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ORIGINAL RESEARCH

Ceramometal Bond Strength Analysis using New and Recast Nonprecious Alloys with Three Different Ceramics

Sulekha Gosavi, Arti Wadkar, Siddharth Y Gosavi

ABSTRACT

Objectives: This study is undertaken to evaluate the dependence of bond strength of 100% fresh nonprecious alloy and the combination of 50% recast (used) alloy and 50% fresh alloy with three different veneering ceramic material.

Materials and methods: To evaluate the shear bond strength between new and recast alloy nonprecious Ni-Cr alloy (System KN®, Adentatec, Germany) was used with three different commercially available ceramics. A total of 60 samples were prepared and divided in two groups depending on the new or recast alloy. The 30 specimens of new alloy (group A) and 30 specimens of recast alloy (group B) were fabricated. Each group was again divided into three subgroups of 10 specimens for ceramic veneering Vita VMK-95 [V], IPS Classic [I] and Noritake [N] as veneering ceramic materials. Thus, six subgroups were formed as groups AV, AI, AN, BV, BI and BN. Groups AV and BV were veneered with Vita Ceramics, Groups AI and BI were veneered with IPS Classic (Ivoclar) and Groups AN and BN were veneered with Noritake. Then, shear bond strength between new and recast alloy was analyzed for each type of ceramics using MTS machine.

Results: The bond strength between new [group A] and recast alloy [group B] using three different veneering ceramics were evaluated. It was found that the new or the fresh alloy had highest shear bond strength than the recast alloy. Statistically, it was found that there was significant difference in bond strength between the new and recast alloys, when same type of ceramics was compared. When comparing ceramics, the Noritake group had highest bond strength, while other groups, that is, Vita and Ivoclar had comparatively low bond strength.

Conclusion: From this study, conclusion can be drawn that the use of 50% recast alloy shows reduction in bond strength values. Therefore, the use of recast alloy should not exceed more than 50%, as it would compromise the properties of alloy and the efficacy of bond strength between ceramic and alloy.

Keywords: Ceramometal bond, Reused alloy, Bond strength, Recast alloy, Interfacial defect.

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INTRODUCTION

Currently metal-ceramic restorations are widely accepted and are the most commonly used extracoronal restoration. It has excellent biocompatibility and superior esthetic qualities. It combines the high esthetic quality of brittle ceramic material supported with the rigid and accurate fitting of metal castings. Ceramic can resist the compressive stresses but not the tensile stresses.[1, 2]

As the popularity of the metal-ceramic restoration increased, the price of the precious alloy especially gold also increased. Certain important secondary elements, present in small amounts in the original alloy composition, are lost during melting through volatilization or oxidation as mentioned by Ayad.[3] So there was need to find the alternatives for the economical reasons. In many dental laboratories, the combinations of the previously casted metal with the new alloy were used to reduce the cost.[3-5]

The metal ceramic compatibility depends on the combination of properties of both the alloy and the porcelain. Acceptable restorations require the alloy and porcelain to be chemically, thermally, mechanically and esthetically compatible.[5]

The adherence, that is, bond between metal surface and overlying porcelain is a complex property and is of fundamental importance in any metal-ceramic restoration. The purpose of the present study was to explore, clarify, and expand the present knowledge regarding the dependence of bond strength on 100% fresh alloy and the combination of 50% recast alloy with 50% fresh alloy using three different veneering materials.

Objective of this study was to explore and expand the dependence bond strength on 100% fresh alloy and the combination of 50% recast alloy 50% fresh alloy using three different veneering materials.

1. Comparison of bond strength between casted 100% alloy with three different veneering ceramic materials.
2. Comparison of bond strength between recast alloy with three different veneering ceramic materials.
3. Comparison of bond strength between 100% new alloy and recast alloy.
4. To evaluate and explore the mode of failure between the ceramic and alloy interface with the help of scanning electron microscope.

MATERIALS AND METHODS

A well-polished self-cure acrylic die, which had a disk (6 mm diameter and 2.5 mm height) and sprue (3 mm diameter and 8 mm height), was fabricated in accordance with ANA/ADA specification No. 38.[6] A mould was prepared for this die having the specified dimension.

A total of 60 wax patterns were fabricated using an inlay wax (German dental lab) from this mould. Out of which, 30 patterns were invested in a phosphate-bonded investment (Wirovest Bego, Germany) and casting was done with help of 100% new alloy, following the standards of the casting procedures in an electronic induction casting machine (ASEG GALLONI SPA MOD OKAY PLUS). Castings were cooled to room temperature. The alloy specimen was retrieved from ring and casting was cleaned thoroughly to remove any remaining investment. Metal specimens were then cut and were critically analyzed for any casting defects. A total of 30 defect-free specimens were selected. Sprue and button of the above casting was steam cleaned and weighed. It was cut and kept aside to be utilized as recast alloy for casting the rest of the 30 patterns.

Remaining 30 patterns were sprued, invested and dewaxed in the same manner as mentioned above. Casting was done using combination of 50% new alloy and 50% once casted alloy, that is, the recast alloy (sprue and button) from the above procedures. All the castings were critically analyzed for any casting defects. After analysis the test surface of all castings were properly finished, microblasted with Al_2O_3 and steam cleaned to remove any surface impurity.

A total of 30 specimens of 100% alloy were then divided into three groups of 10 specimens each as groups AV, AI and AN. A total of 30 specimens of recast alloy were also divided into 10 specimens each as groups BV, BI and BN. All the groups of specimens are ready for the porcelain firing as designated in Figure 1.

Then, accordingly porcelain was applied on all the groups of alloy specimen following the manufacturer›s instruction given for that particular porcelain.

Following three ceramics materials were used for the study:
- Groups AV and BV−Vita/VMK−Vita Germany [V]
- Groups AI and BI−IPS classic−Ivoclar/Vivadent [I]
- Groups AN and BN−Super Porcelain EX-3−Noritake / Japan [N].

The ceramic build-up procedure and firing were carried out according to manufacturers' instructions to obtain a smooth dense surface.

A total of 60 specimens under study were then tested for the bond strength between metal and ceramic by planar interface shear tests.[7-9] Rectangular attachments were devised of 2 mm width and 7 cm length with holes of different diameters at each end, 8 mm away from the border. The bigger hole had a diameter of 6 mm same as the diameter of the alloy specimen and a smaller hole of diameter 4 mm was required for attaching it to the grips of material testing system (MTS 810) (Fig. 2). The porcelain-alloy assembly was aligned at the interface in both attachments through the hole. Both the grips were fixed to the machine and the upper grip was moved in an upward direction at crosshead speed of 2 mm/min, resulting in shear stress at the porcelain-alloy interface until the samples fractured. The peak load required to fracture each of the samples were recorded in kilonewton (KN) which was later converted to PSI units for interpretation of results. The extent and site of fracture was also noted.

One representative specimen from each group was selected for scanning the interface of the porcelain and alloy under electron microscope (model JSM-S4OA; JEOL, Ltd, Tokyo, Japan). The surface was thoroughly scanned and interpreted accordingly for determining the mode of failure and reason of failure.

RESULTS

The following study was conducted to compare the bond strength between 100% alloy and combination of 50% recast alloy with 100% new alloy using three different veneering materials and to evaluate the mode of failure through the scanning electron microscope (SEM) study. The alloy used

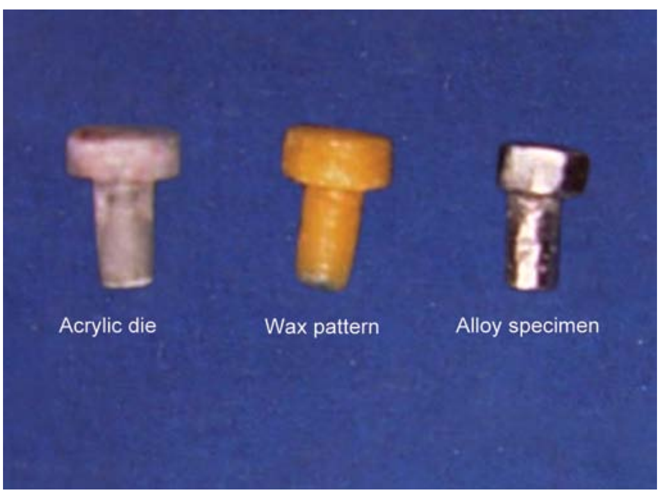


Fig. 1: Die, pattern and casted specimen

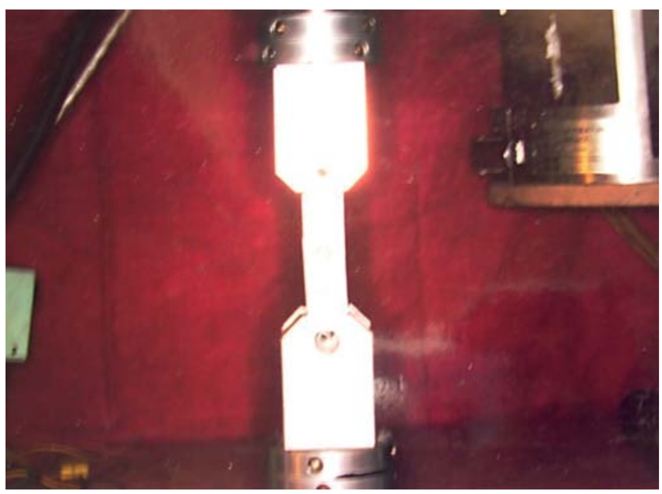


Fig. 2: Specimens with attachments mounted on MTS

in this study was nickel chromium (System KN®, Adentatec, Germany).

The testing of their bond strength was carried out using material testing system (MTS-810). The load was applied at the interface and the values of applied loads needed to fracture bond recorded by machine were noted (Table 1). The values were recorded in KN units. These values were then converted into PSI units for calculations by using the formula as given below.

Stress = Force/Area in N/m^2 [SI units]
1 Newton = 0.000145 PSI
Stress = Force/Area × 0.000145 PSI.

The bond strength value in PSI is shown in Table 2. The data obtained from the study a bar graph were plotted to compare among the groups and following results were obtained. All groups showed satisfactory bonding compatibility according to ANSI/ADA specification No. 38.[6] The results were statistically analyzed.

The mean and standard deviation (SD) were calculated for all specimens (Table 3). Student's 't' test was used for comparison of the results of different groups of 100% new alloy and 50% recast alloy. Tabulated value of 't' at 5% and 1% level of significance recorded from statistical table of 't' (Table 4).

In 't' test comparison, there was significant difference between the bond strength values of groups AV and AN in new alloy. Also, there was significant difference between group BV and BN. The comparison between other groups shows no significant difference.

Table 1: Load required for fracture of specimens in kilonewton (KN)

	100% new alloy (group A)			*Recast alloy (group B)*		
S. no.	*Group AV*	*Group AI*	*Group AN*	*Group BV*	*Group BI*	*Group BN*
1	1.22	1.17	1.48	1.02	1.19	1.45
2	1.21	0.93	0.75	1.12	1.10	1.34
3	1.24	1.21	1.39	1.18	1.14	1.39
4	1.16	1.61	1.48	1.21	1.82	1.24
5	1.28	1.20	1.68	1.16	1.16	2.10
6	1.22	1.15	1.59	0.84	1.13	1.29
7	0.56	1.21	1.47	1.20	1.15	1.36
8	1.27	2.03	1.45	1.15	0.97	1.23
9	1.52	1.22	1.49	1.16	1.01	1.30
10	1.25	1.19	1.54	1.17	1.16	1.26
Mean (KN)	1.193	1.242	1.432	1.121	1.183	1.396

Table 2: Bond strength in PSI

S. no.	*Group AV*	*Group AI*	*Group AN*	*Group BV*	*Group BI*	*Group BN*
1	6254.04	5997.73	7586.87	5228.79	6100.25	7433.08
2	6202.78	4767.42	3844.70	5741.41	5638.89	6869.19
3	6356.57	6202.78	7125.51	6048.99	5843.94	7125.51
4	5946.47	5946.47	7586.87	6202.78	9329.80	6305.30
5	6561.62	6151.52	8612.12	5946.47	5946.40	6356.57
6	6254.04	5895.20	8150.76	4306.06	5792.68	10765.15
7	2870.71	6202.78	7535.60	6151.52	5895.20	6612.88
8	6510.35	10406.31	7433.08	5895.20	4972.47	6971.72
9	7791.92	6254.04	7638.13	5946.47	5177.53	6664.14
10	6407.83	6100.25	7894.44	5997.73	5946.47	6459.09
Average	6121.63	6392.45	7340.81	5746.54	6074.37	7156.26

Table 3: Mean bond strength (kilonewton and PSI) and standard deviation of different groups

S. no.	*Groups*	*Mean breaking load (kilonewton)*	*Mean shear strength (PSI)*	*Standard deviation*
1	AV	1.193	6121.63	1245.55
2	AI	1.242	6392.45	1475.29
3	AN	1.432	7340.81	1295.46
4	BV	1.121	5746.54	574.64
5	BI	1.183	6074.37	1200.84
6	BN	1.396	7156.26	1316.78

Table 4: t-test comparison of the results of different groups

S. no.	*Comparison between groups*	*Degree of freedom*	*Calculate t-value*	*Inference*
1	Group AV with group AI	18	0.4436	Not significant
2	Group AV with group AN	18	2.1453	Significant
3	Group AI with group AN	18	1.5275	Not significant
4	Group BV with group BI	18	0.7787	Not significant
5	Group BV with group BI	18	3.1029	Significant
6	Group BI with group BN	18	1.9367	Not significant
7	Group AV with group BV	18	0.8647	Not significant
8	Group AI with group BI	18	0.5288	Not significant
9	Group AN with group BN	18	0.3159	Not significant

DISCUSSION

Success of metal ceramic restoration depends on the optimum properties that remain constant not only during various laboratory procedures but also in oral environment to provide strength rigidity and strength. Durability of the restoration depends on the integrity and qualities of the bond between the opaque porcelain and the underlying metal.[3]

Several studies have been conducted by various authors related to recasting of alloy on the properties of the metal-like tensile strength, percentage of elongation, yield strength, hardness and microstructure.[10-16]

The effect of surface texture on bond strength of various alloys was conducted and found that bond strength is increased in nonprecious alloys and it was not effective in semiprecious alloys.[17] Study of Rasmussen and Doukoudakis[17] on the bond strength of gold-palladium alloy system subjected to four previous casted, concluded that there was no change in bond strength of the restorations. But study on AgPd alloys in combination with various percentages of previously casted alloy showed decrease in bond strength value when more than 50% of once casted alloys were used. [18]

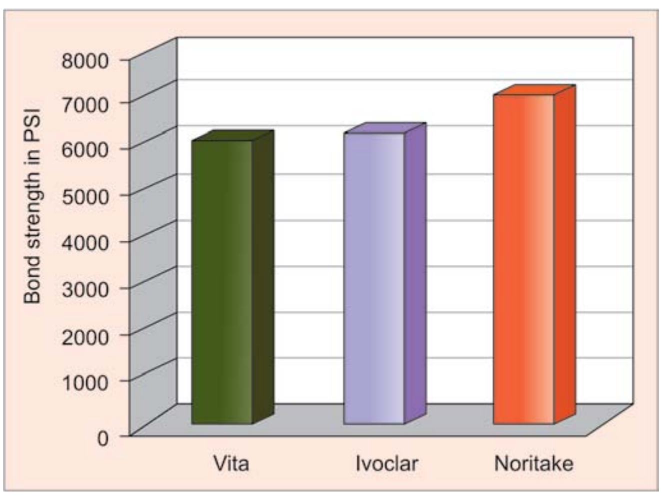
In present study, the effect of recast alloy on the bond strength with addition of 50% of once casted alloy with new alloy using different ceramics was evaluated and it was compared with 100% new alloy. The planar interface shear test was used to design and check the shear bond strength.[7-9] The metal ceramic specimens were fabricated using 100% new alloy and combination of 50% recast and 100% new alloy. Each of this alloy groups (A and B) was divided into subgroup of 3. Each subgroup was then veneered with three different ceramics. The specimens were mounted on the MTS machine and the load on the specimens was applied at the interface until the specimen fracture was noted. Peak load at which specimens fractured was noted.

The loads at which the specimens fractured were then compared between fresh and recast alloys having same ceramics. In comparison, it showed that there was decrease in values comparing bond strength of different ceramic among 100 and 50% recast alloy. Groups with Vita ceramic had lower bond strength value compared to other two, that is, Ivoclar and Noritake. Noritake ceramic was found to have the strongest bond among the other available ceramics when used with System KN® alloy.

Graph 1 shows comparison of the bond strength between 100% new alloy and three different ceramics. Group AI had lowest value of 6121.63 PSI and group AN had highest values of 7340.81 PSI and group BI had value of 6392.45 PSI .

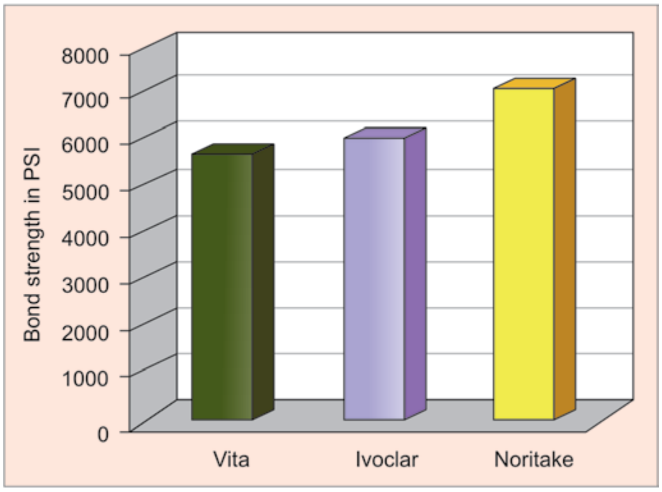
Graph 2 shows comparison of bond strength between the recast alloy and three different ceramics. It was found that the bond between Vita ceramic and recast alloy (group BV) had lowest value, that is 5746.54 PSI, whereas the bond between Noritake ceramic and recast alloy used was highest and strongest, that is 7156.26 PSI. Bond between Ivoclar ceramic and recast alloy was found to be 6074.37 PSI between groups BV and BN.

In comparison of bond strength of different groups, as shown in the Graph 3, it was found that bond strength of group BV, that is recast alloy with Vita ceramics was lowest values of 5746.54 PSI and group AN had highest values of 7340.81 PSI, that is the bond strength between the new or 100% alloy and Noritake ceramic was found to be highest amongst the groups.

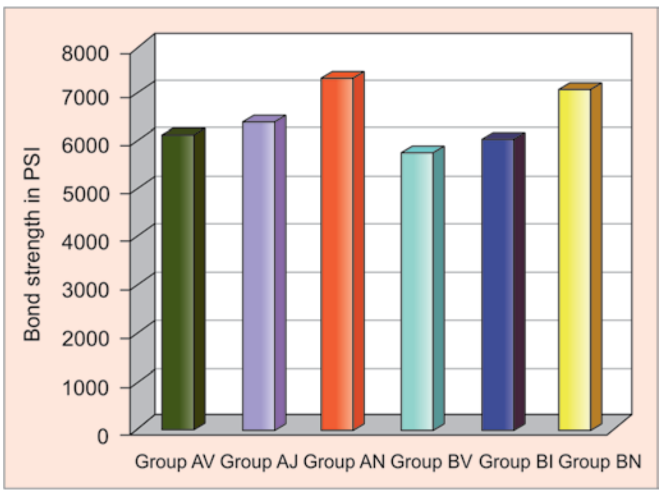


Graph 1: Comparison of bond strength between 100% and alloy and various ceramics

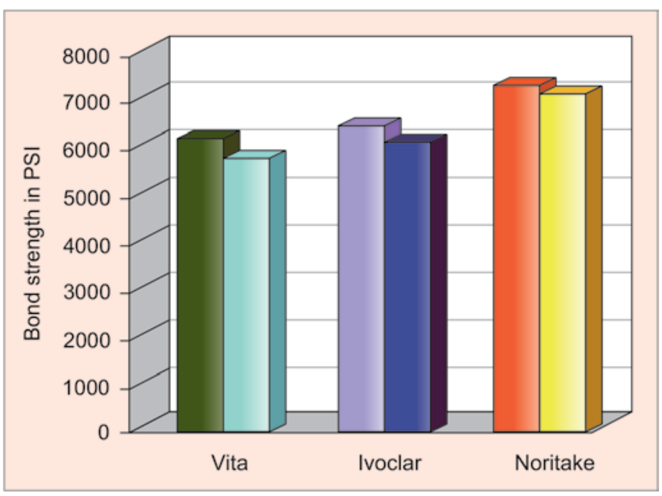
Graph 4 shows the comparison of bond strength between the new and recast alloy with same ceramic. It was found that the values of bond strength decreases when recast alloy was used.



Graph 2: Comparison of bond strength between recast alloy and various ceramics



Graph 3: Comparison of bond strength between alloys and various ceramics



Graph 4: Comparison of bond strength between 100% and recast alloys using various ceramics

This may be due the compatibility of the ceramic material and the alloy. Also, bonding compatibility between the alloy and porcelain is related to the difference in their thermal expansion coefficients, the test specimen geometry, and the porcelain/metal thickness ratio.

McLean suggested that at least 50% new metal should be included in copings for metal-ceramic restorations and most manufacturers concurred. However, there is sparse documented experimental justification for this 50% rule.[23]

When shear bond strength between the fresh alloy and recast alloy was compared the fresh alloy showed much higher bond strength as compared to recast alloy. Initial heat treatment during first casting of metal was adequate for optimum metal ceramic bonding, and subsequent recasting which increases the amount of oxidation does not improve the interfacial bond. Inadvertent addition of contaminants to the recast alloys may have affected the oxide layer and also any loss of the trace elements which are critical for the porcelain adherence may affect the bond.[5,15] There was increased number of interfacial defects or voids in the recast alloys as compared to 100% alloy.[19,20] The voids and defects acts as a stress concentrator which initiates the fracture at the interface.[21,22]

McLean in 1979[23] explained the fracture of metal-ceramic restoration could be cohesive or adhesive in nature on visual examination. In this study, mode of failure was divided into three types for convenience as (1) complete in ceramic (2) partly in ceramic and partly in metal and (3) complete in metal.

To confirm the visual examination, the fracture surfaces at the metal ceramic interface were observed at low magnification [250×] under SEM, it was found that the interface was covered with the thin layer of ceramic appears as white area and metal or metal oxide as dark or gray color. Depending on shade, the mode of failure can be predicted. Certain voids and defects could be seen which would help in determining the reason for failures. Two types of defects or voids were seen like hemispheric void and flat void. The hemispheric voids were seen in all specimens, but flat voids were present only in recast alloy. It was observed that the frequency and size of voids at the interfaces increased in the recast alloy specimens . Under SEM specimens showed that the frequency per unit area and average diameter of hemispheric voids increased for specimens containing 50% recast alloy and was comparatively less for specimens containing 100% alloy. The voids were found in all specimens, but the largest and the greatest number of voids occurred on specimens containing 50% recast metal. The fracture surfaces at the interfaces of new and recast alloy and ceramics specimens are shown in Figures 3 to 8.

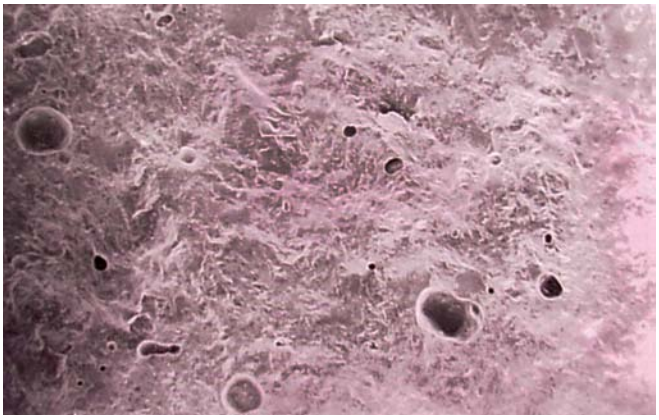


Fig. 3: Photomicrograph of group AV

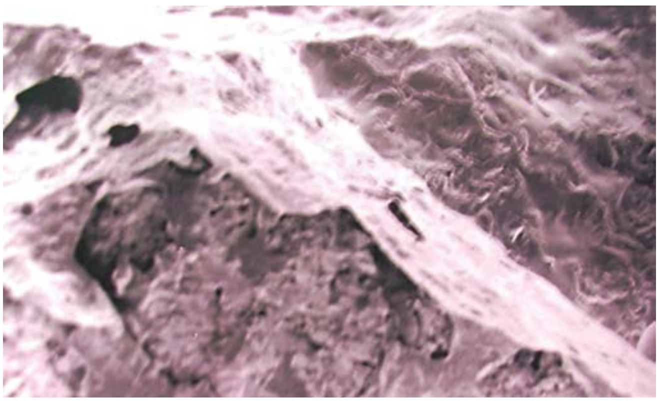


Fig. 4: Photomicrograph of group AI

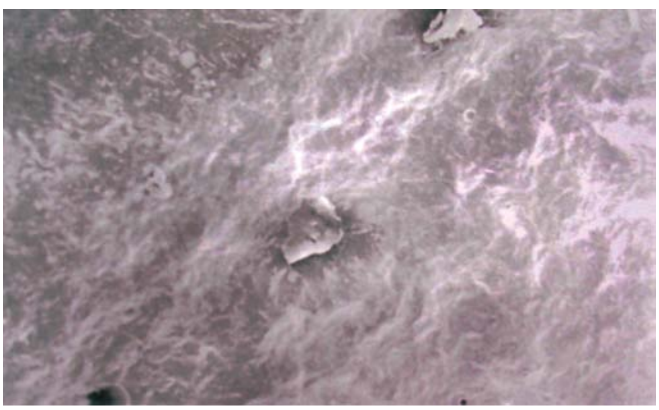


Fig. 5: Photomicrograph of group AN

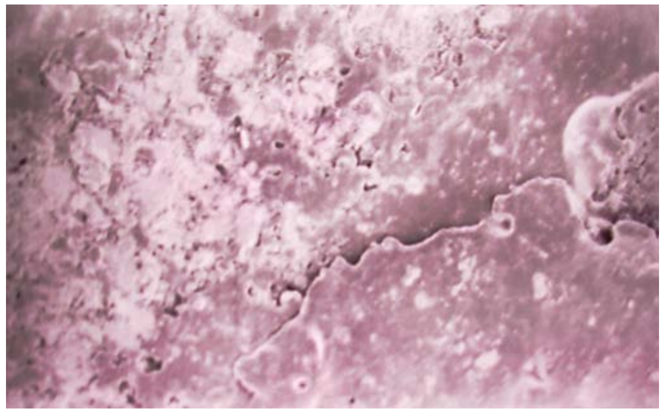


Fig. 6: Photomicrograph of group BI

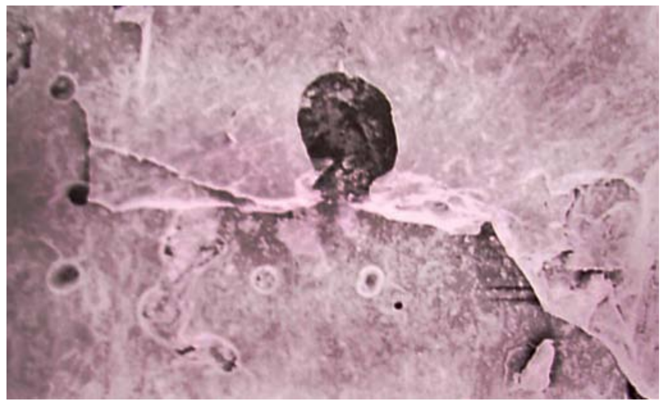


Fig. 7: Photomicrograph of group BN

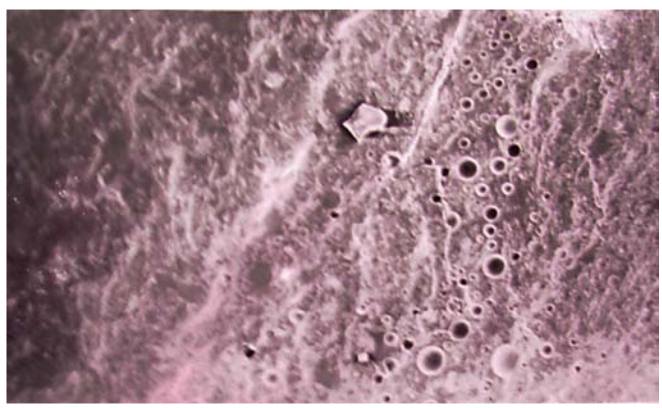


Fig. 8: Photomicrograph of group BV

The most significant observation of this investigation was increase in size and frequency of interfacial porosity in recast alloy. On loading, these interfacial voids could precipitate failure in either the adhesive or cohesive mode. Large interfacial voids at a region of high stress concentration could be responsible for cohesive failure without apparent cause. Such an interfacial void could seriously weaken a metal-ceramic restoration if the void was in an area of high interfacial stress from loading. An increase in frequency and size makes the void a more effective stress concentrator. Consequently, the use of recast metal for metal-ceramic restoration increases the probability of failure (Figs 6 to 8).

According to the present study, the shear bond strength of all the specimens is much higher than the reported biting force in the oral cavity. This adequate from the functional point of view, it is required to limit the use of recast alloy so as not to compromise the bond strength. The difference in coefficient of thermal expansion of porcelain and alloy develops thermomechanical stresses.[20] Thermal compatibility of the metal-ceramic pair could play a significant role in metal ceramic bond strength, because it constitutes the main physical requirement to avoid stress at the interface which initiates the cracks or fracture. Further investigation is required in this regard to check its effect on bond strength. The direction of the forces should also be evaluated.

Most of the dental clinician preferred base metal alloys in metal-ceramic restorations for crown and fixed partial dentures, because it is stronger and durable material, more important, it is cost-effective than precious metal restoration. To achieve highest bond strength and make it more cost-effective, evaluation of use of recast alloys is required. It also helps in recycling of the alloy and wastage is reduced.

An *in vitro* study has its own limitations, so an *in vivo* study is suggested to verify the results of the present study. Further studies are required to investigate the effect of various ratio of fresh and recast alloy on bond strength to know the exact ratio at which the bond strength is significantly affected.

CONCLUSION

Within the limitations of this study, the following conclusion can be drawn:

The bond strength of the Noritake group was found to be highest in 100% new alloy with three different ceramics, while other groups, that is Vita and Ivoclar had comparatively low bond strength.

Comparing the bond strength of 50% recast alloy with three different ceramics, the Noritake group had highest bond strength while other groups, that is Vita and Ivoclar had comparatively low bond strength.

There was decrease in values of the bond strength in recast alloy, when bond strength between alloys having same ceramic group was compared.

The SEM study of the fractured surface showed that there was an increase in interfacial voids and defect. These voids and defects could be the reason for the initiation of failure.

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