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Dentistry Section

# Recasting of Base Metal Alloys and its Effect on Metal Ceramic Bond Strength

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## ABSTRACT

**Introduction:** A steep rise in the cost of noble metals leads to use of base metal alloys, due to their low cost, good mechanical properties and low density. It would be economically advisable to use fresh alloy in combination with reuse alloy, to reduce the cost of fixed partial dentures.

**Aim:** To evaluate the effect of recasting of Nickel-Chromium (Ni-Cr) and Cobalt-Chromium (Co-Cr) base metal alloys on the metal ceramic flexural bond strength.

**Materials and Methods:** This in-vitro study was conducted in the Department of Prosthodontics, Crown and Bridge of Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala, Haryana, India in October 2020. A total of 60 specimens were fabricated using Ni-Cr and Co-Cr metal alloys (n=30). Different proportions of new and old Nickel-Chromium (Group A) and Cobalt-Chromium (Group B) base metal alloys were used to fabricate the specimens i.e., Control subgroup A0/B0 (100% new alloy), subgroup A1/B1 (50% new alloy and 50% remnants from subgroup A0/B0), subgroup A2/B2 (50% new alloy and 50% remnants from subgroup A1/B1). Ceramic was applied in the centre of each prepared metal specimen in the dimension of 8×3×1 mm. All specimens were subjected to three point bending test in Universal Testing Machine (UTM) till failure occurred and values were recorded. Statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) software version 17.5. Data obtained was compiled and analysed using one-way Analysis of Variance (ANOVA), Post-hoc tukey's and Student t-tests. The p-value <0.05 was considered as statistically significant.

**Results:** In Group A (Nickel-Chromium) and Group B (Cobalt-Chromium), maximum flexural bond strength was observed in subgroup A0, B0 (control subgroup) followed by subgroup A1, B1 whereas minimum was observed in subgroup A2, B2. A highly significant difference (p-value <0.001) in flexural strength was observed among all the subgroups. Metal ceramic bond strength observed in Group A (Ni-Cr) was higher than the metal ceramic bond strength observed in Group B (Co-Cr) in all the subgroups. This difference was statistically significant in subgroup 0 and subgroup 1 equal variances assumed (p-value=0.023), whereas no significant difference was observed in subgroup 2 with equal variance assumed (p-value=0.058).

**Conclusion:** From the present study, it can be suggested that recasting of base metal alloys should be avoided, since it causes significant reduction in metal ceramic bond strength.

**Keywords:** Casting technique, Chromium alloys, Dental porcelains, Flexural bond strength, Restorations

## INTRODUCTION

The aim of any dental treatment is to improve and maintain the quality of oral health which mainly includes relieving pain, improvement in mastication, aesthetics and disease prevention [1]. These objectives may require the alteration or the replacement of tooth structure. Numerous biocompatible materials are available. The challenge is to select a restorative material that can withstand the adverse conditions of oral environment and maintain form, function and aesthetics [1].

With an increased demand for aesthetics, ceramic restorations which are known for good clinical performance and mimicking the form and colour of adjacent teeth, become an ideal material of choice [2]. Although all-ceramic restorations provide better aesthetics, metal ceramic restorations are still widely used and accepted extra coronal restorations [3]. Metal ceramic restorations possess the aesthetics of porcelain and strength of metal and hence are considered as choice of material in long-span fixed partial dentures and restorations in stress-bearing areas [4].

Taggart developed the lost wax casting technique for the precision fitting castings, several alloy compositions have been made available as a dental restorative materials i.e., high noble metal, noble metal and predominantly base metal [2]. Noble metal alloys were most commonly used due to their adequate bonding, ease of casting and biocompatibility to produce a metal substructure [2]. But considering the current economy, it is mandatory that dentists and technicians be cost conscious about the materials they used for prosthesis, considering the same as an important factor use of the precious alloys has almost been eliminated by the elevated costs of all the precious metals [5].

Cast base metal alloys introduced in 1929, used in the construction of fixed and removable partial denture [6]. They are often preferred now-a-days because of their better mechanical properties, low density and lower cost [6]. Base metal alloys are free of gold, platinum and palladium and when compared with high-noble alloys, they are advantageous as their melting range is high which reduces the risk of distortion and sagging during porcelain-firing [2].

Very few references [5-10] in dental literature are available regarding recasting of both Nickel-Chromium and Cobalt-Chromium and comparing the effect of recast alloy in detail. Studying properties of recast alloy is advantageous, so as to give appropriate direction to prosthodontists and lab technicians while selecting such alloys for fabrication of prosthesis [6]. Nickel Chromium and Cobalt-Chromium are the most popular base metal alloys which have been considered for the fabrication of metal ceramic prosthesis [11].

Most of the dental prosthesis is obtained by casting procedures using alloys [12]. Casting procedure often requires more molten alloy to be forced forced than is needed to fill the mold. The remaining metal from the casting (from the channels of casting mould, or from casting cones) is known as button and is usually discarded as scrap [12]. It would be economically advisable to reuse alloy in combination with fresh alloy, to reduce the cost of fixed partial dentures, since subsequent demand for base metal alloys in dental prosthesis has led to substantial increase in price of once insignificant alloys, again to a point of financial concern [12].

Effect of recasting of base metal alloy is still controversial. While some researchers do not recommend use of recast alloys [13,14], others permitted the use of 100% reused alloy upto atleast four generations [15], or combination of 50% new and 50% once-recast alloy [16]. Even though various studies [12,17] have shown that alloy can be reused, its effect on bond with ceramic is not well documented and conclusive.

As there is no consensus in the literature regarding whether recast metal alloy should be used or not and its effect on bond strength of base metal alloys with ceramic, so the present study was designed to evaluate the effect of recasting of base metal alloy and its effect on metal ceramic flexural bond strength.

## MATERIALS AND METHODS

This in-vitro study was conducted in the Department of Prosthodontics, Crown and Bridge of of Maharishi Markandeshwar College of Dental Sciences and Research, Mullana, Ambala, Haryana, India in October 2020. Ethical clearance was obtained prior to start of study (IEC no-1412, date of review- 15/03/2019).

A total of 60 specimens were fabricated using Ni-Cr and Co-Cr metal alloys (n=30). Different proportions of new and old Nickel-Chromium (Bego, Germany) and Cobalt-Chromium (Bego, Germany) base metal alloys were used to fabricate the test specimens (10 for each proportion), which is illustrated in [Table/Fig-1].

| Groups | Subgroups based on proportions of new and old alloy |
|---|---|
| (A) Nickel-Chromium alloy | A0- 100% new alloy |
| | A1- 50% new alloy and 50% remnants from subgroup A0 |
| | A2- 50% new alloy and 50% remnants from subgroup A1 |
| (B) Cobalt-Chromium alloy | B0- 100% new alloy |
| | B1- 50% new alloy and 50% remnants from subgroup B0 |
| | B2- 50% new alloy and 50% remnants from subgroup B1 |

**[Table/Fig-1]:** Grouping of specimens.

### Preparation of Metal Specimens

Methodology for the preparation of specimens was same for both the alloys. A metallic mould was fabricated to make standardised wax patterns for metal strip fabrication. The mould had 5 slots of similar dimensions i.e., 25×3×0.5 mm, as per International Standard Organisation (ISO 9693-1999) and American Dental Association (ADA) specification 38 for wax pattern fabrication [Table/Fig-2] [18].

Initially, wax separating oil was applied throughout the mould surface and mould was placed over the glass slab [18]. Then blue inlay wax melted and poured into the mould. Once it set, the excess wax was removed from the metal mould using sharp metal plate and wax patterns were retrieved [18]. Dimensions of the prepared wax patterns was verified using digital vernier calliper [18]. Then wax patterns were attached to the sprue and were sprayed with debubbliser to reduce the surface tension [18]. Wax patterns were placed in a metal casting ring, about 6 mm from the top of the casting ring and were invested. Once it set, casting ring was separated from the crucible former and was transferred to the burnout furnace. The casting ring was placed vertically with the crucible facing downwards for complete elimination of the wax. After removal from the furnace, the ring was transferred to the induction casting machine and casting was completed. Once casting was over, casting ring was allowed to cool, divested manually and abraded with 50 µm Aluminium Oxide ($Al_2O_3$) abrasive under pressure to remove the investment material [18]. Then casting was separated from sprue and cleaned ultrasonically to remove all the debris or contaminations.

Same procedure was followed to prepare other specimens of control subgroup. Thickness of each specimen was measured using digital vernier calliper (JW 150 mm digital vernier calliper, Haryana, India). Distorted one was discarded and new specimens were fabricated using same procedure. For experimental subgroup A1 and B1 buttons and sprues from the control subgroup A0 and B0, and for experimental subgroups A2 and B2, buttons and sprues from experimental subgroups A1 and B1, were steam cleaned and cut into pieces of different sizes and weighed on digital weighing machine to be mixed with new alloys in the appropriate proportion i.e., 50% of new and 50% of old alloy by weight. Then procedure similar to control subgroup was followed for fabrications of experimental subgroup specimens.

### Application of Ceramic

Ceramic (Vita Master Zahnfabrik, Germany) was applied in the dimension of 8×3×1 mm in the centre of each prepared metal specimen [18]. For this a customised metallic mould was fabricated. It had 2 parts, one to retain metal specimen and other to maintain uniform thickness of ceramic during application. The 2nd part of the mould had a single metallic plate with a slot of dimension 8×3×1 mm in its centre [18]. It was screw tightened on the first part of assembly in such a way that slot falls in the centre of metal specimen [Table/Fig-3].

Ceramic was applied with brush using conventional layering techniques [18]. Same procedure was followed for all the metal specimens and was evaluated for their accuracy using digital vernier calliper [Table/Fig-4].

### Testing of the Specimens

All specimens fabricated were subjected to three point bending test using a Universal Testing Machine (UTM) (Asian UTM, Muradnagar, UP, India) [Table/Fig-5].

Each specimen was placed on the testing apparatus where the distance between two supports was 20 mm. The ceramic surface was placed down and opposite to the applied load. The force was applied at a rate of 1.5 mm/minute till failure occured and values were recorded. Flexural strength was calculated using following formula [18]:

$$\Sigma=3Pl/2bd^2$$

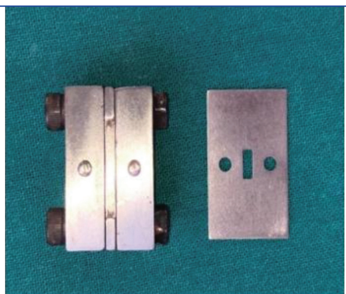
Where, Σ=Flexural bond strength (MPa)

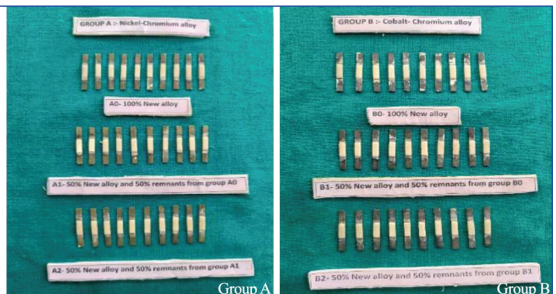
P=Load (N)

l=Distance between the supports in mm

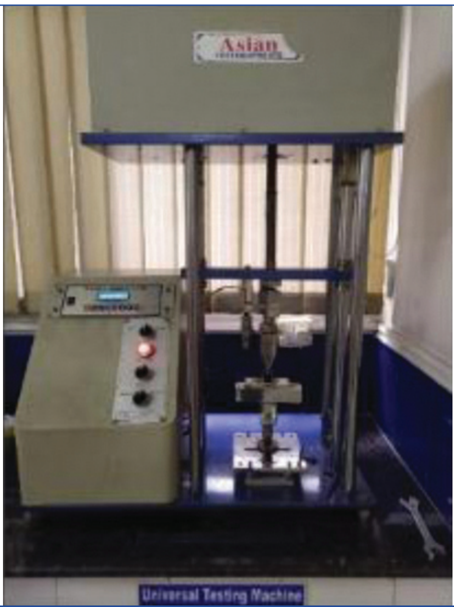
b=width of the sample in mm

d=thickness of the sample in mm.






**[Table/Fig-2]:** Metallic mould for preparation of wax specimens; **[Table/Fig-3]:** Four piece metallic mould for standardisation of porcelain application; **[Table/Fig-4]:** Specimens of Nickel-Chromium alloy (Group A) and Specimens of Cobalt-Chromium alloy (Group B). (Images from left to right)



**[Table/Fig-5]:** Universal Testing Machine (UTM).

## STATISTICAL ANALYSIS

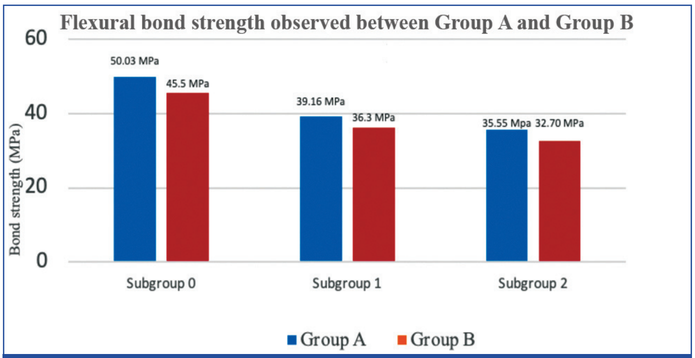
Statistical analysis was carried out using Statistical Package for the Social Sciences (SPSS) software version 17.5. Mean of flexural strength±standard deviation of all specimens in each group/subgroup was tabulated. Intragroup comparison was done using one-way Analysis of Variance (ANOVA) followed by Post-hoc tukey's Test, whereas Inter group comparison was done using Student t-test (unpaired). The p-value <0.05 was considered significant in all tests.

## RESULTS

Results showed that in Group A (Nickel-Chromium) and Group B (Cobalt-Chromium), maximum flexural bond strength was observed in control subgroup A0 (50.03±2.17 MPa), B0 (45.5±2.7 MPa) followed by subgroup A1 (39.16±3.01 MPa), B1 (36.3±2.05 MPa) whereas minimum was observed in subgroup A2 (35.55±3.85 MPa), B2 (32.70±2.24 MPa) [Table/Fig-6,7]. A highly significant difference (p-value=0.001) in flexural strength was observed among all the subgroups [Table/Fig-8]. Significant differences in flexural strength were also observed among all the subgroups [Table/Fig-9].

| Group | Subgroup | N | Mean (MPa) | Standard Deviation | Standard Error | 95% Confidence interval for mean | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower bound | Upper bound |
| Group A | A 0 | 10 | 50.0390 | 2.17662 | 0.68831 | 48.4819 | 51.5961 |
| | A 1 | 10 | 39.1640 | 3.01286 | 0.95275 | 37.0087 | 41.3193 |
| | A 2 | 10 | 35.5540 | 3.85999 | 1.22064 | 32.7927 | 38.3153 |
| | Total | 30 | 41.5857 | 6.93684 | 1.26649 | 38.9954 | 44.1759 |
| Group B | B 0 | 10 | 45.5030 | 2.70384 | 0.85503 | 43.5688 | 47.4372 |
| | B 1 | 10 | 36.3000 | 2.05802 | 0.65080 | 34.8278 | 37.7722 |
| | B 2 | 10 | 32.7000 | 2.24404 | 0.70963 | 31.0947 | 34.3053 |
| | Total | 30 | 38.1677 | 5.93396 | 1.08339 | 35.9519 | 40.3834 |

**[Table/Fig-6]:** Mean of metal ceramic bond strength after adding different proportions of new and old alloy.



**[Table/Fig-7]:** Flexural bond strength observed in specimens of Group A and Group B.

| Group | | Sum of squares | daf | Mean square | F | p-value |
|---|---|---|---|---|---|---|
| Group A | Between subgroups | 1137.043 | 2 | 568.522 | 59.397 | 0.001** |
| | Within subgroups | 258.431 | 27 | 9.572 | | |
| | Total | 1395.474 | 29 | - | - | - |
| Group B | Between subgroups | 871.907 | 2 | 435.953 | 78.872 | 0.001** |
| | Within subgroups | 149.238 | 27 | 5.527 | | |
| | Total | 1021.144 | 29 | - | - | - |

**[Table/Fig-8]:** Intragroup analysis of flexural bond strength using one-way ANOVA.
*p-value≤0.05 statistically significant; **p-value≤0.001 statistically highly significant

| Group | (I) Subgroup | (J) Subgroup | Mean Difference (I-J) | Std. Error | p-value | 95% Confidence interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower bound | Upper bound |
| Group A | Subgroup A0 | Subgroup A1 | 10.87500 | 1.38358 | <0.001** | 7.4445 | 14.3055 |
| | Subgroup A0 | Subgroup A2 | 14.48500 | 1.38358 | <0.001** | 11.0545 | 17.9155 |
| | Subgroup A1 | Subgroup A2 | 3.61000 | 1.38358 | 0.038* | 0.1795 | 7.0405 |
| Group B | Subgroup B0 | Subgroup B1 | 9.20300 | 1.05141 | <0.001** | 6.5961 | 11.8099 |
| | Subgroup B0 | Subgroup B2 | 12.80300 | 1.05141 | <0.001** | 10.1961 | 15.4099 |
| | Subgroup B1 | Subgroup B2 | 3.60000 | 1.05141 | 0.005* | 0.9931 | 6.2069 |

**[Table/Fig-9]:** Post-hoc comparison between subgroups.
*p-value ≤0.05 statistically significant; **p-value ≤0.001 statistically highly significant

Results also showed that metal ceramic bond strength of Group A (Ni-Cr) was higher than the bond strength of Group B (Co-Cr) in all the subgroups. This difference was statistically significant with equal variances assumed (p-value=0.023) in subgroups 0 and 1, whereas no significant difference was observed in subgroup 2 with equal variances assumed (p-value=0.058) [Table/Fig-10].

## DISCUSSION

Metal ceramic restorations are widely accepted and are the most commonly used extra coronal restoration [4]. The metal ceramic compatibility depends on the combination of properties of both the alloy and the porcelains. When selecting an alloy for dental restorations, number of factors are considered prior to selection. Some of the factors considered are biocompatibility, mechanical properties and cost, out of which, cost has become the most influential over the last two decades [4].

This study was done to evaluate the metal ceramic flexural bond strength of ceramic with new and recast Ni-Cr and Co-Cr alloy. The findings of this study showed that, with each recasting, there was a significant reduction in bond strength. In this study, the first group was fabricated from 100% new alloy and served as control. The other groups were cast with the addition of 50% new alloy each time to the remnants of the previous group. The mean bond strength of group A0 and B0 was significantly higher than that of groups A1, B1, A2, and B2. The findings of the present study showed that with each recasting, there was a significant reduction in bond strength. The findings were in agreement with previously published literature

| Group statistics | | | | | | |
|---|---|---|---|---|---|---|
| Subgroup | | Group | N | Mean | Standard deviation | Standard error mean |
| Subgroup 0 | Bond strength | Group A | 10 | 50.0390 | 2.17662 | 0.68831 |
| | | Group B | 10 | 45.5030 | 2.70384 | 0.85503 |
| Subgroup 1 | Bond strength | Group A | 10 | 39.1640 | 3.01286 | 0.95275 |
| | | Group B | 10 | 36.3000 | 2.05802 | 0.65080 |
| Subgroup 2 | Bond strength | Group A | 10 | 35.5540 | 3.85999 | 1.22064 |
| | | Group B | 10 | 32.7000 | 2.24404 | 0.70963 |

| Independent samples test | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Levene's test for equality of variances | | Unpaired t-test for equality of means | | | | | | |
| | | | | | | | | | | 95% Confidence interval of the difference | |
| Subgroup | | | F | p-value | t | df | p-value (2-tailed) | Mean difference | Standard Error difference | Lower | Upper |
| Subgroup 0 | Bond strength | Equal variances assumed | 2.102 | 0.164 | 4.132 | 18 | 0.001** | 4.53600 | 1.09765 | 2.22992 | 6.84208 |
| | | Equal variances not assumed | | | 4.132 | 17.215 | 0.001** | 4.53600 | 1.09765 | 2.22235 | 6.84965 |
| Subgroup 1 | Bond strength | Equal variances assumed | 0.342 | 0.566 | 2.482 | 18 | 0.023* | 2.86400 | 1.15381 | 0.43993 | 5.28807 |
| | | Equal variances not assumed | | | 2.482 | 15.897 | 0.025* | 2.86400 | 1.15381 | 0.41674 | 5.31126 |
| Subgroup 2 | Bond strength | Equal variances assumed | 5.283 | 0.034 | 2.021 | 18 | 0.058 | 2.85400 | 1.41192 | -0.11234 | 5.82034 |
| | | Equal variances not assumed | | | 2.021 | 14.460 | 0.062 | 2.85400 | 1.41192 | -0.16526 | 5.87326 |

**[Table/Fig-10]:** Intergroup Analysis of flexural bond strength using t-test (Unpaired).
*p-value ≤0.05 statistically significant; **p-value ≤0.001 statistically highly significant

which states that recasting of the same alloy multiple times may interfere with the compositional stability of the alloy [19, 20]. A change in minor and trace elements (Al, Be, C, Si, Fe, and Sn) is expected, after multiple castings [21,22]. A change in minor and trace elements affects the chemical bond between the metal and ceramic and leads to decreased bond between metal and ceramic [21-23]. Another study evaluated that metal ceramic bond strength will be affected by the properties of oxide layer on metal surfaces, compared to base metal alloys, it is better with high noble and noble alloys [24].

Hong JM et al., studied the effect of using different percentages of reused silver-palladium alloy on the bond strength of porcelain and it was found that 50% new alloy should be added to each casting [25]. Ucar Y et al., studied the metal ceramic bond strength of Ni-Cr alloy and documented a value of 39.8 MPa for castings containing 100% new alloy and for castings containing 100% recycled alloy; the value was 24.4 MPa and no significant difference was found between three groups [26]. Liu R et al., studied that all three noble alloys after three castings showed satisfactory bonding compatibility with porcelain [27]. Kul E et al., reported that noble alloys can be reused because there is no problem with porcelain [28]. However, the same cannot be said for base metals, because after the second and third casting, the bonding compatibility with porcelain was not satisfactory [28].

Though recasting is an economically viable option, it should not affect the physical and mechanical properties of base metal alloys [15,18]. Various studies [12,17] have shown that base metal alloys can be reused, its effect on bond with ceramic is not well documented and conclusive.

In group A (Nickel-Chromium), maximum flexural bond strength was observed in subgroup A0 (control subgroup) followed by subgroup A1, whereas minimum was observed in subgroup A2. Also, a significant difference (p-value ≤0.001) in flexural strength was observed among all the subgroups. This suggests that addition of recast alloy has negative effect on metal ceramic bond strength i.e., metal ceramic bond strength decreases with addition of recast alloy. This is supported by Mahale P et al., who concluded that recasting of Nickel-Chromium alloys had a negative effect on the bond strength of metal ceramic depending upon its proportions (p-value <0.001 between groups) [29]. As the amount of recast alloy increased, the bond strength decreased. Meenakshi T et al., also in their study on effect of recasting of base metal alloy on metal ceramic bond strength concluded that multiple recasting decreased the metal ceramic bond strength (p-value <0.001) [18].

In group B (Cobalt-Chromium), maximum flexural bond strength was observed in subgroup B0 (control subgroup) followed by subgroup B1, whereas minimum was observed in subgroup B2. A significant difference (p-value=0.001) in flexural strength was observed among all the subgroups. This is supported by Atluri KR et al., who evaluated the bond strength of Co-Cr with dental ceramic after use of new and recast alloys and observed significant reduction (p-value <0.001) in bond strength with addition of recast alloy [30]. Amitha GL et al., also found significant difference (p-value <0.0001) in the mechanical properties of Cobalt-Chromium alloys, concluded that there is deterioration of properties when the content of reused alloy was more than 50% [31]. Current study also showed a significant difference in the flexural bond strength between group A and Group B, though no significant difference was observed in subgroup 2. This suggests that metal Ni-Cr alloy has better ceramic bond strength than Co-Cr alloy. This is supported by Atluri KR et al., who evaluated metal ceramic bond strength of alloys on repeated castings and concluded that, when bond strength of Ni-Cr alloys and Co-Cr are compared, Ni-Cr alloys showed higher bond strengths than that of Co-Cr alloys (p-value<0.001) [30]. This reduction in the bond strength can be due to an increase in the frequency of interfacial voids as the percentage of recast metal is increased [30]. Another possible reason for failure in metal ceramic bond strength can be the compositional change that occurs after multiple castings [32].

## Limitation(s)

Since, it was an in-vitro study, true simulation of oral conditions was not possible. Only properties such as tensile strength, yield strength, castability, modulus of elasticity, surface roughness also affect the choice of material and needs to be studied.

## CONCLUSION(S)

From the present study, it can be suggested that recasting of base metal alloys should be avoided, since it causes significant reduction in metal ceramic bond strength. However, further studies are required to evaluate other physical and mechanical properties of base metal alloy using various proportions of used alloy to find out the most suitable combination to be used.

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