A Comparative Study on Relative Adherence of Metal Ceramic Porcelain with Precious and Non Precious Alloys Using Electron Spectroscopy for Chemical Analysis Technique

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Citation

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Abstract

With advent advancement in All Ceramic System available, the metal ceramic restorations are still widely used. For any metal ceramic restoration to survive the masticatory load, environment, and time exponential stress in form of tensile, compressive and shear in the oral cavity, a strong bond is required between the cast metal coping and the porcelain. The aim of this study was to make a comparison between the relative adherence of porcelain (VITA VMK68) with two precious and two non precious metal ceramic alloys using ESCA. 20 cast plates 13mmX13mmX1mm in dimension, 5 High Palladium Alloy (Neopal), 5 Silver Palladium (Degustar-F), 5 Nickel Chrome (Remanium CS), 5 Cobalt Chrome (Remanium2000), were prepared according to ADA specifications, porcelain 1mm thick was applied. These cast plates were subjected to bi-axial flexure of the specimen in a constant strain in a special apparatus loaded on an Instron machine and compressive load was applied at a stroke rate of 0.25 mm/minute. This resulted in adhesive fracture of the porcelain. The area of retained porcelain after fracture from a surface of the cast plate was calculated by using ESCA instrument. The value of relative adherence of Vita VMK 68 to all the four alloy groups was calculated as numbers of squares occupied by silica peak in ESCA reading chart. The value obtained was statistically analyzed using one way variance analysis (ANOVA). From the statistical analysis it was found the value of relative adherence of two precious alloys is varying and is statistically significant.The value of relative adherence of two non-precious alloys varying and is statistically significant. The overall comparison of relative adherence of precious alloys with that of non precious alloys shows appreciable variation between them. When these values are subjected to statistical analysis, they are statistically highly significant.

INTRODUCTION

Even after many advancement in All Ceramic System available, the metal Ceramic restorations are still widely used. The formation of a strong bond between the cast metal coping and the porcelain is essential for any metal ceramic restoration to survive the masticatory load, environment, and time exponential stress in form of tensile, compressive and shear in the oral cavity.

Factors such as wettability of porcelain, oxide layer formation, type of alloy, composition, coefficient of thermal expansion of metal and porcelain and manipulative procedures play a vital role in bonding of porcelain with the metal.[1]

The present study was undertaken to evaluate the bond strength in terms of relative adherence of porcelain with metal by using test specimen with standardized dimension and procedure. Four commercially available Metal ceramic alloys were chosen, out of which two were precious alloys and two were non precious alloys. Five specimens were prepared for each group. The entire test specimens were subjected to constant flexural strain in a special apparatus to debond the porcelain from the metal. The retained porcelain after the surface of cast metal plates was calculated by using ESCA (Electron Spectroscopy for Chemical Analysis).

The study had following aim:

1. To compare the relative adherence of porcelain to two precious alloys namely, 1 st generation High Palladium alloy (Neopal, Dentaurum, Germany) and Palladium Silver alloy (Degustar F, Degussa Germany).

2. To compare the relative adherence of porcelain to two Non precious alloys namely Nickel-Chrome alloy (Remanium CS Dentaurum, Germany) and Chrome Cobalt alloy (Remanium 2000).

3. To compare the relative adherence of porcelain between precious and non precious alloys.

The result obtained concluded that precious alloy group exhibited better adherence to porcelain than non precious alloy group. Amongst the precious alloy the first generation High- Palladium alloy exhibited better adherence to porcelain than Palladium Silver alloy.

Nickel Chrome alloy exhibited better adherence to porcelain than Cobalt Chrome alloy.

MATERIALS AND METHODS

PREPARATION OF THE SPECIMENS

The precious alloy group consisted of first generation High palladium alloy (Neopal, Dentaurum, Germany) and Silver palladium alloy (Degustar- F, Degussa, Germany).

The base metal group consisted of Nickel Chrome alloy (Dentaurum, Germany) and Chrome Cobalt alloy (Remanium -2000, Dentaurum, Germany).

Composition of Precious alloys used for this study is given in Table1.

Figure 1

Table 1

Name	Palladium	Gold	Silver	Copper	Gallium	Tin	Trace elements
Neopal	79%	2%	-	9%	9%	-	Ruthenium Aluminium Zinc
Degustar-F	51.9	-	38%	-	-	7.5%	Ruthenium

The composition of the Non precious alloys used for this study is given in Table2

Figure 2

Table 2

Name	Cobalt	Nickel	Chromium	Molybdenum	Tungsten	Silica	Trace Elements
Remanium 2000	61	-	25	7	5	1.5	Copper Manganese Cilium
Remanium CS	-	61	26	11	-	1.5	Iron Cobalt Cilium

5 test specimens were prepared from each alloy according to ADA specifications. The wax patterns used to fabricate cast plates were prepared from a standard metal Die in order to standardize the dimension. Each specimen was casted with dimension of 13mm X 13mm X 1mm.

After divesting, the cast plates were trimmed and metallographically polished on both sides using silicon carbide abrasive paper of 400 to 600 grit. One side of the plates was sandblasted using 50 micron alumina particles in a non recycling air abrasive sand blasting unit to create surface roughness for.[2])

In case of non-precious alloys used in this study, no oxidation was required prior to bonding with porcelain. For precious alloys, following the manufacturer’s instructions, oxidation was carried out at 980 °C under vacuum.

Acrylic template of 1 mm thickness with a circular opening of 6mm in the centre was used for the application of the porcelain, on the cast plate to obtain a uniform thickness of bonded porcelain on all specimens. Opaque porcelain was applied for a total thickness of 0.2 mm. Body porcelain was applied to obtain a final thickness of total 1mm. The thickness of the porcelain was checked using Iwanson’s metal measuring gauge.

DEBONDING OF THE PORCELAIN

Fracture of the porcelain was accomplished by bi-axial flexure of the specimen in a constant strain. The apparatus described by Mackert et al was used which consisted of a metal plunger and a die. [3] Radius of curvature at the tip of the plunger was 36mm. A deflection of 0.4 mm is possible at the centre of the specimen by constant loading of the plunger on the specimen. This deflection of the cast plate caused the fracture and removal of the porcelain from the cast plate.(Fig 1)

The plunger and die were connected to the Instron testing machine and the specimens were loaded with the porcelain facing down. A compressive load was applied at a stroke rate of 0.25 mm/minute. The maximal deflection was recognized from the point of inflection on the load-deflection plot as a break in the graph. At this point the specimens acquired the shape of the plunger.

Any loosely retained porcelain fragments were removed from the surface of the cast plates with a soft bristle brush. This was followed by cleaning in ultrasonic unit with distilled water for 10 minutes.(Fig 2)

ESTIMATION OF RELATIVE ADHERENCE VALUE OF RETAINED PORCELAIN USING ESCA

The area of retained porcelain after fracture from a surface of the cast plate was calculated by using ESCA instrument.

Electron spectroscopy for chemical analysis is a powerful instrumental technique. The photons beam from an X-Ray source interacts with the substance and the kinetic energy of the electron emitted is monitored. [4]The kinetic energy of the ejected electron is equal to the energy of the incident photon less the binding energy E. A measurement of the kinetic energy is thus a means of identifying the sample and the quantity of the electrons is proportional to the concentration. The ESCA instrument is used for accurate analysis of surface composition and characterization of given samples. Prior to testing the specimen in the ESCA unit they were Argon ion etched for 5 minutes. This aids in removing of surface impurities. Estimation of Silica ion concentration was selected to calculate the area covered by the porcelain as silica-dioxide is the major constituent of the dental porcelain.

The area of adherent porcelain on the cast plates after deflection was calculated by the ESCA testing units and results were obtained.(Fig 3,4)

The value of adherent porcelain on each sample was obtained by the Square Grid Method to calculate the area occupied by each silica peak, which denotes the concentration of silica ions. The results were subjected to statistical analysis to find out its statistical significance. Statistical analysis using one way variance analysis(ANOVA) was carried out to determine whether there was any significant difference overall amongst 4 group of alloys.(Fig 5)

RESULTS

The value of relative adherence of Vita VMK 68 to all the four alloy groups was calculated as numbers of squares occupied by silica peak in ESCA reading chart. These values are tabulated in Table 3

Figure 3

Table 3

Alloy	Mean Adherence Value of Porcelain
Neopal	658.6
Degustar-F	619
Remanium CS	520.2
Remanium 2000	400.6

These values were subjected to one way variance analysis (ANOVA) to compare the relative adherence of the retained porcelain after bi-axial flexure of the specimen.

From the statistical analysis it was found the value of relative adherence of two precious alloys is varying and is statistically significant.

The value of relative adherence of two non-precious alloys varying and is statistically significant.

The overall comparison of relative adherence of precious alloys with that of non precious alloys shows appreciable variation between them. When these values are subjected to statistical analysis, they are statistically highly significant.

Figure 4

Figure 1 Bi-axial Flexure apparatus showing metal plunger and die

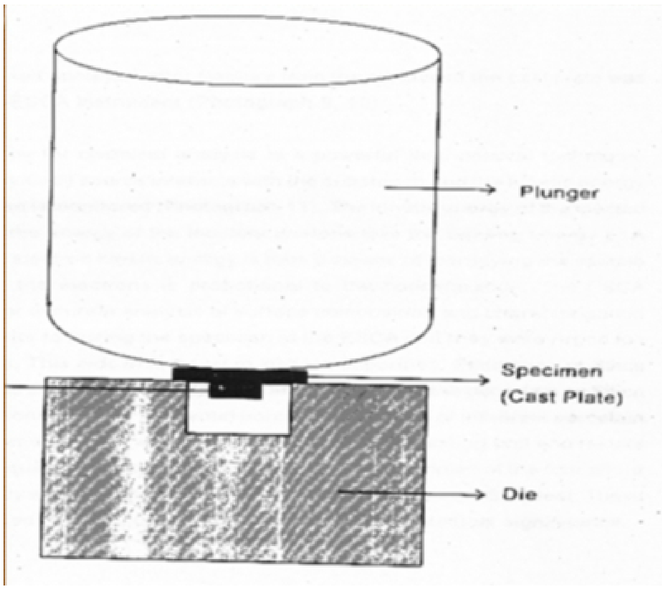


Figure 5

Figure 2 Apparatus loaded in Instron testing machine

Figure 6

Figure 3 ESCA testing unit with control Panels

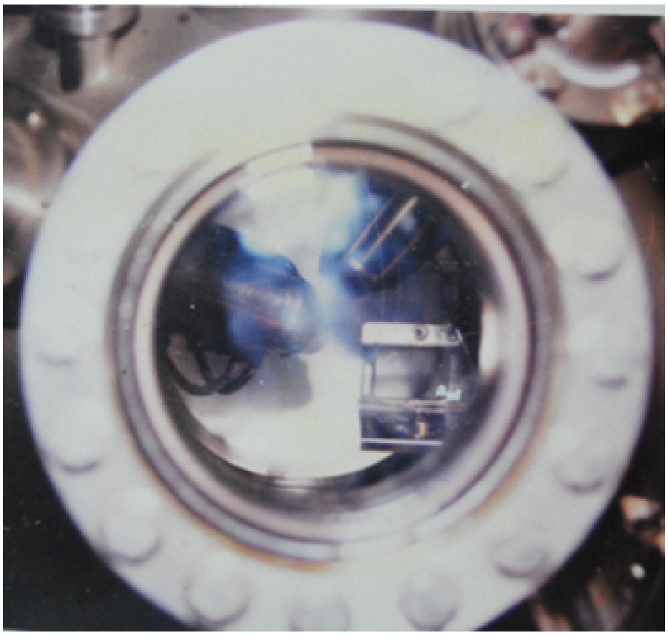


Figure 7

Figure 4 ESCA chamber for placement of the specimens

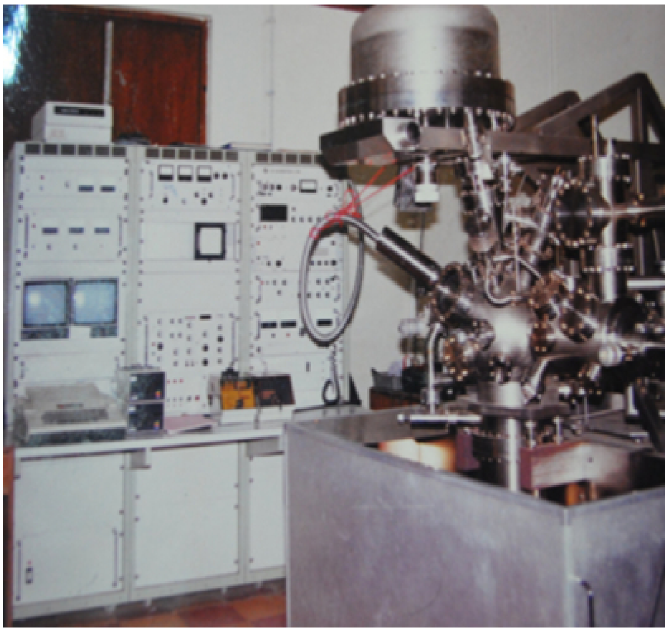
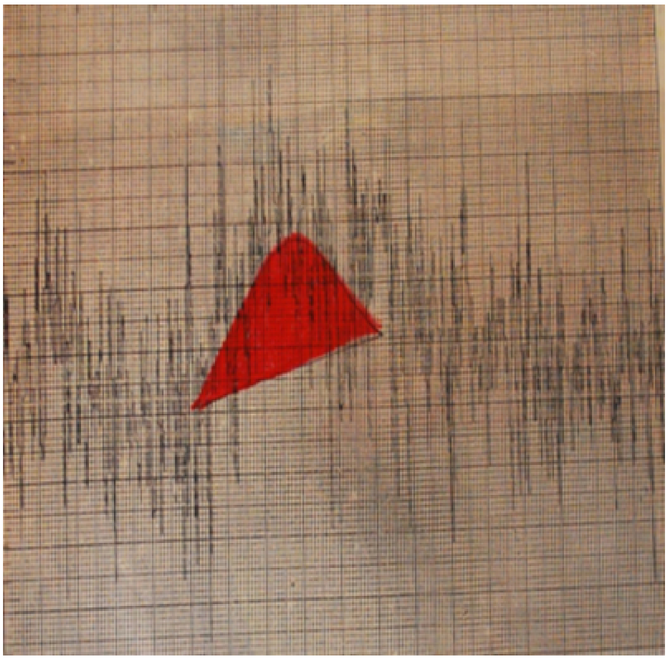


Figure 8

Figure 5 ESCA reading chart with superimposed Square Grid



DISCUSSION

Metal ceramic restorations have to overcome masticatory forces in the form of compressive, tensile and shear forces during function. Hence, a strong bond between porcelain and metal is of utmost importance so as to avoid failure of bonding in metal ceramic restoration. In 1977 O'Brien formulated Non specific cohesive plateau theory to describe the metal ceramic bond. [5]In contrast to other theories which attempted to explain fundamental process for attachment of porcelain to metal, the cohesive plateau theory characterizes the general nature of bond failure. The interfacial bond strength was found to be low in cases where high incidence of adhesive failure occurs between the porcelain and metal. The interfacial bond strength was high when cohesive failure occurs within the porcelain indicating the presence of optimal bond strength.

It has been observed by several investigators that the type of failure rather than the numerical values generated by a particular test may be the more important indicator of the quality of the porcelain-metal bond (Sced and McLean, 1972; Mc-Lean, 1974; O'Brien, 1977). [6]Thus, the examination of the fracture surfaces to determine the cohesive site density of retained porcelain has been suggested as a method of evaluating the porcelain-metal bond (O'Brien, 1977). Based on cohesive plateau theory, a universally accepted test design for characterization of bond strength was deployed to evaluate the bond strength in terms of relative adherence. [7]This study was done to evaluate the bond strength in terms of relative adherence of porcelain with metal by using test specimen with standardized dimension and procedure. All the four alloys used in this study show a combination of cohesive failure in the porcelain and adhesive failure between the porcelain and the oxide layer. The area covered by the retained porcelain on the debonded surface of the specimen was estimated by using ESCA test. This technique helped in estimating the concentration of silica ions present in each specimen after debonding. ESCA is surface chemical analysis technique used as a quantitative measure. Depth of penetration of X-Ray beam is about 50-100 A. When measuring the concentration of an element present in the specimen it may show an error of about 5-7%. However this study compared the quantity of silica ions as a measure of relative adherence of porcelain. When relatively comparing the values this technique gives accuracy of about 0.1%. Hence the values obtained regarding porcelain adherence to alloy specimen are much reliable.

the results obtained in this study it was found that the relative adherence of two precious and two non-precious alloys taken in this study are varying. The precious alloys showed increased area of porcelain adherence with the ESCA analysis, by showing higher silica peaks, in the reading chart. The mean adherence of 1 st generation high palladium alloy (Neopal) is 658.9, and that of Palladium Silver alloy is 619. A variation of 39.9 is noticed between these two alloys. The variation in the mean value of these two alloys may be attributed to the composition of alloys taken for this study. Presence of copper in high palladium alloys not only helps in formation of the oxide layer, but also promotes bonding of the porcelain to the metal. [8]On the contrary the bonding between porcelain and Palladium-silver is more of physical in nature, because formation of oxide layer is not totally proven in these alloys. Mackert, Ringle, Fairhurst have observed Palladium Silver alloy specimen after oxidation procedure using SEM and have reported presence of surface nodules which may be possible mechanism behind the bonding with porcelain.[9] These finding are in conformity with the interfaces of selected precious metal alloys with adequate oxide layer have greater resistance to adhesive failure by flexure than the interface where oxide layer is too thin or thick. Hence adequate thickness of the oxide layer is essential in preventing bonding failures. The mean value of relative adherence of Nickel Chrome alloy (Remanium CS) is 520.2 and that of Chromium-Cobalt alloy (Remanium 2000) is 400.6. Variation of 119.6 is noticed between these two alloys. This variation also may to attribute to the composition of these alloys. Baran et.el deployed ESCA technique to study various oxides present on the surface of Nickel chrome alloy and concluded that various oxides that contribute to bonding are Nickel oxide, Chromium oxide and Molybdenum oxide. [10]The high percentage of Molybdenum and presence of iron as trace elements may the reason for the better bond strength of Remanium CS that that of Remanium 2000.

When comparing mean value of relative adherence of precious alloys with that of non-precious alloys it is noticed that precious alloys claim superiority over non precious alloys. This variation may be attributed to the following reasons:

1. One of the principle difficulties in the non precious alloys is to control the thickness of the oxide layer which is critical for porcelain bonding. [11]

2. One of the prime requirements of good interfacial bonding is adequate wetting of the alloy surface by the porcelain. This is accomplished by formation of low contact angle.

The contact angle between porcelain and precious alloys has been found to be lower than that of Non precious alloys. [12]

In this study it can be concluded that relative adherence of porcelain with precious alloys is better than that of non precious alloys. However when selecting the alloy for metal ceramic application apart from adherence value of porcelain it is also important to consider other physical and mechanical properties such as percentage of elongation yield strength, Coefficient of thermal expansion, sag resistance, hardness of the alloy etc.

SUMMARY

This study was done to evaluate the bond strength in terms of relative adherence of porcelain with metal by using test specimen with standardized dimension and procedure. Four commercially available Metal ceramic alloys were chosen, out of which two were Precious alloys and two were Base metal alloys. Five specimens were prepared for each group. The entire test specimens were subjected to constant flexural strain in a special apparatus to debond the porcelain from the metal. The retained porcelain after the surface of cast metal plates was calculated by using ESCA (Electron Spectroscopy for Chemical Analysis).

It was concluded that relative adherence of porcelain with 1 st generation High Palladium alloy is better that of the Palladium Silver alloy. The relative adherence of porcelain with Nickel chrome alloy is better than that of Chrome cobalt metal ceramic alloys.

According to this study precious metal ceramic alloys exhibited a stronger metal ceramic bond than that of non precious alloys.

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