

Evaluation and comparison of bond strength and the effect of ingredients of two high-palladium alloys with porcelain - An *in vitro* study

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Keywords:

Begopal high-palladium alloy, bond strength of porcelain, high-palladium alloy, option high-palladium alloy

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Received: 23 September 2017;

Accepted: 28 October 2017

doi: 10.15713/ins.jcri.187

Abstract

Purpose: This study was conducted to evaluate and compare the bond strength of porcelain with two commercially available high-palladium alloys (Option and Begopal). **Materials and Methods:** A total of 20 wax patterns, 10 for each alloy were made and casting was carried out using the high-palladium alloys Option and Begopal. The cast specimen was subjected to sandblasting with 50 μ m aluminum oxide and later cleaned with ultrasonic cleaner. Conventional degassing in the porcelain furnace was done. D1 shade of opaquer and dentine of total 2mm thickness were then fired over the degassed specimen. The metal-ceramic specimen of both groups of test samples was subjected to the evaluation of bond strength on a Universal Testing Machine.

Result: The Option high-palladium alloy exhibited higher bond strength values as compared to that of Begopal, though both showed more of a cohesive fracture as evaluated by the (scanning electron microscope/energy dispersive spectrometric) study as well as visual examination. The statistical tests suggested that the Begopal alloy resulted in a weaker bond as compared to Option alloy.

Introduction

Since the past four decades, metal-ceramic restorations have held their own due to their esthetic and physical properties. There has always been a search for the ideal metal-ceramic alloy which leads to the development of many new alloy systems which claimed superiority in some or the other properties.^[1] Metal-ceramic restorations being central to the practice of fixed prosthodontics, numerous high noble, noble, and conventional base metal alloys are available for porcelain veneering.^[2] The obvious advantages of base metal alloys are lighter weight, higher strength properties (although exceptions may be found), and of course reduced costs. However, due to adverse effects of Ni-Cr alloys and other base metal alloys such as allergies and sensitivity, economically low-priced palladium alloys could substitute precious metal alloys. The high-palladium groups can be subdivided into those containing silver and those that are silver free.^[3]

High-palladium dental casting alloys that contain greater than 75% weight of palladium based on Pd-Cu-Ga (first generation) and Pd-Ga (second generation) systems were introduced in the 1980's as an alternative to gold-based alloys for fixed prosthodontics.^[4-6]

High-palladium based alloys are widely used for fabrication of ceramo-metallic restoration such as implant superstructures and crown and bridge-fixed partial dentures. There exist wide variations in the composition of these alloys either containing silver, copper, gallium, or ruthenium. It was thought appropriate that such variations in composition might affect the bonding of porcelain to such high-palladium based alloy copings.

Therefore, a study is proposed to evaluate two commercially available high-palladium alloys having different compositions with the following objectives:

- To evaluate the shear bond strength of two commercially available high-palladium alloys with porcelain.
- To compare the bond strength of two commercially available high-palladium alloys with porcelain.
- To evaluate the effect of ingredients on this porcelain bond strength.

Materials and Methods

In this proposed study, the shear bond strength of two commercially available high-palladium alloys with porcelain was evaluated and compared.

Metal specimen preparation

Wax pattern for the metal specimen was made from inlay wax. 10 wax pattern for each alloy were prepared to a size of 10 mm length × 10 mm width × 1 mm thickness. These wax patterns were then attached to a ×3 crucible former. They were sprayed with Lubrofilm, a wax surface tension reducing agent. A ×3 casting ring lined with a wet asbestos liner was attached to the crucible former. The wax pattern was invested in a carbon-free phosphate-bonded investment material with a powder-liquid proportion specified by the manufacturer and mixed in a vacuum mixing machine. 45 min after investing wax, burn out was carried out in a burnout furnace. The temperature was raised from room temperature to 430°C and the ring was heat soaked at 430°C for 1 h. Then, the temperature was finally raised to 900°C and the rings were heat soaked for 30 min.

The two types of high-palladium alloys Option and Begopal were melted in individual ceramic crucibles in a broken arm centrifugal induction casting machine, and the casting was carried out. The castings were then bench cooled, divested, and cleaned by air abrasion (50 µm aluminum oxide) and ultrasonic cleaning [Figure 1].

Metal-ceramic specimen preparation

A single metal specimen was taken placed on a silicon nitride porcelain firing tray, placed in a porcelain furnace, and degassed at 980°C under vacuum.

10 mg opaque porcelain of D1 shade was mixed with modeling liquid to a paste consistency. Opaquer was applied on a cooled metal specimen with a porcelain brush placed in a furnace and fired up to 970°C. The specimen was taken and cooled to room temperature. 10 mg of dentin powder of D1 shade was mixed with modeling liquid to a paste consistency and applied to the specimen with a porcelain brush to thickness 2 mm and subjected to firing at 910°C under vacuum in the porcelain furnace. The metal-ceramic specimen was allowed to cool to room temperature. Autoglazing was done by heating the test sample in the porcelain furnace. This was later allowed to cool to room temperature. The same procedure was carried out for the remaining 19 specimens.

The test metal-ceramic specimens were grouped as follows:

- Group A - metal-ceramic specimen of Option alloy designated as A1, A2... A10.
- Group B - metal-ceramic specimen of Begopal alloy designated as B1, B2... B10.

Each of these samples was embedded in individual autopolymerizing resin blocks which were made to fit into the metal die for the purpose of testing. The metal-ceramic specimens were tested for shear bond strength [Figure 2] on a Universal Testing Machine.

The amount of force required to fracture the bond between porcelain and metal was noted for each specimen of both metal alloys which formed the data of this study. The data for each specimen were tabulated and subjected to statistical analysis. A scanning electron microscope (SEM)/EDM evaluation of the



Figure 1: High-palladium alloys - Option and Begopal after casting



Figure 2: Metal-ceramic specimen of Option and Begopal after debonding

fractured site for one specimen of each alloy was carried out on a SEM and an energy-dispersive spectrometric (EDS) machine.

Results

Visual examination of the fractured sites revealed more of adhesive fracture through the bond. However, the cohesive nature of the bond was confirmed by a SEM/EDS analysis.

The shear bond strength of metal-ceramic specimen [Tables 1 and 2] was determined in KN/cm². These were calculated in MPa using the formula:

$$1\text{MPa} = 0.1\text{KN}/\text{cm}^2$$

Discussion

Ceramic metal restorations combine the beauty of porcelain and the strength of a metal substructure. It is well known that adherence between dental porcelain and alloy substrate generally depend on the development of strong chemical bond across the interface through an oxide layer on the alloy, as well as on mechanical interlocking at microirregularities created on the

alloy surface by air abrasion with Van der Waals forces playing a minor role.^[7]

Ideally, the oxide that forms during oxidation firing forms a monomolecular layer, which is part of the metal and part of the glass. Excessive thickness of the oxide layer may diminish the bond strength by permitting fracture through the oxide. The so-called metal conditioners and bonding agents function to absorb excess oxides formed on the surface of the alloy and/or to provide oxidation elements for the formation of appropriate oxidation elements for the formation of appropriate stable oxides for bonding with ceramic veneer during firing.^[8]

Due to the unpredictability and many processing variables influencing the bond strength between porcelain and high-palladium alloys, this study was undertaken to evaluate the shear bond strength of porcelain with two commercially available high-palladium alloys. In this study, two first-generation high-palladium alloys based on the Pd-Cu-Ga system were used for comparing the bond strength with porcelain. There were variations in the amount or atomic percentage of palladium, copper, and gallium in the two alloys tested. In alloy A (Option), it was 78.8%, 10%, and 9%, respectively. In alloy B (Begopal), it was 78%, 13.5%, and 1.4%, respectively.

The cast alloy specimen in this study was air-abraded with 50 μm aluminum oxide before oxidation to simulate the metal surface treatment in the normal dental laboratory practice. This enhanced mechanical interlocking and chemical interactions at the interface. The oxidation treatment of the ceramic alloys before porcelain application is also crucial. The variability of porcelain was kept to a minimum by single operator application. During this study, each alloy was heated according to the respective manufacturer's instructions.

Table 1: Shear bond strength values for Option and Begopal alloy

Option alloy		Begopal alloy	
Samples	Force (MPa)	Samples	Force (MPa)
A1	22	B1	26
A2	23	B2	28
A3	27	B3	22
A4	37	B4	26
A5	30	B5	33
A6	28	B6	22
A7	24	B7	28
A8	26	B8	28
A9	29	B9	23
A10	28	B10	22

Table 2: Comparison of mean and standard deviation of Option and Begopal alloys

Alloy	Mean \pm SD	t value	P value	Significance
A (Option)	27.4000 \pm 4.2739	0.8569	>0.05	NS
B (Begopal)	25.8000 \pm 3.6148			

SD: Standard deviation

The difference in the mean bond strength value of alloy A and B could be attributed to more of gallium content in alloy A (option) which was found to help in porcelain adherence due to the formation of gallium oxide.^[9] O'Brien systematically described the different interfacial failure modes possible with metal-ceramic systems and noted that optimum bonding is achieved when the metal oxide and oxide ceramic interfacial bonds, as well as the oxide layer, are sufficiently strong to create cohesive failure through the porcelain as is evident in this study.

The failure mode for the test samples of both these alloys was mostly cohesive, and it was confirmed by the SEM coupled with EDS (SEM/EDS) evaluation of the fractured site. The SEM/EDS observations of the fractured metal-ceramic specimen of alloy A (option) at three locations on the metal surface [Figure 3] showed that silicon K- α -X rays were associated at three points in varied areas. Visual observations of the fractured specimens surface revealed that a grayish layer, which was assumed to be metal oxide sparsely covered the debonded porcelain. This indicated that the failure was mostly cohesive with fragments of the porcelain still present on the metal surface though not clear on visual examination. SEM/EDS evaluation for the group of tested samples of alloy B (Begopal) [Figure 3] displayed similar fracture behavior but with comparatively very less incidence of silicone K- α X-rays. These observations were supported by the quantitative SEM/EDS data. The values of the bond strength of porcelain with these two commercially available high-palladium alloys are pertained to the materials, their nature, and fabrication. The testing methodology in the study was technique sensitive. The values obtained may not be repeated if the materials and the methodology differed.

Conclusion

The following conclusions were drawn from the study:

1. Both the alloys tested - Option and Begopal had adequate bond strength with porcelain.
2. Option had a higher mean bond strength value as compared to Begopal.
3. No significant ($P > 0.05$) difference existed in the mean bond strength values of the two alloys.
4. Gallium played a major role in the bond of porcelain to the alloy due to the formation of gallium oxide which resulted in a better bond of porcelain to the Option alloy.
5. SEM/EDS evaluation of the bond site concluded that the



Figure 3: Scanning electron microscope photograph of the surface of debonded Option metal-ceramic specimen and Begopal metal-ceramic specimen

silica content of the fractured specimen of the Option alloy was more as compared to Begopal.

Hence, we can conclude that porcelain adherence to the Option alloy is better as compared to Begopal.

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How to cite this article: Pai SA, Keerthi R, Abigail S, Nagaraj T. Evaluation and comparison of bond strength and the effect of ingredients of two high-palladium alloys with porcelain - An *in vitro* study. *J Adv Clin Res Insights* 2017; 4:171-174.

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