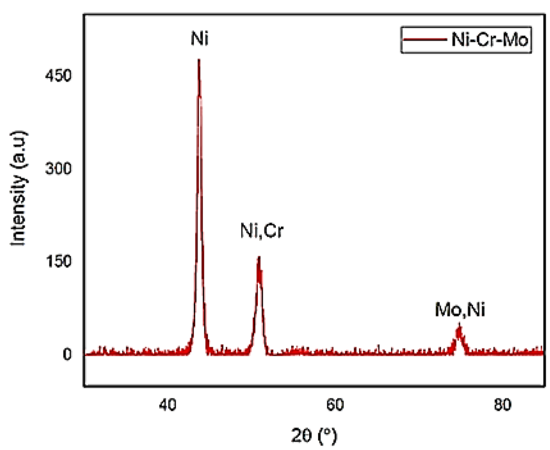
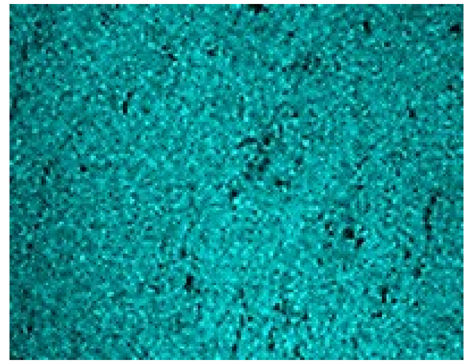
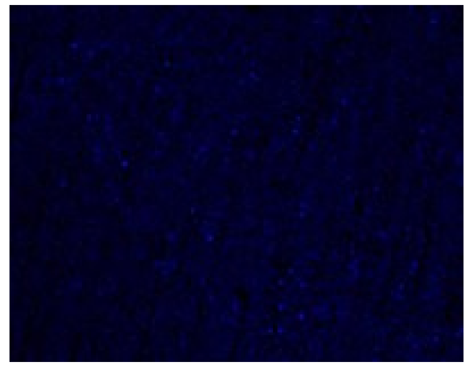


Figure 1. XRD patterns of the alloy.

a



b



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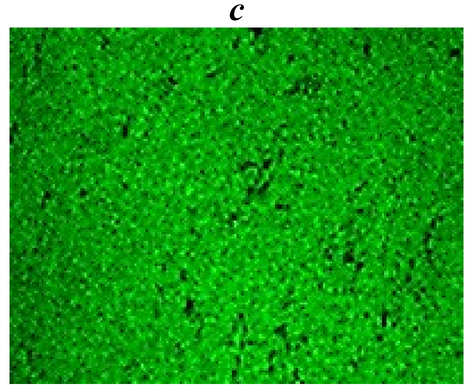
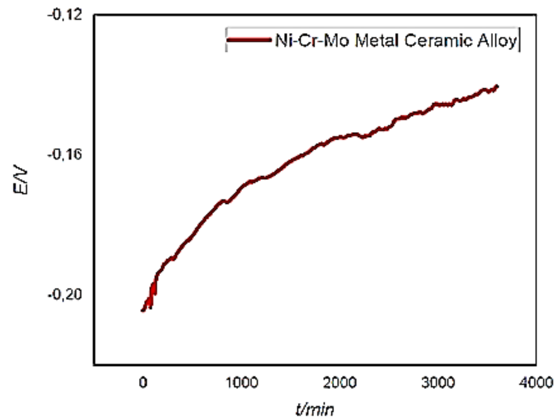


d

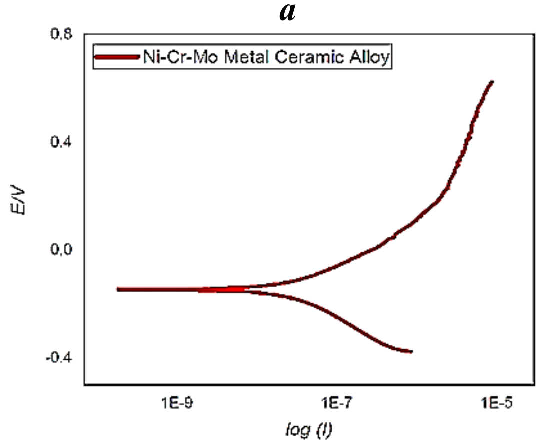
Figure 2. (a) Microstructure of Ni-Cr-Mo alloy; (b, c and d) SEM mapping of Cr, Mo and Ni respectively.

3.1. Micro Hardness and Electrochemical Corrosion Tester

In order to determine the final micro hardness value of Ni-Cr-Mo metal ceramic alloy, measurements were taken from five different surfaces of the sample and the final value was decided by taking the average of five measurements. (100 g load, 10 sn holding) Accordingly, the hardness values measured are; 342,1 kgf/mm^2, 353,5 kgf/mm^2, 367,6 kgf/mm^2, 384,4 kgf/mm^2 and 385.,1 kgf/mm^2. The final average micro hardness value was measured as 366,54 kgf/mm^2.



a



b

Figure 3. (a) open circuit voltage of Ni-Cr-Mo alloy, (b) Tafel extrapolation of Ni-Cr-Mo.

In Figure 3a, open circuit potential measurements of Ni-Cr-Mo metal ceramic alloy in ringer's solution for 40 minutes are shown. Ni-Cr-Mo metal-ceramic alloy has deviated positively and accomplished its measurements at higher potentials than it started. Samples exhibiting this behavior are due to the protective oxide layer composed on their surface. In consequence of the measurement, equilibrium with the solution and thermodynamic stability could not be reached completely. In future studies, a longer-term open circuit potential measurement can be performed for this alloy to investigate how it will behave. Figure 3b shows the graphical data resulting from the Tafel analysis. It is seen that Ni-Cr-Mo metal ceramic alloy is close to show passivation feature. It is seen that the protective layer formed on its surface has a strong adhesion and reaction to the electrolytic solution. It is seen that it exhibits a behavior close to passivation feature.

Table 3. The result of Tafel extrapolation of NiCrMo.

Variables	Values
Beta A	166,3e-3 *V/decade*
Beta C	201,6e-3 *V/decade*
Icorr	34,50 *nA*
Ecorr	-146,0 *mV*
Corrosion Rate	940,3e-3 *mpy*
Chi Squared	3,36E-01

4. CONCLUSION

Implants used in dental prostheses are produced from expensive metals and alloys that resist corrosion in terms of proper production and usage technique. For this purpose, the important thing is to produce alloy types that are inexpensive but of the same quality, or to examine existing alloys. The Ni63,4-Cr23,6-Si1,4-Mo11 alloy investigated in this study is found to meet the expected these properties. For this purpose, the homogeneous microstructural properties (Ni-Cr-Mo-Si) and annual corrosion value (940,3e-3 mpy) of the examined alloy were found. Ni63,4-Cr23,6-Si1,4-Mo11 metal ceramic dental alloy is suitable for use as dental prosthesis instead of expensive noble metals with its passive corrosion property and homogeneous structure.

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