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Effect Of Surface Treatment on The Shear Bond Strength Between Nickel-Chromium Alloy and Veneering Porcelain

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Abstract

Nickel–chromium (Ni–Cr) alloys, have been used widely, due to their superior physical properties and economic issues in relation to other precious alloys. Many studies have been carried out on porcelain fused to metal restorations to enhance the bonding quality of the porcelain to Ni-Cr alloy, such as mechanical treatment by air abrasion particles or chemical treatment by acid etching to increase the longevity of the restoration. The purpose of this study is to investigate the effect of surface treatments sandblasting with Aluminum Oxide (Al_2O_3), acid etching with Potassium hydrogen difluoride acid (KHF_2) and combination treatment on the shear bond strength between Nickel-chromium alloy substructure and porcelain veneer. Twenty-one cylindrical shaped samples have base of 5 mm in diameter and 1 mm in thickness and a cylinder with 4 mm in diameter and 4 mm in length were prepared from Ni – Cr alloy. The samples were divided into 3 groups (n=7) according to surface treatment: Nickel -chromium treated with sandblasting with 50µm Al_2O_3 group (c), Nickel – chromium etching with KHF_2 group (k), and Nickel – chromium sandblasting with 50µm Al_2O_3 followed with acid etching with KHF_2 group (comb). Then ceramic build up (opaque, dentin, enamel, and glaze Vita VMK Master opaque, dentin, enamel, and glaze Vita VMK Master) and sintering was performed according to manufacturer's instructions and the final dimension of porcelain cylinder (4 X 4X 1) were checked with a metal gauge. All samples were subjected to shear force in a universal testing machine at cross head speed 0.5 mm/min. and recorded in MPa. The fractured samples were checked under (DIGITAL MICROSCOPE) (X50) to evaluate the mode of failure, it was adhesive, cohesive and mixed failure modes. The shear bond strength values were analyzed with one-way ANOVA and LSD. The results showed that the highest mean of shear bond strength values was in Ni – Cr combination surface treatment group (26.11 ± 1.85), while the lowest mean was for Ni- Cr acid etched group (22.02 ± 1.5) and Nic group (20.85 ± 1.5). Within the limitation of the present study, the following conclusion can be drawn: Combination surface treatment produced the highest shear bond strength between Ni – Cr surface and veneering porcelain, followed by etching with KHF_2, so combination method would increase longevity of porcelain fused to metal restorations.

Introduction:

In dentistry, many alloy are used in for biomedical applications. An example of these alloys is the Nickel–chromium (Ni–Cr) alloys. This alloy has been widely used, due to its superior physical properties and economic issues in relation to other precious alloys [1,2]. It has been found that some restorations made from Ni-Cr may cause hypersensitivity and some tissue reactions [3]. Many studies have been carried out on ceramic restoration focusing at enhancing the bonding quality of the porcelain to metal system [4], since chipping and fracture of veneering porcelain is a serious clinical problem. Several surface treatments had been applied in order to improve bonding between alloy surface and porcelain. A mechanical treatment can be done by air borne particle abrasive (APA) with aluminum oxide Al_2O_3 and silica coated aluminum of different geometry. Also, a surface treatment chemically to improve the bonding includes acid treatment, hydroxylation and monomer [5]. Noteworthy, for improving the bond strength, sand blasting is the common surface treatment used. It increases the surface roughness and provides desirable undercuts [6].

Materials and methods:

1. Metal samples preparation

In this study, (21) cylindrical shaped wax pattern (Renfert, Germany, GEO Crowax). were fabricated with dimension of each sample as follows: the base is 5 mm in diameter and 1 mm in thickness and the cylinder is 4 mm in diameter and 4 mm in length using custom made rubber mold, for each wax pattern [7]. Each six samples of wax pattern were sprued by minor wax (Rinfert, Germany) wire 2 mm in diameter and 3 mm in length and it was attached to a major sprue. Wetting agent (renfert, Germany) was painted on the wax pattern to increase the surface tension and create a smooth model surface [8]. Then, the casting ring (4,8cm X 4cm, Germany), was seated on the crucible former and the investment (Bego- Sol ®, Germany) was mixed according to manufacture instruction. The mixing was done first by hand spatulation and then with aid of vacuum mixing machine, the ring was filled with investment material. The investment material was allowed to set according to manufacturers' instruction and following setting, wax elimination procedure was performed. The casting ring was ready to be placed in the casting machine when it was cherry-red in color in appearance [9]. When the alloy (Ni- Cr alloy, (Eisenbacher Dental Waren ED GmbH), was melted it has a mirror-like appearance and casting procedure was performed. After the casting ring was cooled, the investment was pushed out from the casting ring and broken. Sandblasting machine (Gudi England) was used to clean the sample from the remaining investment materials with (250μm) aluminum oxide particles (Renfert, Germany) according to the manufacturer instructions [10]. The final shape of metal substructures was shown in Fig. (1). The twenty-one metal samples were divided randomly into three groups according to surface treatment applied (n = 7).

2. Sandblasting with aluminum oxide group

Seven samples of nickel-chromium were air abraded with (50 µm) Al_2O_3 (Renfert, Germany). This was done by using sand blast unite (Gudi England) under pressure 80 Psi for 10 seconds and 10 mm distance from the nozzle opening of the sandblast head [10]. The samples were cleaned with steam cleaner to remove the debris on the metal surface before porcelain build up procedure [11].

3.Etching metal surface with potassium hydrogen difluoride acid group (KHF_2) group.

Seven samples of nickel-chromium were surface treated with KHF_2 acid (Merck, Germany). The metal surface was powder coated with 70 mg of KHF_2. the sample was heated in a porcelain furnace at temperature of 280 C°. The metal surface was cleaned for 15 second by using steam cleaner [21].

4.Combination of sandblasting with Al_2O_3 and etching with KHF_2 acid group (Ni comb group)

Seven samples were air abraded with Al_2O_3 by using sand blast unite (Gudi England) under pressure 80Psi for 10 seconds and at 10 mm distance from the nozzle opening of the sandblast head to the samples [10]. The samples were cleaned with steam cleaner to remove the debris on the metal surface [11]. Following air abrasion, etching by KHF_2 (Germany) (Merck)70 mg was performed. The metal surface was powder coated with 70 mg of KHF_2. the sample was heated in a porcelain furnace at temperature of 280 C°. The metal surface was cleaned for 15 second by using steam cleaner [12].

5.Porcelain build up

The procedure of veneering metal surface was performed by the conventional layering technique according to manufacturers` instruction. All layers of veneering ceramic (Vita VMK Master ®) were applied until the required 4 mm length and diameter of each sample was obtained. The mold consisted of a base of stainless steel with two joining plastic parts. These two plastic parts were connected by screw to allow opening and closing during build up procedure. The mold was isolated by ceramic separating solution to avoid adhesion of ceramic during layering technique. A specially designed custom-made metal mold was designed for porcelain build up. First, two layers of opaque porcelain (Vita Zahnfabrik, Bad Sackingen, Germany) with 0.5 mm thickness were applied and sintered. The Dentin powder (Vita Zahnfabrik, Bad Sackingen, Germany) of shade A3 was mixed with its liquid to form creamy consistency, the dentin layer was applied by brush. Then the 3rd layers of dentine and first layer of enamel were added into the mold, and each sample was removed from the mold, sintered according to the manufacturers' instructions [13] Fig. (2).

6.Shear Bond Strength Test

Each sample was placed in a custom-made cubic holder, 12 mm in dimensions having a hole in the center. The holder was held in a horizontal position in the lower member of a universal testing machine (Laryee WDW-50, China), as shown in Fig. (3). Each sample was secured tightly to lower jaw and parallel to horizontal plane during the application of the load (100 kg). The shear bond force was exerted vertically to the bonding interface between the edge of the Nickel- chromium sample and veneering ceramic with a stainless-steel chisel rod at a constant crosshead speed of (0.5 mm/ min) until fracture occurred [14,15].

Shear bond strength (MPa) = Maximum force (N)/ bonding area (mm2).

The surface bonding area was calculated as follows:

Surface area = (r)^2 ×π

(r)^2 = radius. π =3.14

Surface area= (2)^2 × 3.14 =12.56 mm^2

The mode of failure of each sample was evaluated under the (DIGITAL MICROSCOPE) (Dino-light, Shodensha, Taiwan) of magnification (X50). The sample failure was classified into three modes: (adhesive, cohesive and mixed) [14,15] Fig. (4). The data were analyzed by One-way ANOVA and least significant difference test LSD. One-Way analysis of variance (ANOVA) test was down to know whether there is statistically significant difference or not in the mean values.

Results:

According to Table (1), one- way ANOVA test manifested that there was statistically highly significant difference in shear bond strength among groups at P<0. 001.The results of the LSD manifested that there is non- significant difference between (Nic) group and (Nik) group, and among (Ni comb) and (Ni k) group was a significant difference. When comparing group (Nic) with (Ni comb) group, there was a significant difference between them. Fig. (5) showed that the highest mean of the shear bond strength value was in group (Ni com), while the lowest mean of the shear bond strength was for group (Ni c).

Discussion:

The success of porcelain-fused to-alloy restorations depends on an optimal bond between ceramic and metal substructure. The chemical compatibility between metal and porcelain allows the restoration to withstand thermal stresses and mechanical forces. This includes a fusing temperature of porcelain that not only does not cause distortion of the metal substructure and contraction of the porcelain, but also can be resisted by the metal. Therefore, many studies have been carried out to investigate the metal/ ceramic bonding. If planning to use base metal alloys for fabrication of Ceram metal restorations, dental technicians and dentists must select the materials taking into account the quality of the adhesion between the alloy and the porcelain system [(17)]. Shear Bond strength can be established by different methods such as macro mechanical and micro mechanical retention, van der Waals interaction and an oxide layer chemically [(18)]. Surface sandblasting by air abrasion with aluminum oxide along with an acid etch are done to achieve a micromechanical retention of the Ni-Cr alloy [(19)]. Many studies have been proved that the sandblasting using alumina particles makes the bonding complicated as debonding can occur and also the contamination and accumulation of elements on the surface [(20)]. In this study, a surface treatment with three methods was performed using, 50µm particles, 70 mg KHF_2 acid etching and combination technique; sandblasting with 50µm Al_2O_3 and KHF2 acid etching. Sandblasting surface treatment was chosen as the positive control, because it is the mostly depended method to enhance the bonding of the metal [(21)]. Therefore, the study sample was sandblasted by 50 µm of Al_2O_3, in which it creates a high mechanical bonding strength [(22)]. For a positive adhesion effect the KHF_2 was chosen because it provides the etching technique with fluoridated surface on which the hydroxyl groups attached after water cleaning [(23)]. The shear bond strengths of Ni- Cr (comb) groups etched with KHF_2 were significantly higher than those of (c) groups [(24)]. The micro retentions are uniformly distributed by using the acid etch treatment, unlike those created by the air-abrasion treatment. Thus, increasing the bonding strength of metal-ceramic with Ni comb group [(25)]. Akazawa *et al.*, 2019 found that the etching treatment with KHF2 is better than AL_2O_3 sandblasting in providing metal-ceramic bonding strength. Kato *et al.*2000 confirmed that the undercuts which were created by etching treatment were well-organized and uniform compared to those created by alumina blasting. If the metal can be dissolved by an etchant, the undercuts created by acid etching treatment are deeper and more retentive for bonding than those created by alumina blasting [(24)]. The results of the present study were disagreed with Kassab and Behnam, 2020. Their study suggests that the etching Nickle Chromium surface following air abrasion with 50 µm led to reduction in shear bond strength. Their explanation is that the etching treatment may affect part of the irretentive irregularities created by sandblasting followed by creating sharp ended irregularities instead. This results in decreasing the bonding strength compared to that formed by sandblasting treatment alone and also producing a higher shear bond strength than etching alone. The difference in results may be attributed to the variables used. The results of this study were in agreement with Monetta and Bellucci, 2012. It showed that the acid treatment improved the Ni surface roughness compared to sandblasting alone. While. The shape of the surface was entirely changed after sandblasting treatment. Sandblasted specimens experience some changes in the shape of the peaks which was depending on the treatment time, but the acid etching seems to be more effective on (comb) groups compared to the (c) group.

Conclusion

Within the limitation of the present study, Combination surface treatment produced the highest shear bond strength between Ni – Cr surface and veneering porcelain, followed by etching with KHF_2, so combination method would increase longevity of porcelain fused to metal restorations.

Figure (1): Nickle Chromium Metal samples.

Figure (2) : Nickle Chromium Metal samples following ceramic build up.

Figure (3): The sample in holder and mounted in a universal testing machine for shear bond strength test.

(A) (B) (C)

Figure (4): Mode of failure (A)Cohesive. (B)Mixed. (C) Adhesive.

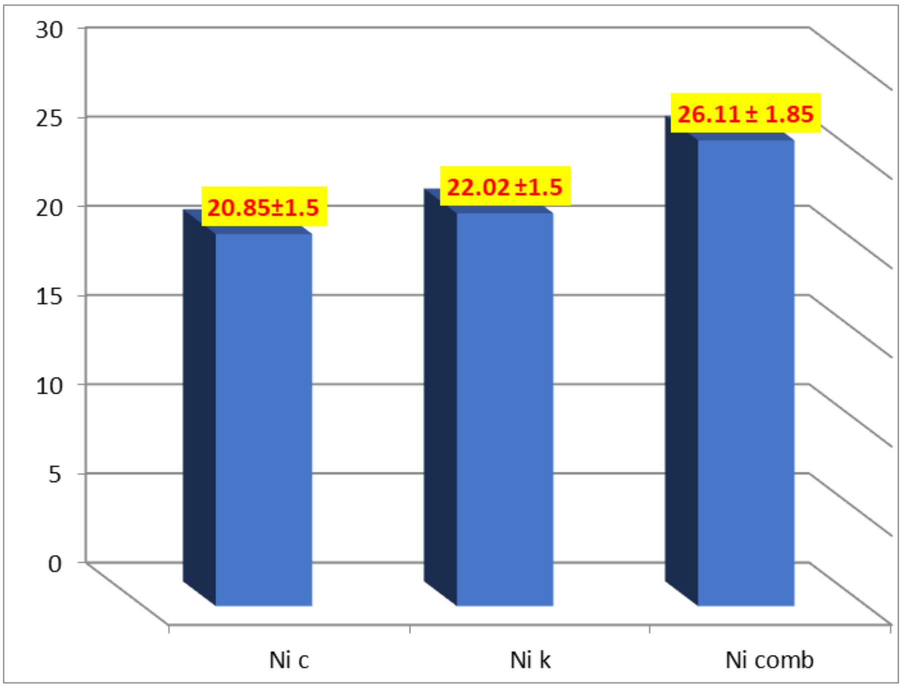

Figure (5): Bar Chart Demonstrating the Means ± SD of shear bond strength of nickel-chromium treated samples.

Table (1): One-way ANOVA test and LSD for groups Nic, Nik, Ni comb.

Groups		Mean Difference	Std. Error	F value	P-value	Sig
Ni c	Ni k	-1.16143	0.88272	19.53	0.205	NS
	Ni comb	-5.25143-*	0.88272		0.001	S
Ni k	Ni comb	-4.09000-*	0.88272		0.002	S

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