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# The Galvanic Interaction Between a CoCrMo Alloy, Pure Titanium and Two Different Dental Amalgams with Special Attention on the Area Size

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**Abstract:** The purpose of this study was to determine the galvanic interaction between pure titanium, a CoCrMo alloy, as well as their galvanic interaction with a high copper and a conventional amalgam at different area ratios.

Pure titanium, a CoCrMo alloy and two dental amalgams with different copper compositions were tested in this study in 0.9% NaCl environment of pH 7. Polarization curves were recorded for different couples with different area ratios.

The conventional amalgam is more prone to galvanic corrosion than the higher copper containing amalgam in contact with the CoCrMo alloy as well as titanium. Since there is higher galvanic interaction of amalgams with CoCrMo casting alloys, either all amalgams should be exchanged with non-metallic restorations, or titanium should be chosen as casting metal for partial denture framework, if too many amalgam restorations exist in the oral cavity.

**Keywords:** Galvanic corrosion, high copper amalgam, different area ratios.

## INTRODUCTION

Most of the materials used in the oral cavity are metals or alloys which are susceptible to metallic corrosion [1]. Galvanic corrosion is an accelerated attack occurring on a less noble metal when electrochemically dissimilar metals are in electrical contact in an aqueous environment. Two or more dissimilar alloys can come into contact. The galvanic interaction may be continuous, for instance between adjacent restorations, between dental implants or root canal posts and fillings or crowns, or between soldered parts of an appliance [2]. These interactions can cause except corrosion also effects, such as burning, tingling sensation in several teeth and metallic taste [3-5].

The conventional restorative material amalgam is often in contact with gold, stainless steel, nickel-chromium crowns or removable dentures [6]. Gold, cobalt-chromium and amalgam are the most often tested restorative materials related to corrosion [6-10]. In the recent years titanium is used in fixed or removable dentures and also implants [11].

The purpose of this study was to determine the galvanic interaction between pure titanium and a CoCrMo alloy as well as between both and two different amalgams of two different compositions. Another objective of the investigations was to determine the role of electrode area size on the galvanic interaction and corrosion behavior.

## MATERIALS AND METHODS

The dental amalgams used in this investigation are presented in Table **1**. Casting metals were pure titanium (Rematitan®-Gussmetall, Dentaurum, Germany) and the CoCrMo alloy (DEGUSSA, Degussa-Hüls AG/Germany; 63% Co, 28% Cr, 5% Mo, 4% others).

**Table1. Composition (Weight %) of the Investigated Dental Amalgams**

| Amalgam | Manufacturer | Powder (%) |
|---|---|---|
| **Oralloy Magicap S** | Coltene/Whaledent AG<br>Altstaetten - Switzerland | 60.0 **Ag**<br>27.5 **Sn**<br>12.5 **Cu** |
| **NOVALLOY** –<br>Non Gamma II Amalgam | President PD, President Dental Handels GmbH,<br>München - Germany | 45.0 **Ag**<br>31.0 **Sn**<br>24.0 **Cu** |

Cylindrical specimens of both amalgams as well as the pure titanium and the CoCrMo alloy were prepared. The dental amalgams were triturated by an amalgamator (Dentomat 2–Degussa GmbH, Düsseldorf–Germany) and mechanically condensed according to ANSI/ADA Spec. No.1 into a cylindrical mould in the same shape and dimensions. The CoCrMo alloys were cast according to the manufacturers' instructions by the lost wax technique in a centrifugal, induction-heated casting machine (Jeol Ltd., Tokyo, Japan). Rematitan Plus (Dentaurum®, Pforzheim, Germany) was used as the investment material and Rematitan® (Dentaurum®, Pforzheim, Germany) was cast in a Rematitan® Casting Unit (Dentaurum®, Pforzheim, Germany).

After 24 h storage in distilled water (37 °C), all materials were grinded successively with 120, 400 and 600 grit silicon-carbide discs. 0.9% NaCl (saline) was used as test environment. The solution in the corrosion cell was held constantly at 37°C with a heater and thermostat ("Mariner Heater and Thermostat", Springfield Electrical Co. Ltd.,

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Thruxton Industrial Estate-Nr-Andover; Hampshire SP 11 8PW).

Area ratios were as follows: CoCrMo alloy-amalgam, 1:1, 8:1; Ti-amalgam, 1:1, 8:1; CoCrMo alloy-titanium, 1:1, 1:8; 8:1.

A saturated calomel electrode was utilized as a reference electrode in potential measurements. Graphite was used as the opposite electrode and the experiments were carried out at a scanning speed of 10 mV/min. The tests were performed using a potentiostat/galvanostat (EG&G Model 273). A recording software "EG&G Princeton Applied Research Model 332 Software" was used for determination of the polarisation curves. Replicate tests were performed for each area ratio to make certain of the reproducibility. All data were analysed by a computer program (model 352/252 Corrosion Analysis Software, v.2.23) and the results were saved in the computer for further analysis and interpretation.

## RESULTS

Corrosion potential ($E_{corr}$) and corrosion current density ($I_{corr}$) of casting alloys and amalgam are given in Tables **2-5**. Polarization curves are shown in Figs. (**1-10**).

**Table 2. Corrosion Potential ($E_{corr}$) and Corrosion Current Density ($I_{corr}$) of the CoCrMo Alloy (1cm$^2$) (Cathodic) Between High Copper Amalgam, Conventional Amalgam and Titanium (1cm$^2$) (Figs. 5-7)**

| | $E_{corr}$ (mV) | $i_{corr}$ (nA/cm$^2$) |
|---|---|---|
| CoCrMo alloy (1cm$^2$)/ high copper amalgam(1cm$^2$) | -425 | 371,9 |
| CoCrMo alloy (1cm$^2$)/ conventional amalgam(1cm$^2$) | -445 | 519,4 |
| CoCrMo alloy (1cm$^2$)- titanium(1cm$^2$) | -350 | 29,72 |

**Table 3. Corrosion Potential ($E_{corr}$) and Corrosion Current Density ($I_{corr}$) of the CoCrMo Alloy (8cm$^2$) (Cathodic) Between - Non Gamma II Amalgam, Conventional Amalgam and Titanium (1cm$^2$) (Figs. 5-7)**

| | $E_{corr}$ (mV) | $I_{corr}$ (nA) |
|---|---|---|
| CoCrMo (8cm$^2$) / high copper amalgam (1cm$^2$) | -416 | 2730 |
| CoCrMo (8cm$^2$) / conventional amalgam(1cm$^2$) | -429 | 3440 |
| CoCrMo (8cm$^2$) / titanium(1cm$^2$) | -336 | 31 |

The high copper amalgam exhibited lower galvanic current densities (18.93 nA/cm$^2$) than the conventional amalgam (30.89 nA/cm$^2$) in contact with titanium (1:1), too. The density ($I_{corr}$) increased with the increasing titanium /amalgam ratio (8:1) to 138 nA/cm$^2$ for the high copper and 125 nA/cm$^2$ for the conventional amalgam.

**Table 4. Corrosion Potential ($E_{corr}$) and Corrosion Current Density ($I_{corr}$) Between Titanium (1cm$^2$) (Anodic) and High Copper Amalgam, conventiOnal Amalgam and the CoCrMo Alloy (1cm$^2$) (Figs. 8-10)**

| | $E_{corr}$ (mV) | $i_{corr}$ (nA/cm$^2$) |
|---|---|---|
| Ti(1cm$^2$) / high copper amalgam(1cm$^2$) | -421 | 18,93 |
| Ti(1cm$^2$) / conventional amalgam(1cm$^2$) | -326 | 30,89 |
| Ti(1cm$^2$) / CoCrMo(1cm$^2$) | -350 | 29,72 |

**Table 5. Corrosion Potential ($E_{corr}$) and Corrosion Current Density ($I_{corr}$) Between Titanium (8cm$^2$) (Anodic) and High Copper Amalgam, Conventional Amalgam and the CoCrMo Alloy (1cm$^2$) (Figs. 8-10)**

| | $E_{corr}$ (mV) | $I_{corr}$ (nA) |
|---|---|---|
| Ti(8cm$^2$) / high copper amalgam(1cm$^2$) | -429 | 138 |
| Ti(8cm$^2$) / conventional amalgam(1cm$^2$) | -449 | 125 |
| Ti(8cm$^2$) / CoCrMo(1cm$^2$) | -385 | 176 |

The high copper amalgam exhibited lower corrosion current densities (371.9 nA/cm$^2$) than the conventional amalgam (519.4 nA/cm$^2$) in contact with the CoCrMo alloy in a ratio of 1:1. The density ($I_{corr}$) increased with the increasing CoCrMo /amalgam ratio (8:1) to 2730 nA/cm$^2$ for the high copper amalgam and to 3440 nA/cm$^2$ for the conventional amalgam.

The interaction between the CoCrMo alloy and titanium showed relatively a low galvanic current density (29.72 nA/cm$^2$) in a ratio of 1:1. The increasing CoCrMo alloy area (8 cm$^2$) did not cause a change in the behavior (31 nA/cm$^2$). When the titanium area was increased to 8 cm$^2$ (Ti/ CoCrMo alloy = 8:1), a corrosion current density of 176 nA/cm$^2$ was observed.

The corrosion potential ($E_{corr}$) of titanium was negative, whereas the CoCrMo alloy exhibited positive corrosion potentials.

CoCrMo alloy interaction was anodic to amalgam and titanium. Titanium showed very low current galvanic densities in comparison to the CoCrMo alloy in contact with amalgams in both surface ratios and reacted cathodic.

## DISCUSSION

This study was designed to determine the galvanic interaction between pure titanium and a CoCrMo casting alloy which is most often used in partial denture framework casting, at three different area ratios (1:1; 1:8; 8:1) and the interaction of both with two different amalgams with high and conventional copper percentages in two different area ratios. Corrosion studies are most often accomplished to investigate either the rate of ion release [9] or galvanic current densities [12]. *In vitro* corrosion behavior is studied either with regard to media [13-16] or area ratios of dental

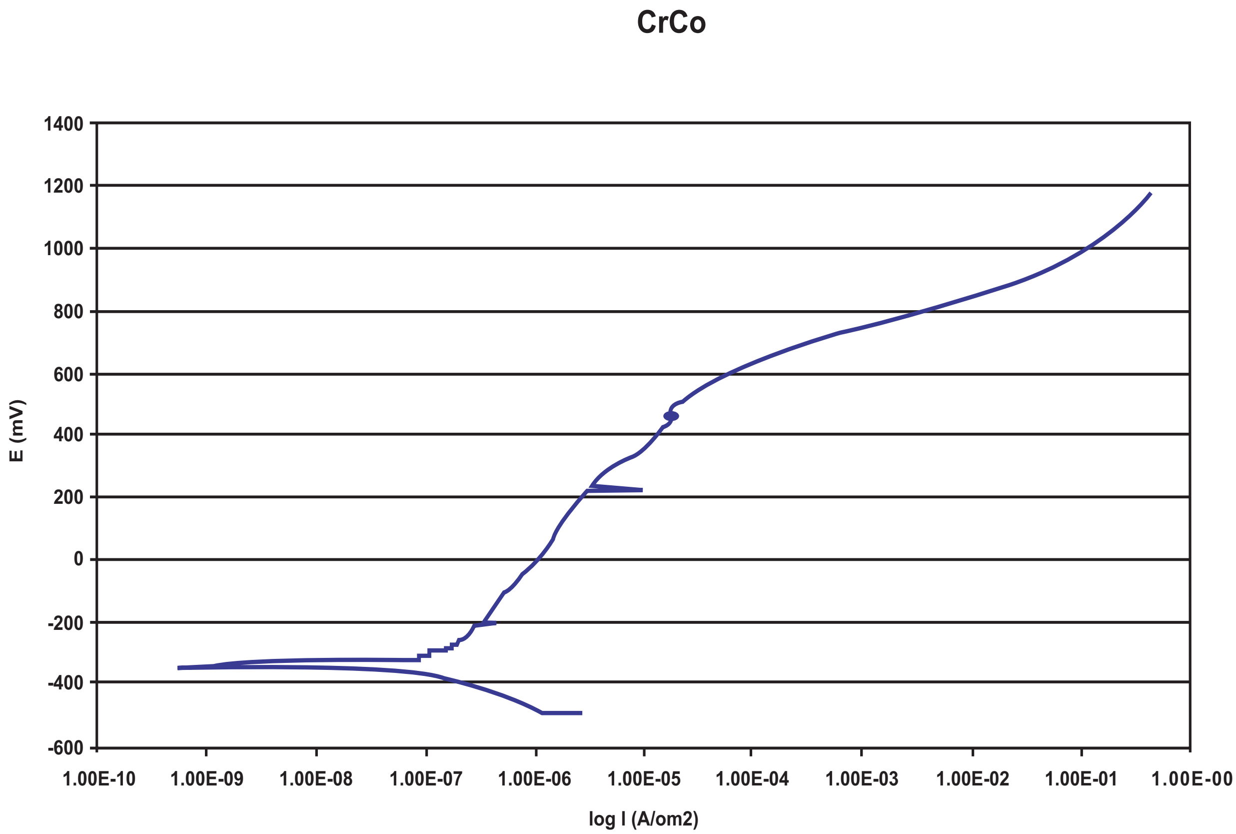


**Fig. (1).** Polarization curve for the "CoCrMo alloy".

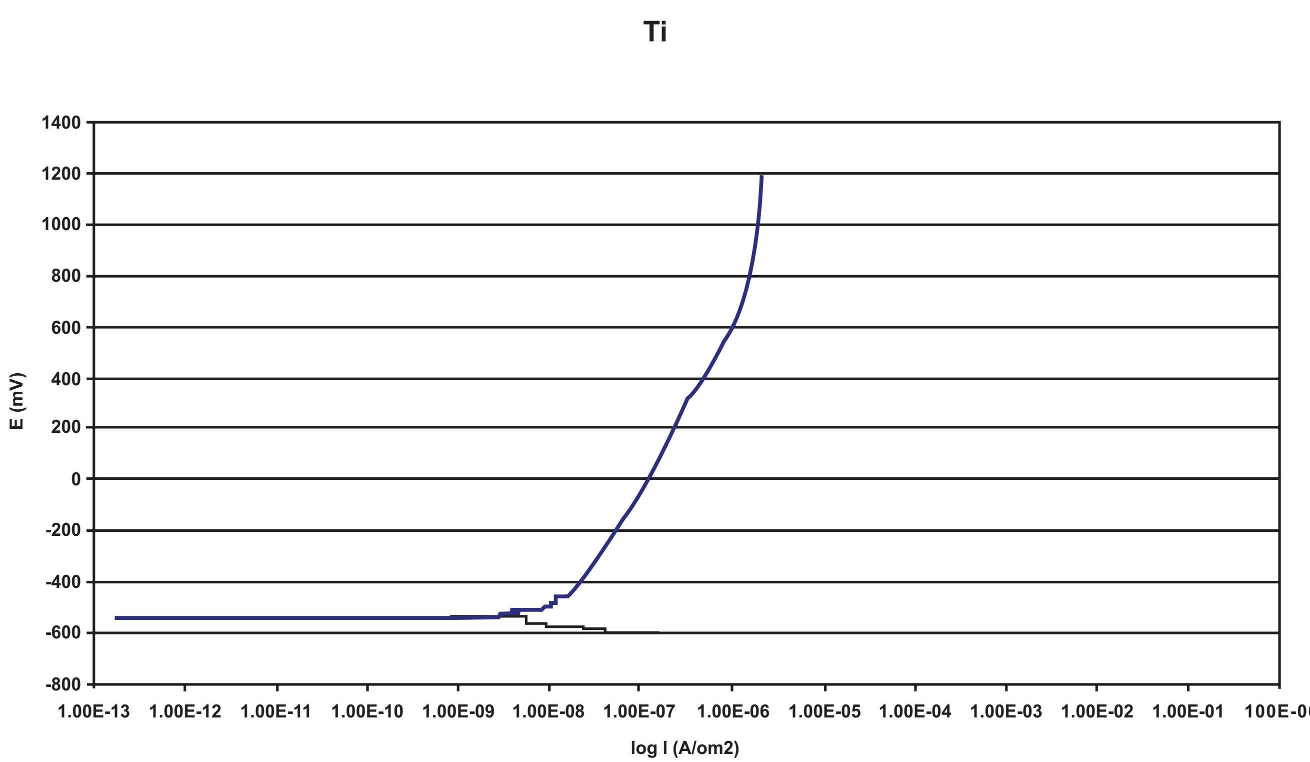


**Fig. (2).** Polarization curve for titanium.

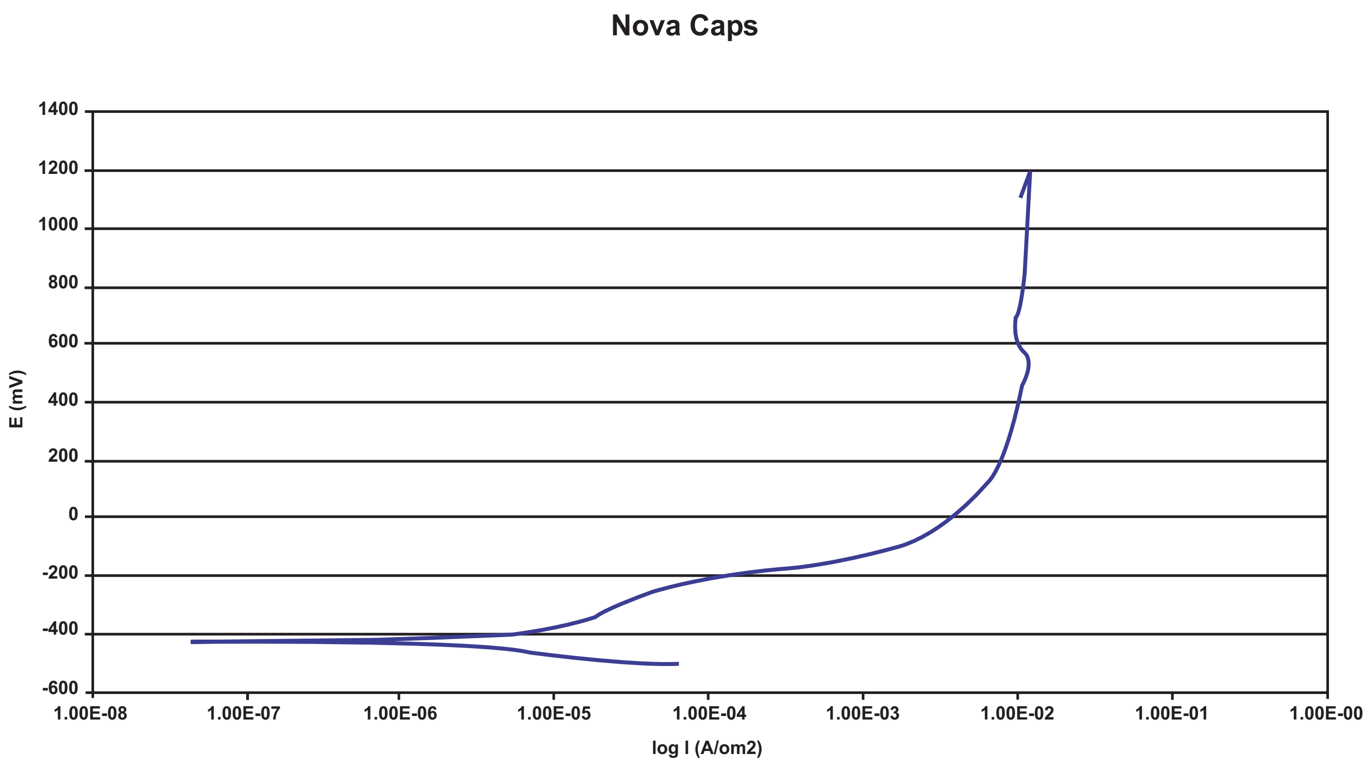


**Fig. (3).** Polarization curve for the “high copper amalgam”.

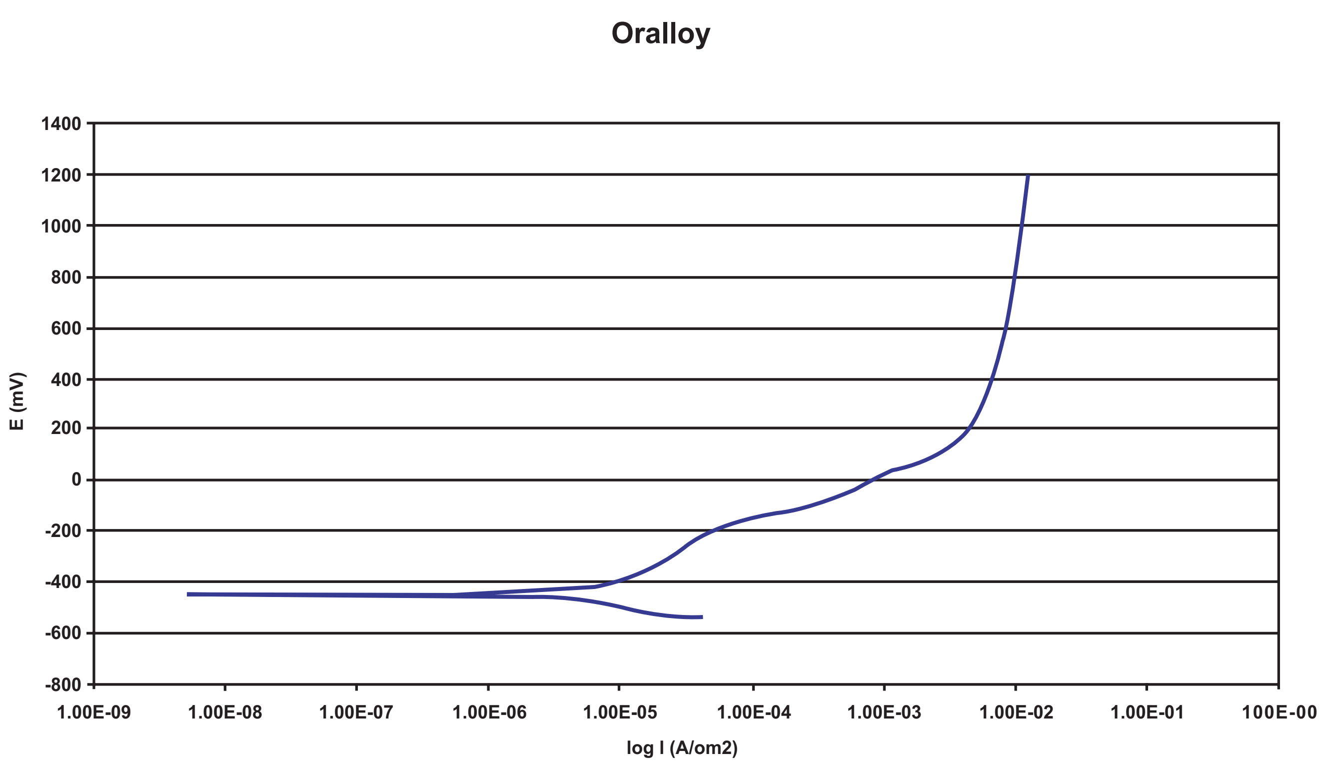


**Fig. (4).** Polarization curve for the “conventional amalgam”.

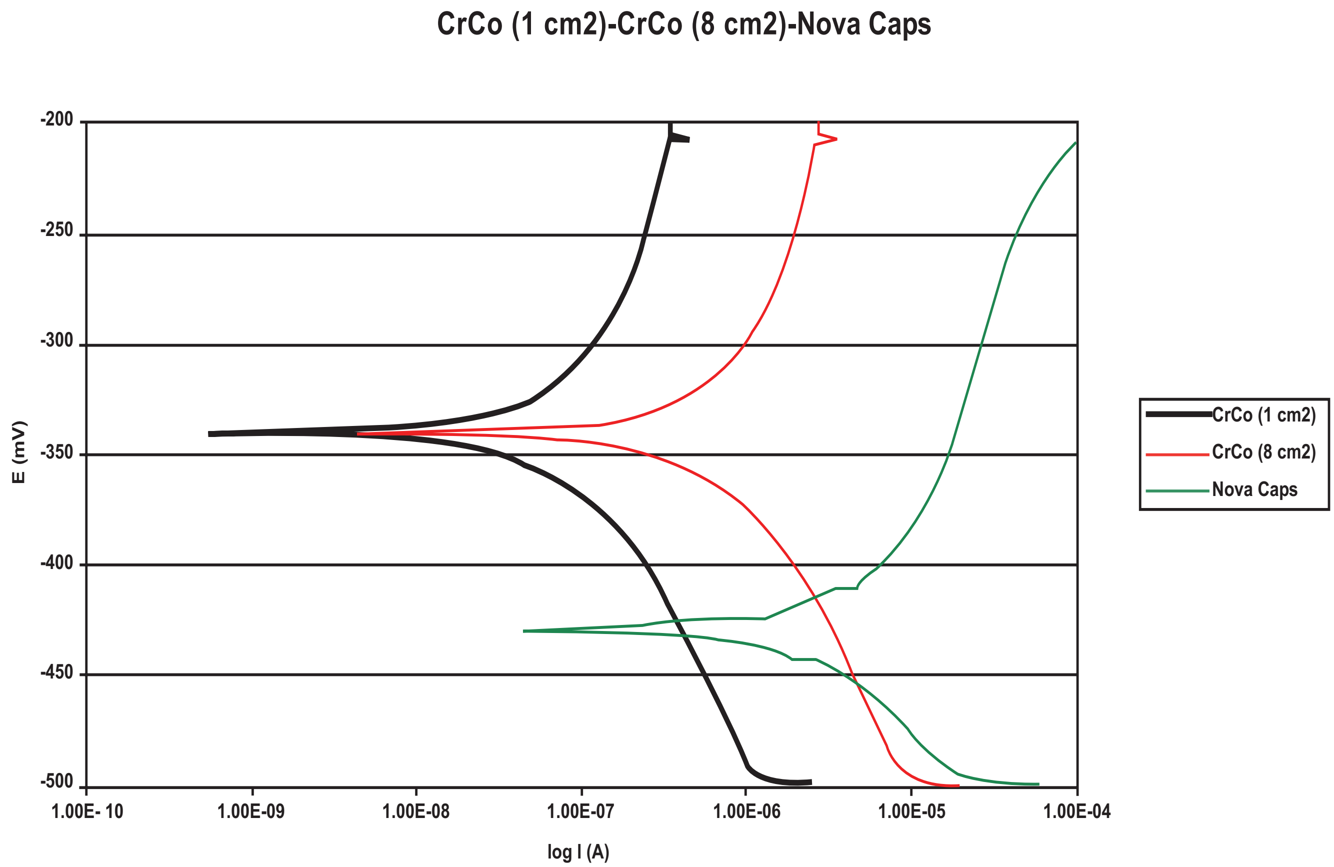


**Fig. (5).** Cathodic polarization curves for the "CoCrMo alloy" (1cm$^2$ and 8cm$^2$) and the "high copper amalgam"(1cm$^2$).

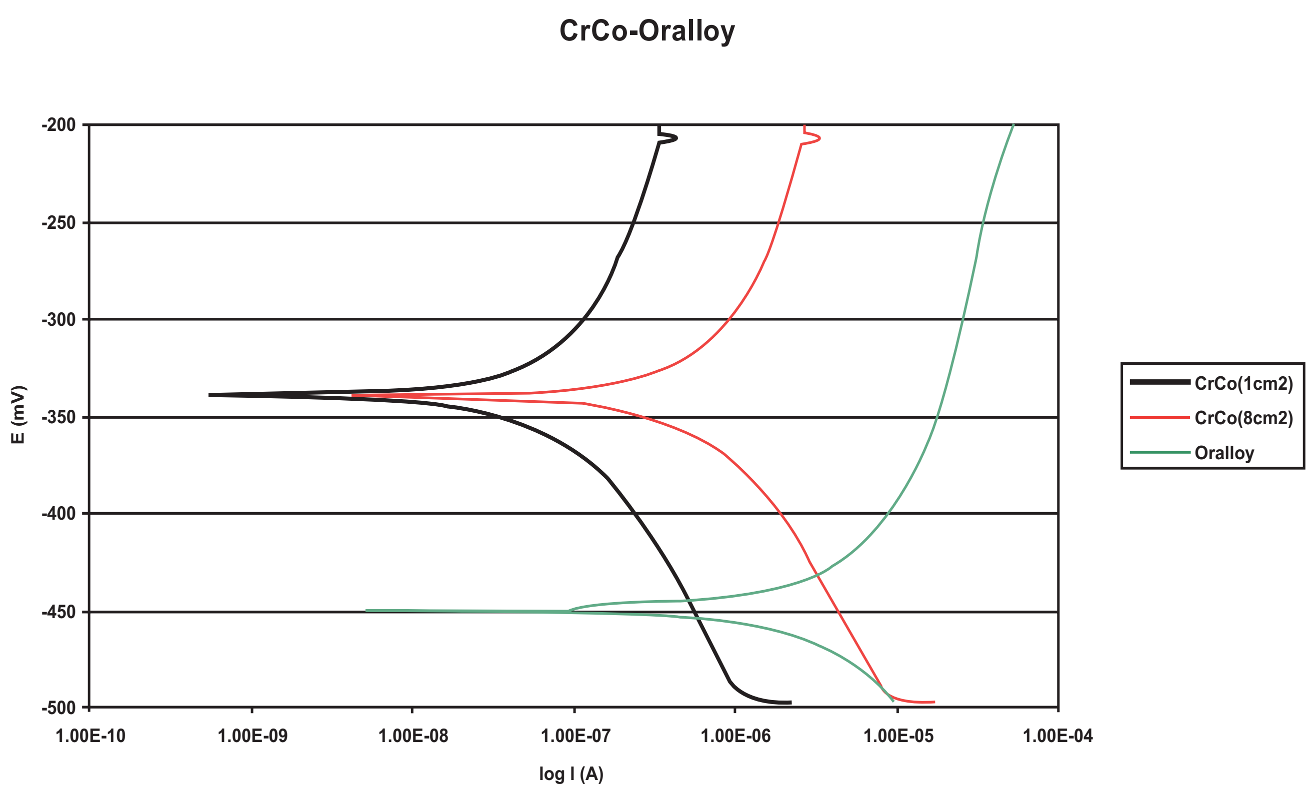


**Fig. (6).** Cathodic polarization curves for the "CoCrMo alloy" (1cm$^2$ and 8cm$^2$) and the "conventional amalgam" (1cm$^2$).

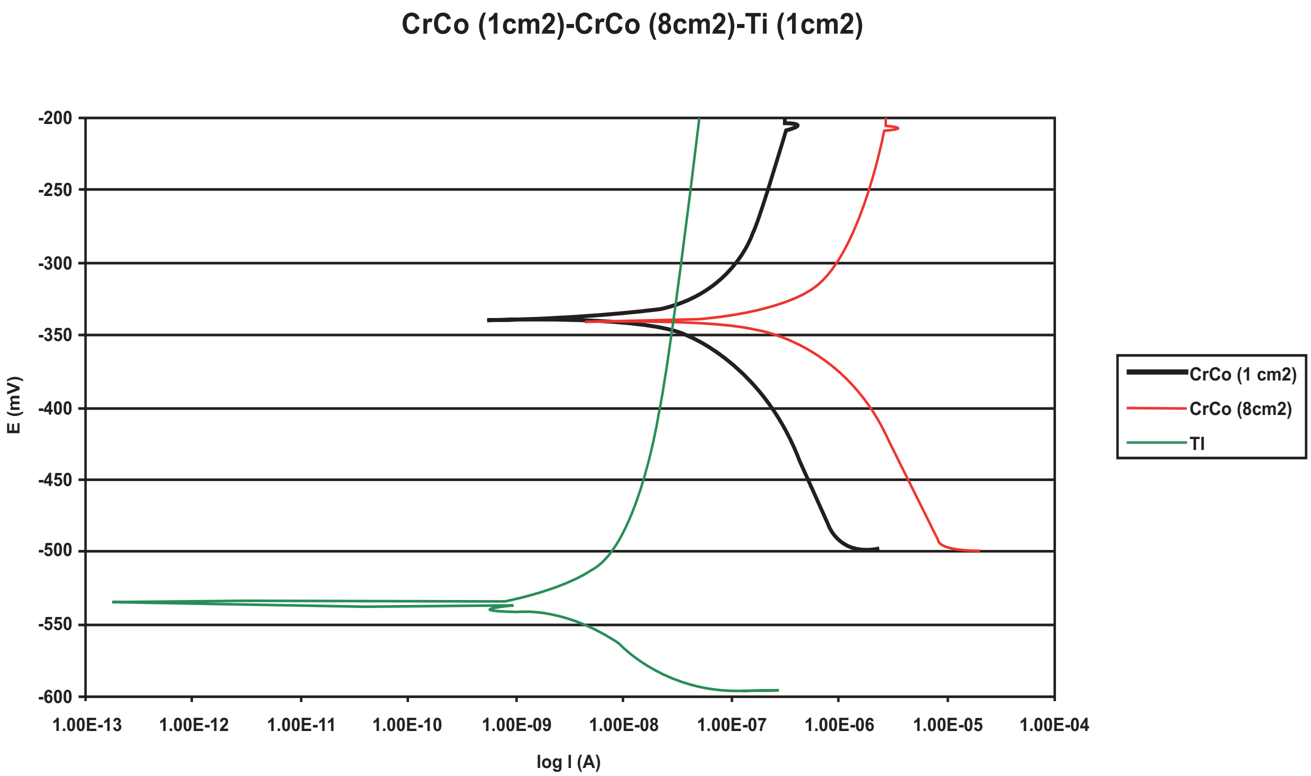


**Fig. (7).** Cathodic polarization curves for the "CoCrMo alloy" ($1cm^2$ and $8cm^2$) and titanium($1cm^2$).

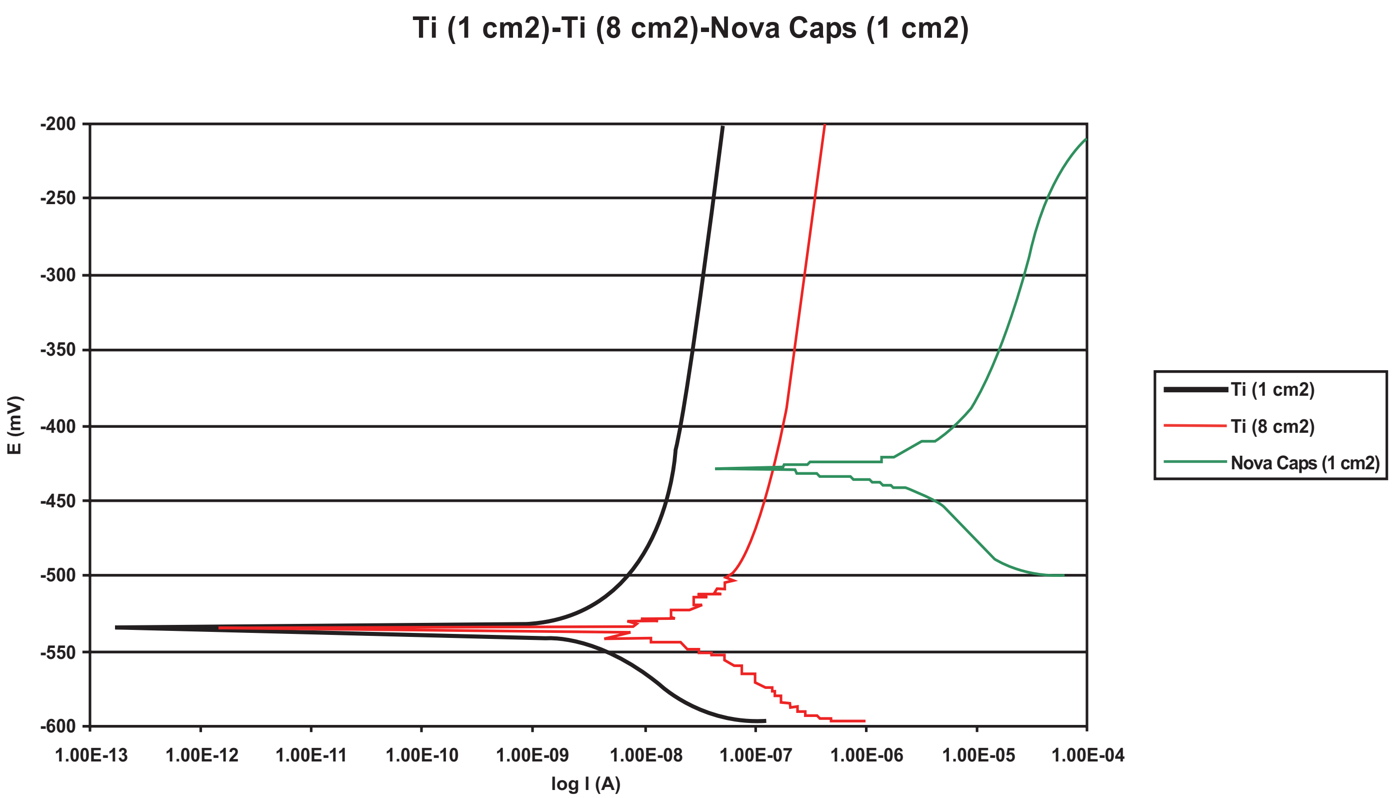


**Fig. (8).** Anodic polarization curves for titanium ($1cm^2$ and $8cm^2$) and the "high copper amalgam" ($1cm^2$).

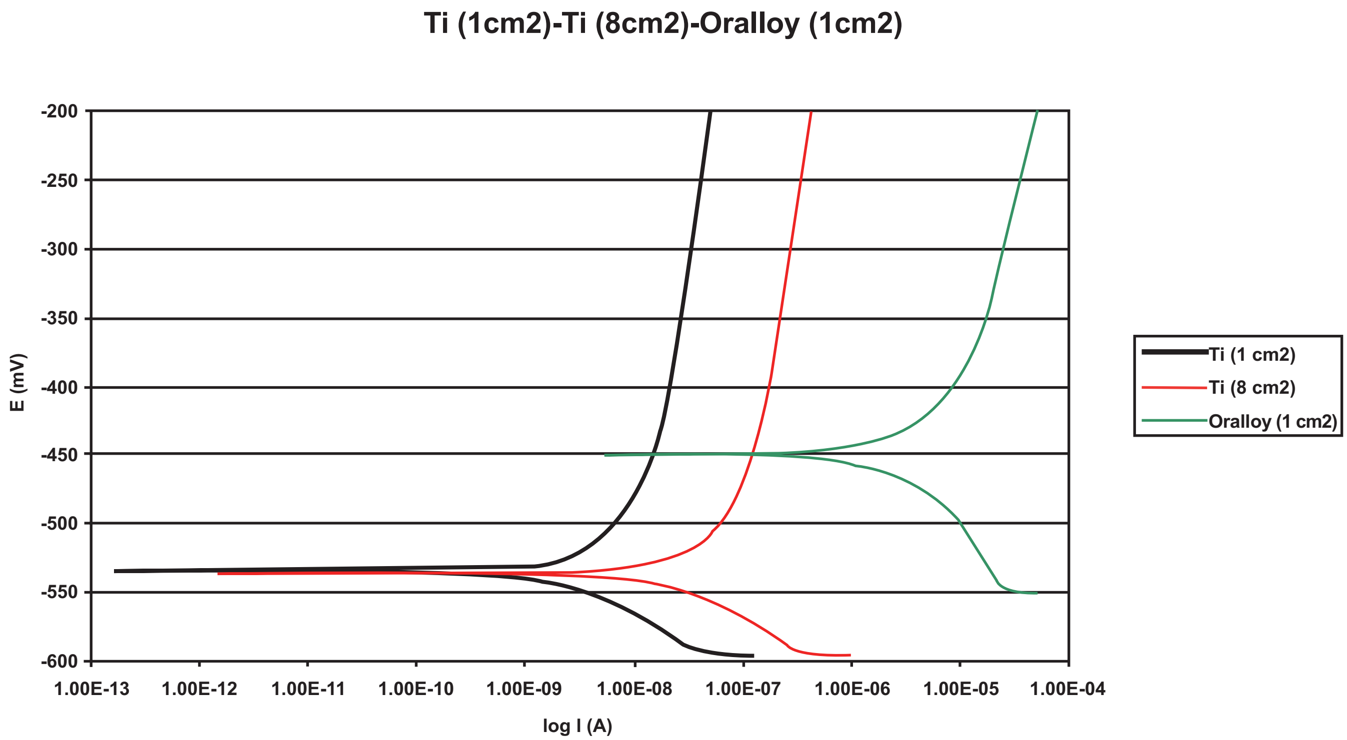


**Fig. (9).** Anodic polarization curves for titanium (1cm$^2$ and 8cm$^2$) and the "conventional amalgam" (1cm$^2$).

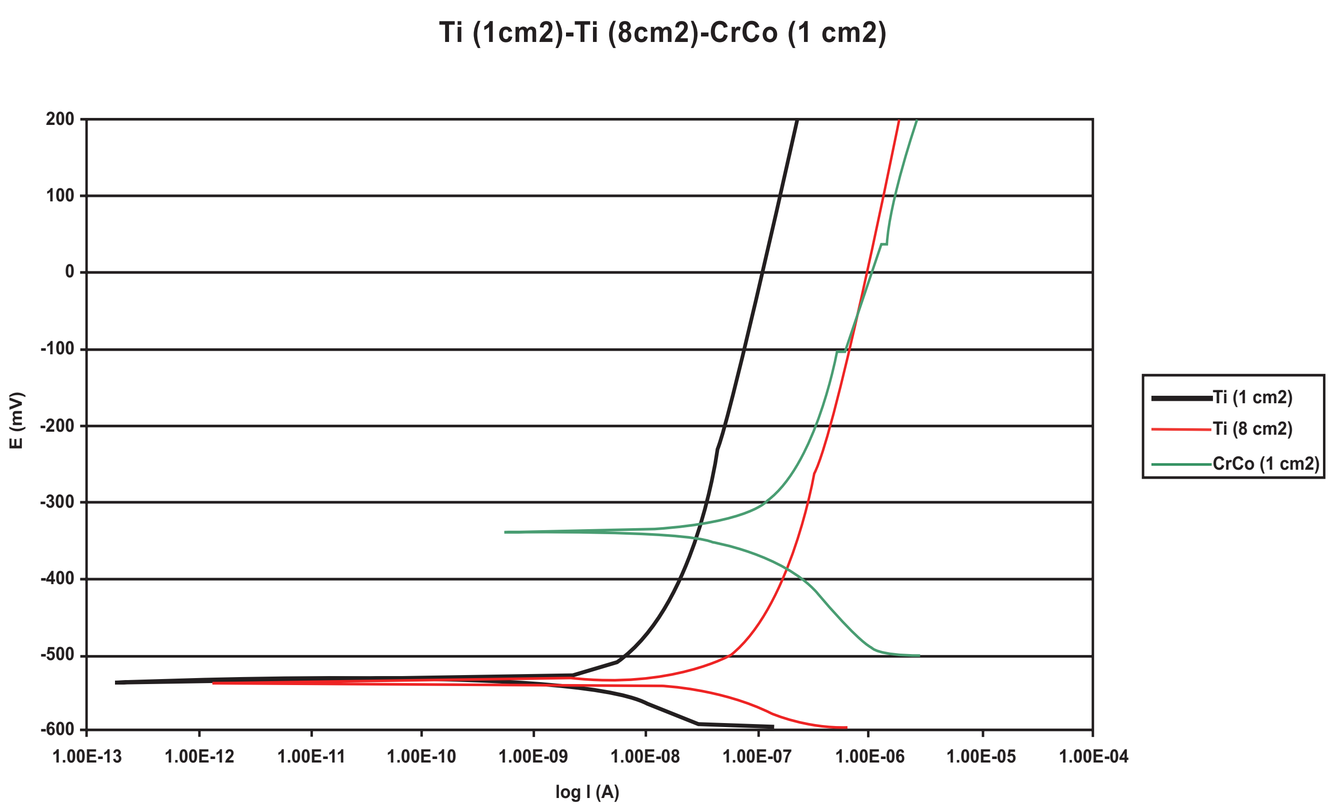


**Fig. (10).** Anodic polarization curves for titanium (1cm$^2$ and 8cm$^2$) and the "CoCrMo alloy" (1cm$^2$). $E_{corr}$: Corrosion potential - $I_{corr}$: Corrosion current density - $I_p$: Passive current density.

alloys [2, 8, 17, 18] or type of restoratives. Corrosion is influenced by several factors such as pH, test environment and the metal [16]. It is known that the corrosion decreases time dependent due to the formation of corrosion products on the amalgam surface [18]. The currents in the beginning are original and not shadowed by corrosion products covering the surface. Surface finish was shown to be highly important for galvanic corrosion and the observed currents in gold-amalgam couples are markedly reduced with good surface polishes, especially in the case of spherical alloy amalgams [19]. In the present *in vitro* study, amalgam surfaces were highly polished in order to avoid false high currents.

In the present study titanium or CoCrMo/amalgam area size ratio was 1:1 and 8:1. Two different amalgams with different composition were chosen to be investigated (Table **1**). The increasing area ratio of titanium or CoCrMo resulted in a higher current density in agreement with other studies [2, 17]. The interesting finding of this study was that titanium exhibited very little current densities compared to the CoCrMo casting alloy when coupled to the amalgams in both area ratios. These results force the recommendation: in the case of a partial denture planning where too many amalgam restorations exist in the oral cavity, either all amalgams should be exchanged with non-metallic restorations such as composite or ceramic, or titanium should be chosen as casting metal for the framework, to avoid the higher galvanic interaction of amalgams with the CoCrMo casting alloy.

The results of this study have confirmed the knowledge that the conventional amalgam exhibits a higher $I_{corr}$ than the high copper amalgam [20-22]. Another finding was that the CoCrMo/titanium ratio of 1:1 and 8:1 showed a similar low current density, respectively, while the raise of area size ratio of CoCrMo/ titanium to 1:8, increased the galvanic current density seriously. It can be speculated, that the use of titanium as casting alloy for partial denture framework fabrication should be avoided in the presence of one or two CoCrMo alloy crowns, whereas in the presence of several CoCrMo alloy crowns it would be rather harmless due to similar area sizes of CoCrMo and titanium, where the galvanic interaction would be negligable.

The present study was designed under *in vitro* conditions, which do not simulate the oral cavity conditions exactly. The corrosion process taking place in the oral cavity is effected by several parameters such as the action of mechanical forces and the environment and comparisons of *in vitro* and *in vivo* results are difficult [23].

It can be concluded that there is a requirement of clinical follow-up of the interaction of amalgam restored teeth and denture framework produced from the CoCrMo alloy or titanium.

## CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions can be drawn:

1. The galvanic current densities were seriously lower for titanium and the amalgams in comparison to the CoCrMo alloy and the amalgams for both area ratios. In the case of a partial denture planning where too many amalgam restorations exist in the oral cavity, either all amalgams should be exchanged with non-metallic restorations such as composite or ceramic, or titanium should be chosen as casting metal, to avoid the higher galvanic interaction of amalgams with the CoCrMo casting alloy for the framework.
2. The interaction between titanium and the CoCrMo casting alloy showed a low galvanic current density (titanium / CoCrMo; 1:1, 1:8), whereas higher titanium area ratio (titanium / CoCrMo, 8:1) raised it. It can be speculated, that the use of titanium as casting alloy for partial denture framework fabrication should be avoided in the presence of one or two CoCrMo alloy crowns, whereas in the presence of several CoCrMo alloy crowns it would be rather harmless due to similar area sizes of CoCrMo and titanium, where the galvanic interaction would be negligable.
3. The high copper amalgam exhibits lower corrosion current densities than conventional amalgam in contact with CoCrMo alloy and titanium in all area size ratios.
4. There is a requirement of clinical follow-up of the interaction of amalgam restored teeth and denture framework fabricated from a CoCrMo alloy or titanium.

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