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ORIGINAL ARTICLE

Surface Bond Strength in Nickel Based Alloys

Ganesh Ramesh · T. V. Padmanabhan · Padma Ariga · Shalini Joshi · S. Bhuminathan · Vasantha Vijayaraghavan

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Abstract Bonding of ceramic to the alloy is essential for the longevity of porcelain fused to metal restorations. Imported alloys used now a days in processing them are not economical. So this study was conducted to evaluate and compare the bond strength of ceramic material to nickel based cost effective Nonferrous Materials Technology Development Center (NFTDC), Hyderabad and Heraenium S, Heraeus Kulzer alloy. An Instron testing machine, which has three-point loading system for the application of load onto the specimen was utilized for analyzing bond strength of both alloys. Student *t* test was conducted and *t* value obtained was 0.644, and the mean value of flexural bond strength of indigenous alloy is 81.75 with standard deviation of 12.25 and of imported alloy is 84.42 with standard deviation of 10.35, indicating that there was no significant difference between the two alloys. Due to ever increasing cost of imported non-precious alloy the need for a cost-effective replacement was fulfilled by indigenous NFTDC alloy.

Keywords Nickel based alloy · Surface bond strength · Flexural strength

G. Ramesh (✉) · S. Bhuminathan
Department of Prosthodontics, Sree Balaji Dental College and Hospital, Chennai, India
e-mail: rameshganesh@yahoo.com

T. V. Padmanabhan
Department of Prosthodontics, Faculty of Dental Sciences, Sri Ramachandra University, Porur, Chennai, India

P. Ariga
Saveetha Dental College and Hospitals, Saveetha University, Chennai, India

S. Joshi
Department of Prosthodontics, AME's Dental College & Hospital, Raichur, Karnataka, India

V. Vijayaraghavan
Department of Prosthodontics, Bharati, Vidyapeeth Dental College & Hospital, Pune, Maharashtra, India

Introduction

An "Attractive Smile" can be a prime asset to a person's appearance. Esthetic dental treatment can enhance a patient's own intensely personal image of how he or she would like to look.

Porcelain veneering has caused major breakthrough in esthetic dental treatment. Porcelain is presently the only material capable of maintaining its surface texture and color for extended periods without losing its naturalness. However, because of its excessive fragility, porcelain has its limitations. This limitation is overcome by the use of porcelain-fused-to-metal alloys. The technique of bonding feldspathic porcelain to a metal framework was invented in the late 1950's by Dr. Abraham Weinstein. The metal alloy could be precisely formed to fit the tooth via the lost wax technique. Since the alloys could form naturally integrated oxide coatings on their surfaces, the feldspathic porcelains formulated to veneer these frameworks could bond intimately with their surfaces.

The metal–ceramic restoration is considered a routine procedure with high predictability. Because of lower costs, the use of non-noble or base metal alloys for metal–ceramic restorations is now widespread. But compared to currently available alloys the cost of indigenous alloy is even more economical. Considering this a study was conducted to evaluate and compare the surface bond strength of ceramic to an indigenous alloy [Nonferrous Materials Technology

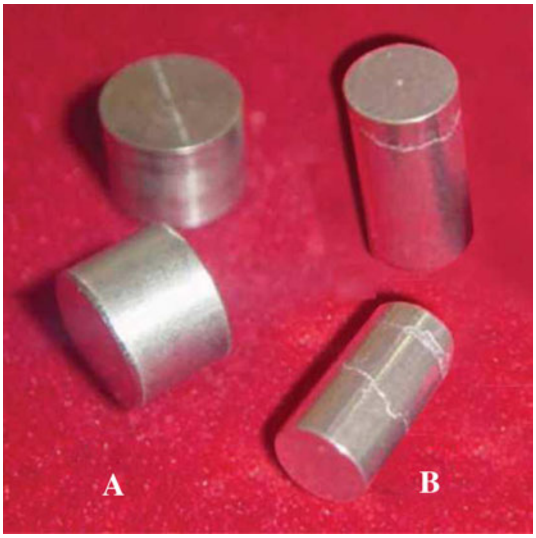

Fig. 1 **a** Indigenous alloy (Alloy A) and **b** currently available alloy (Alloy B)

Fig. 2 Brass metal die

Development Center (NFTDC), Hyderabad] (Fig. 1a) and currently available nickel based Alloy (Heraenium S, HeraeusKulzer) (Fig. 1b).

Materials and Methods

Thirty resin patterns using metal dies (Fig. 2) were prepared and divided into two groups of fifteen each. Castings from nickel based Alloy A (NFTDC, Hyderabad) and nickel based Alloy B (Heraenium S, HeraeusKulzer) with chemical composition (in weight percentage) of Ni 74.80 %, Cr 12.70 %, Mo 9.00 %, Al 2.00 %, Ti 0.32 %, Be −1.95 %, Co −0.45 % and Ni 60.98 %, Cr 23.8 %, Mo 11.3 %, Si 1.9 %, Fe 1.4 %, Ce 0.6 %, respectively were made from the resin patterns. Porcelain was then fired onto the castings, the specimens so obtained were mounted in an Instron testing machine and load was applied until a sharp cracking sound signifying bond failure was produced.

Sample Preparation

Brass metal die of dimension 30 mm length, 10 mm width, 3 mm height and a trough of 1.5 mm depth in the center was fabricated, using this resin patterns (Fig. 3) were made [1]. Castings of Alloy A and Alloy B prepared from resin patterns were trimmed, finished, sand blasted and placed in ultrasonic cleaner. On these castings, porcelain (Zeo CE porcelain light) build up was done in the trough after oxidation cycle. The surface of the porcelain was smoothened with a medium garnet sandpaper disc, ultrasonically cleaned and were brought to a high glaze.

Fig. 3 Resin patterns

Testing Bond Strength of Samples

An Instron testing machine which can record data up to 50 Kilo Newtons (KN) with a three-point loading system (Fig. 4) onto sample was used for study. Sample was placed in the bending apparatus with the porcelain portion positioned on the side opposite to the applied load (at a constant speed of 0.5 mm/min). An indication of failure of a specimen was easily noted by a sharp cracking sound accompanied by a sudden change in the digital signal indicating amount of load in KN required inducing failure in a specimen. It was then converted to flexural strength or surface bond strength (σ) using the following formula:

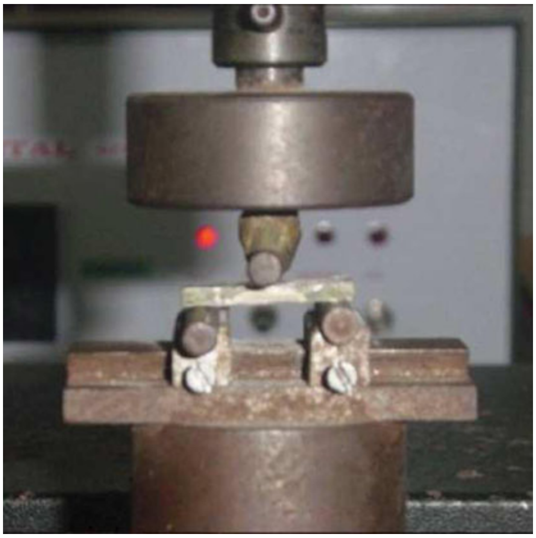

Fig. 4 Instron machine

$$\sigma = \frac{3P1}{2wh2},$$

where σ is the flexural strength, P is the applied load, l is the span length (distance between the two supports on which the specimen was placed), w is the sample width and h is the sample height.

Results

The mean value of surface bond strength/flexural bond strength of indigenous alloy is 81.75 (with standard deviation of 12.25) and that of imported alloy is 84.42 (with standard deviation of 10.35). Statistical analysis was done using Student t test for significant difference between alloys. The t value is 0.644 signifying that the difference between the surface bond strength of Alloy A and Alloy B is statistically insignificant.

Discussion

Dental porcelains are attractive because of biocompatibility, long term colour stability, wear resistance, and their ability to be formed into precise shapes, although they require processing equipment and specialized training. The chief objection to the use of dental porcelain as a restorative material is its low strength under tensile and shears stress conditions. A method by which this disadvantage can be minimised is to bond the porcelain directly to a cast alloy substructure made to fit the prepared tooth. The metal–ceramic alloys like high noble, noble and base metal alloys are used to bond with dental porcelain.

The base metal alloys form a surface oxide layer which is responsible for chemical bonding with porcelain [2]. Study by Uusalo et al. [3] showed, that the bond strength in nonprecious alloys was somewhat lower and the location of the fracture lines was more variable. It seems that non-precious alloys are more sensitive to laboratory procedures. But according to Anusavice [2], the bond strength values of nickel–chromium alloys to porcelain as determined from in vitro studies have not generally been superior or inferior to those for noble metal alloys. Three most common types of bond failures that can occur are cleavage through porcelain–metal interface, fracture through opaque and body porcelain and crazing of the surface of the restoration.

The base metal alloys feature lower cost, lower density, higher modulus of elasticity, higher hardness, and comparable clinical resistance to tarnish and corrosion compared to Type IV gold alloys [4, 5]. The nickel–chromium alloys exhibit the best range of mechanical properties for the porcelain-baked-to-metal technique, when considering the three most relevant properties: proof stress, plastic stiffness, and modulus of elasticity [6]. Bargi et al. [7] studied that porcelain-veneered-to-base metal alloy crowns had a higher fracture strength compared with high noble alloy crowns. Currently nickel based alloys are commonly used in clinical practices for metal ceramic crowns and fixed partial dentures.

Alloy A being more economical than Alloy B a study was conducted to compare the surface bond strength using rectangular metal strips with a trough in the middle with porcelain bonded to it. These gave precise control over thickness of porcelain and metal–porcelain interfacial surface area, which is critical for bond strength. They also allow uniform distribution of interfacial stresses and allow for testing effects of different texture for metal surfaces [8]. This has been substantiated by Caputo et al. [9], in their study of bond strength using flat specimens. Flexural tests using different loading systems have been considered. In a four-point system, specimen configuration dictates the location of failure [10] as the exact site and type of fracture is difficult to determine. Because of the complexity of stress distribution below the line of force application, this test may give misleading information concerning effects of experimental variables on interface failure [11]. A three-point loading system was used to test bond strengths of high palladium-content alloys by Lorenza et al. [12], as recommended by ADA council. So the specimens were placed in an Instron machine and three-point load was applied to determine the surface bond strength.

According to a study by Acova et al. [13] the mean shear bond strength was highest for the cast Ni–Cr metal–ceramic specimens (81.6 ± 14.6 MPa). All metal–ceramic specimens prepared from cast Ni–Cr exhibit a mixed mode of cohesive and adhesive failure [13]. In the present study similar mean bond strength value of 81.75 ± 12.25 MPa for nickel based NFTDC metal ceramic alloy was obtained suggesting promising results for the use of this alloy. Also previous study regarding castability using Alloy A also showed favourable results [14].

Further in vitro studies and certain in vivo studies such as bio compatibility of Alloy A, can also be conducted in the future. Future studies can be attempted by incorporating much higher speed of load application to simulate the normal intensity of masticatory load. Rate of loading was 0.5 mm/mt on the Instron testing machine. This is far slower than the rate of chewing which occurs at 7.4 mm/second. However, teeth would seldom strike at this rate of acceleration without food being interposed. It is only at the sustained muscle contraction as in bruxism or clenching, that teeth might come in contact applying forces at a rate closer to the actual testing conditions described in this study and also thickness of the specimen could be reduced to simulate the clinical crown thickness of 0.3–0.5 mm for metal framework and 1 mm thickness for porcelain section as mean bond strength would be lesser in these test specimens.

Summary and Conclusion

Within the limitations of this study i.e. rate of loading when compared to chewing, it can be concluded that due to ever increasing cost of imported non-precious Ni–Cr alloys in particular, the urgent need for a cost-effective indigenous replacement was fulfilled by Alloy A

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