THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

# Comparison of the metal-ceramic bond after recasting and after laser sintering

Esra Kul, DDS,[a] Lütfü Ihsan Aladag, PhD, DDS,[b] and Zeynep Yesil Duymus, PhD, DDS[c]


## ABSTRACT

**Statement of problem.** Failure of the bond between metal and ceramic is common with metal ceramic prostheses.

**Purpose.** The purpose of this in vitro study was to investigate how recasting affects the metal-ceramic bond strength for 1 base metal and 1 noble alloy compared with laser-sintered Co-Cr alloy by using a procedure based on ANSI/ADA Specification No. 38.

**Material and methods.** One laser-sintered (Co-Cr) and 2 metal (Co-Cr, Pd-Ag) alloys were used. Metal strips (25×3×0.5 mm) were obtained with 2 different methods: torch melting and laser sintering. Twelve alloy specimens were processed for each group. Vita VM13 porcelain layers (8×3×1.1 mm) were fabricated at the centers of the metal frameworks. Specimens containing 100% fresh alloy were used in the first casting group (control). Metal ceramic specimens were prepared for each alloy, and no new metal was added to the second and third castings. The findings were statistically analyzed and compared with a 2-way analysis of variance (ANOVA).

**Results.** The second casting of the noble alloy-ceramic specimen had the highest mean metal-ceramic bond strength in flexure. No significant differences were found between the laser-sintered Co-Cr and the Pd-Ag metal ceramic specimens after the first and third castings.

**Conclusion.** All groups had adequate porcelain bond strength, except C2 (second casting of Co-Cr alloy) and C3 (third casting of Co-Cr alloy). Co-Cr alloy fabricated with new laser-sintering techniques is a promising alternative for metal ceramic restorations. Further research is needed before its use can be advocated in the dental laboratory. (J Prosthet Dent 2015;114:109-113)


Metal ceramic restorations have had a high degree of success, as they integrate the esthetics of porcelain and the strength and durability of metal. Because of their biocompatibility, ease of casting, and adequate bonding and mechanical strength, noble metal alloys are commonly used to produce the metal substructure. However, casting alloys comprising base metals (Ni–Cr and Co–Cr) are often preferred because of their lower cost, mechanical properties, and low density.[1] For these reasons, casting alloys have gained considerable popularity since the 1970s. Unlike noble alloys, remelting base metal alloys results in a higher melting range and the potential for oxidization during casting.[2] Additionally, the hardness of base metal alloys leads to increased processing time in the laboratory.

Laser sintering is a new technology that can substitute for base metal alloy casting[3-5] and has recently been considered a computer-aided design/computer-aided manufacturing method. The metal frameworks of partial fixed dental prostheses, facial prostheses, surgical models and stents, and titanium implants can be fabricated with these systems.[6-8] Direct and effective metal parts can be obtained from many kinds of metal alloys without time-consuming prepocessing and postprocessing steps.[7] In this technique, which provides an alternative to the lost wax method, the virtual image of the restoration is transferred to the device.[9] The laser beam sinters selected areas of the Co-Cr alloy powders, and the restoration is produced layer by layer.[10] Laser sintering is particularly appropriate for obtaining metal components of diverse shapes without the need for manual completion after production.[7] Recent studies have compared the marginal adaptation,[11] corrosion resistance,[12] and

[a]Research Assistant, Department of Prosthodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.
[b]Professor, Department of Prosthodontics, Atatürk University, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.
[c]Professor, Department of Prosthodontics, Atatürk University, Faculty of Dentistry, Atatürk University, Erzurum, Turkey.

## Clinical Implications

The new laser-sintering technique of base metal is a promising alternative for improving metal-ceramic bond strength in patients who cannot afford the more expensive noble alloys.

biocompatibility[13] of this method with the casting method. In these studies, laser sintering performed similarly in terms of clinical marginal and axial wall adaptation[11] and provided advantages in biocompatibility[13] and high corrosion resistance.[12]

In dental laboratories, combining surplus alloy from the initial casting with the new alloy is common.[14] Remelting noble alloys for metal restorations a few times does not significantly change their composition or mechanical properties.[14] However, the loss of trace base metal such as Zn, In, Sn, and Fe during the recasting of noble alloys for porcelain can be detrimental to their castability and cause the formation of an oxide layer during initial oxidation; this could adversely affect porcelain bonding.[15]

Metal ceramic prostheses possess clinical longevity because of the strength of the bond between the metal framework and the porcelain. Therefore, this study aimed to determine how recasting influences the bonding between metal and ceramic by using ANSI/ADA Specification No. 3[16] and whether recasting up to 3 times affects the bond strength of metal-ceramic. The null hypotheses were that no difference would be found in the porcelain bond strengths of the 2 cast and 1 laser-sintered alloys and that recasting each of the alloys would have no effect on the bond strength.

## MATERIAL AND METHODS

One representative noble metal alloy (IPS d.SIGN 53; Ivoclar Vivadent), 1 base metal alloy (Starbond CoS; Scheftner), and 1 laser-sintering powder (EOS CobaltChrome SP2; EOS GmbH Electro Optical Systems) were selected for this study. IPS d.SIGN 53 is a Pd-Ag alloy, and EOS CobaltChrome SP2 and Starbond CoS are Co-Cr alloys. Their nominal compositions, which were obtained from the manufacturer, are presented in Table 1. Metal frameworks (25×3×0.5mm) were cast from patterns cut from 0.5-mm wax sheets (Corning Wax; Dentsply Intl) in accordance with ANSI/ADA Specification No. 38.[16] The wax patterns were filled with a phosphate-bonded investment (Sure-Vest High Heat; Ivoclar Vivadent Inc). A standard broken-arm centrifugal casting machine (Centrifico; Kerr Corp) was used to melt the alloys in suitable ceramic crucibles with a multiorifice propane-oxygen torch and cast. Before the castings were devested, they were cooled and airborne-particle abraded with

**Table 1.** Compositions of tested alloys as provided by manufacturer (wt%)

| Alloy | Pd | Ag | Pt | Zn | Sn | In | Li | Re | Ru |
|---|---|---|---|---|---|---|---|---|---|
| IPS d.SIGN 53 | 53.8 | 34.9 | <1.0 | 1.2 | 7.7 | 1.7 | <1.0 | <1.0 | <1.0 |
| | Co | Cr | Mo | W | Si | Mn | Fe | | |
| EOS CobaltChrome SP2 | 61.8-65.8 | 23.7-25.7 | 4.6-5.6 | 4.9-5.9 | <0.8-1.2 | <0.6 | <0.1 | | |
| Starbond CoS | 59,0 | 25,0 | 3,5 | 9,5 | 1,0 | <1.0 | <1.0 | | |

**Table 2.** Test specimen groups (n=12)

| Group | Metal Type | Preparation Method |
|---|---|---|
| C1 | Starbond CoS | First casting |
| C2 | Starbond CoS | Second casting |
| C3 | Starbond CoS | Third casting |
| L | EOS CobaltChrome SP2 | Laser sintered |
| P1 | IPS d.SIGN 53 | First casting |
| P2 | IPS d.SIGN 53 | Second casting |
| P3 | IPS d.SIGN 53 | Third casting |

50-μm $Al_2O_3$ (Sterngold Dental). The buttons and sprues from the first and second castings were airborne-particle abraded and ultrasonically cleaned in distilled water. They were then visually inspected to ensure that the remaining investment materials had been removed before they were cast for the second and third times. No new metal was added for the second or third castings. Seven groups of test specimens (n=12) were prepared (Table 2). The cast alloy strips were finished with a laboratory handpiece (W&H), ultrasonically cleaned in distilled water, and oxidized according to the manufacturer's recommendations. The selected alloys were coated with porcelain (VITA Omega 900 Metallkeramik; VITA Zahnfabrik). Two 0.1-mm layers of opaque porcelain were poured into a rectangular area (8×3 mm) in the center of 1 side of each cast metal specimen strip. Subsequently, 2 layers of body porcelain were used to produce porcelain with a rectangular shape that was 1.1 mm thick after firing, as measured by a Boley gauge (Benco Dental). The glaze was fired according to the manufacturer's recommendations. Figure 1 shows a photograph of a representative specimen. All specimens were subjected to 3-point flexure, following ANSI/ADA Specification No. 38.[16] The specimens were supported by a jig (20 mm between supports), and the ceramic was symmetrically positioned on the side opposite the applied load. The surface of the loading piston in contact with the specimen was 1-mm square. The apparatus for bond testing was positioned on a universal testing machine (Model 3344 Single Column System; Instron Ltd). The speed of the crosshead was 1.5 mm/min, and the effect of the force on the test specimen was reported until failure. The fracture force (fail) for each specimen corresponded to the formation of a debonding crack, which was visually observed at one end of the ceramic layer

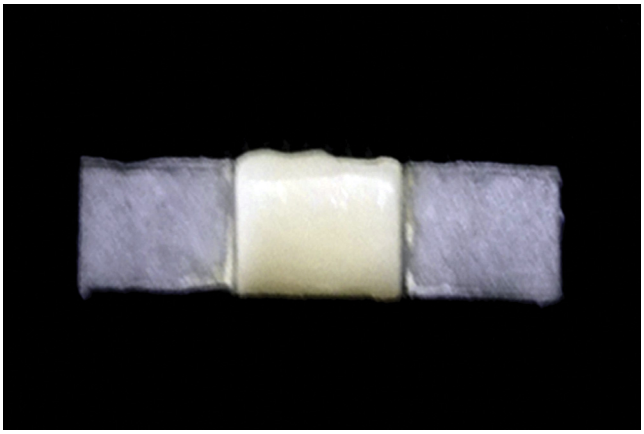

Figure 1. Photograph of representative specimen.

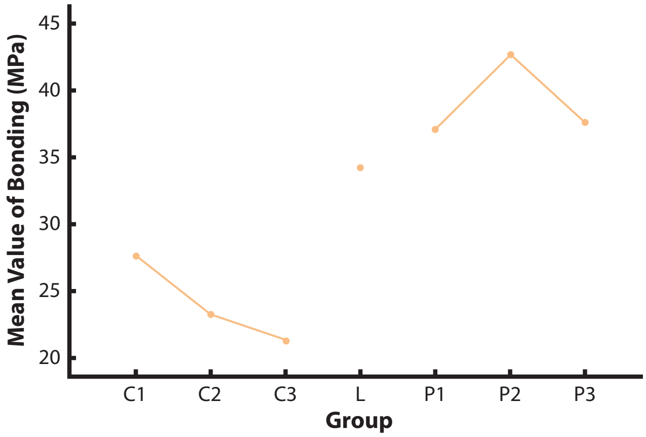


Figure 2. Mean bonding values of all groups.

Table 3. Summary of bonding compatibility index (τb) results for the tested alloy groups with values for standard deviations (SD)

| Group | Mean τb (MPa) | SD τb (MPa) |
|---|---|---|
| C1 | 27.66[b] | 2.45 |
| C2 | 23.29[a] | 4.00 |
| C3 | 21.34[a] | 5.96 |
| L | 34.24[c] | 6.31 |
| P1 | 37.09[c] | 7.02 |
| P2 | 42.68[d] | 3.22 |
| P3 | 37.60[c] | 5.84 |

Means indicated by different superscript letters are statistically different (*P*<.05).

Table 4. Means for groups in homogeneous subsets

| Duncan[a]/ Group | N | Subset for alpha=.05 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| C3 | 12 | 21.348000 | | | |
| C2 | 12 | 23.298967 | | | |
| C1 | 12 | | 27.666092 | | |
| L | 12 | | | 34.246833 | |
| P1 | 12 | | | 37.090742 | |
| P2 | 12 | | | 37.608792 | |
| P3 | 12 | | | | 42.680075 |
| Sig. | | .364 | 1.000 | .141 | 1.000 |

[a]Uses harmonic mean sample size = 12 000.

and was recorded on the load-deflection plot as a sudden drop in force. The metal-ceramic bond strength was calculated as the bonding compatibility index (τb), according to ANSI/ADA Specification No. 38. The thicknesses of all specimens were measured at both ends, and the mean values for each specimen were analyzed with ANOVA. The mean thickness and Young modulus (E) values were provided by the manufacturer and were used for calculating τb for each alloy (IPS d.SIGN 53, 132 GPa; EOS CobaltChrome SP2, 200 GPa; Starbond CoS, 200 GPa). After τb was calculated for each specimen, 1-way ANOVA and the post hoc Duncan tests (α=.05) were performed to compare the τb after 3 castings and laser sintering. The effects of remelting metal manufacturing techniques on flexure bond strength (FBS) were analyzed with ANOVA. The FBS values of the metal groups were compared with a post hoc test.

## RESULTS

A 1-way ANOVA showed that FBS was significantly affected by the alloy compositions, the casting number, and the use of laser sintering (*P*<.001). Even after several reuses, the Ag-Pd alloy showed a significantly higher bond strength with porcelain than did the Co-Cr casting alloy (Table 3). Two groups (C2, C3) decreased gradually and did not show satisfactory bonding compatibility (τb<25 MPa) according to ANSI/ADA Specification No. 38. Although the Pd-Ag alloy showed the highest bond strength after the second casting (P2: 42.68 MPa), the results were not statistically significant after the first and third recastings of the Ag-Pd alloy (P1-P3) and laser sintering (L). The FBS values of the Co-Cr laser-sintering group (L) were better than the values of the Co-Cr casting groups (C1,C2, C3) (Table 4). After the first casting, the mean τb values for each alloy were 27.66 MPa (Starbond CoS), 34.24 MPa (EOS CobaltChrome SP2 laser sintering), and 37.09 MPa (IPS d.SIGN 53). Figure 2 shows the mean values of groups.

## DISCUSSION

The data supported rejection of the null hypothesis that recasting, laser sintering, and metal type would have no effect on the porcelain bond strength for the alloy groups. In clinical dental practice, noble and base metal alloys are often reused in melting and recasting implementations. Studies examining the effect of recasting on the physical properties of metal-based alloys have achieved different results. Although relevant literature shows that the alloys of base metals can be used at least 4 times without losing their various physical properties,[17] Madani et al[18] discovered that adding more than 50% of the recast alloy significantly decreased the metal-ceramic bond strength.

The effects of remelting on palladium-based porcelain alloys have been reported. Hong et al[2] found that the thickness of the oxidation zone and the microporosities increased after each remelting of the commercial Pd-Ag alloy for up to 4 remeltings. The reusability of the Pd-Ag porcelain alloy remains questionable. Jochen et al[19] investigated how different amounts of reused Ag-Pd alloy affected the bond strength of porcelain and found that if the percentage of new alloy added to the once-cast alloy was less than 50%, the strength of the metal-ceramic bond was lower. Horasawa and Marek's study[14] demonstrated that the corrosion behavior of the silver palladium alloy remained usable until at least the fourth casting, but severe degradation of the gold content on the alloy's surface occurred after the fifth casting. Thus, the silver palladium alloy can be remelted several times. Liu et al[15] indicated no significant differences in metal-ceramic bonding for the Au-Pd alloy W-5 and the Pd-Ag alloy IPS d.SIGN 53 when they were cast up to 3 times.

Remelting 4 times without adding new alloy does not appear to greatly affect the physical properties of the much less expensive Co-Cr base metal alloys, indicating that the metal can be reused at least 4 times.[17] However, further studies examining the effect of remelting base metal alloys on porcelain bonding are required.

Papazoglou and Brantley[20] compared the results of a 3-point flexure test of the metal-ceramic bond of centrally coated ceramic alloy strips. The objective of this work was to compare, for palladium-gallium alloys, the metal-ceramic bonding results from the porcelain adherence test in the former ADA Specification No. 38[16] with results obtained from the force-to-failure test (Schwickerath test) in the ISO Standard, which was subsequently adopted by the American Dental Association. It is suggested that this test can provide reliable results.

Recent studies have shown that thermocyling did not affect the adhesion of laser-sintered specimens to porcelain, but did reduce porcelain adhesion in cast and milled specimens.[4] Co-Cr dental alloy fabricated with selective laser melting is a promising alternative to conventional cast alloy for metal ceramic restorations.[5] Liu et al[15] showed no effect on porcelain compatibility when 3 noble alloys were remelted twice, even without the addition of new alloy; these results are similar to the present results. Furthermore, Brite Gold XH showed a significant increase in $\tau b$ after 3 castings. Recasting may have increased the oxidation of this high-noble alloy (98% Au and Pt), which thereby increased the bonding compatibility index ($\tau b$). Unlike our findings, it was hypothesized that the amount of oxidation after initial heat treatment of the first-cast metal was adequate for optimum metal-ceramic bonding, and subsequent recasting did not further improve the interfacial bond for the IPS d.SIGN 53 alloy.

In the present study, the data supported the finding that recasting may adversely affect porcelain bonding for the Starbond CoS alloy group. The Ag-Pd alloy (IPS d.SIGN 53) showed a significantly higher bonding compatibility than the Co-Cr alloy (Starbond CoS). After all 3 castings, the Ag-Pd alloy showed satisfactory bonding compatibility with the selected porcelain, according to ANSI/ADA Specification No. 38 ($\tau b>25$ MPa). No significant difference was found in the bonding compatibility between laser sintering and the Ag-Pd alloy after the first and third castings. Therefore, it can be concluded that the newly developed laser-sintering technique is more successful than base metal casting and is less expensive than noble alloys. Laser sintering is a promising alternative to metal-ceramic restorations, though further research is needed before this technique can be applied in dental laboratories.

## CONCLUSION

The present results show that noble alloys can be remelted, because there is no problem with porcelain compatibility when IPS d.SIGN 53 is remelted 3 times without adding new alloy. However, the same cannot be said for base metals, whose bonding compatibility was not satisfactory after the second and third castings. Thus, without further research, the base metal alloys should not be remelted in dental laboratories. Additionally, laser sintering seems to be more successful than traditional casting methods.

## REFERENCES

1. Ucar Y, Aksahin Z, Kurtoglu C. Metal ceramic bond after multiple castings of base metal alloy. J Prosthet Dent 2009;102:165-71.
2. Hong JM, Razzoog ME, Lang BR. The effect of recasting on the oxidation layer of a palladium-silver porcelain alloy. J Prosthet Dent 1988;59:420-5.
3. Xu D, Xiang N, Wei B. The marginal fit of selective laser melting-fabricated metal crowns: an in vitro study. J Prosthet Dent 2014;112:1437-40.
4. Serra-Prat J, Cano-Batalla J, Cabratosa-Termes J, Figueras-Alvarez O. Adhesion of dental porcelain to cast, milled, and laser-sintered cobalt-chromium alloys: shear bond strength and sensitivity to thermocycling. J Prosthet Dent 2014;112:600-5.
5. Wu L, Zhu H, Gai X, Wang Y. Evaluation of the mechanical properties and porcelain bond strength of cobalt-chromium dental alloy fabricated by selective laser melting. J Prosthet Dent 2014;111:51-5.
6. Kanazawa M, Iwaki M, Minakuchi S, Nomura N. Fabrication of titanium alloy frameworks for complete dentures by selective laser melting. J Prosthet Dent 2014;112:1441-7.
7. Iseri U, Ozkurt Z, Kazazoglu E. Shear bond strengths of veneering porcelain to cast, machined and laser-sintered titanium. Dent Mater J 2011;30:274-80.
8. Chen J, Zhang Z, Chen X, Zhang C, Zhang G, Xu Z. Design and manufacture of customized dental implants by using reverse engineering and selective laser melting technology. J Prosthet Dent 2014;112:1088-95.e1081.

9. Kim KB, Kim JH, Kim WC, Kim JH. Three-dimensional evaluation of gaps associated with fixed dental prostheses fabricated with new technologies. J Prosthet Dent 2014;112:1432-6.
10. Yüksel ZE. Application of rapid prototyping technologies in dentistry: clinical report. Cumhuriyet Dent J 2011;14(3):225-9.
11. Tamac E, Toksavul S, Toman M. Clinical marginal and internal adaptation of CAD/CAM milling, laser sintering, and cast ceramic crowns. J Prosthet Dent 2014;112:909-13.
12. Zeng L, Xiang N, Wei B. A comparison of corrosion resistance of cobalt-chromium-molybdenum metal ceramic alloy fabricated with selective laser melting and traditional processing. J Prosthet Dent 2014;112:1217-24.
13. Yang X, Xiang N, Wei B. Effect of fluoride content on ion release from cast and selective laser melting-processed Co-Cr-Mo alloys. J Prosthet Dent 2014;112:1212-6.
14. Horasawa N, Marek M. The effect of recasting on corrosion of a silver-palladium alloy. Dent Mater 2004;20:352-7.
15. Liu R, Johnston WM, Holloway JA, Brantley WA, Dasgupta T. The effect of metal recasting on porcelain-metal bonding: a force-to-failure study. J Prosthet Dent 2010;104:165-72.
16. ANSI/ADA Specification No. 38 2000 Reaffirmation (Reaffirmed 2010) Metal-ceramic dental restorative systems. Fed Reg 2010;7191:61148-57.
17. Hesby DA, Kobes P, Garver DG, Pelleu GB Jr. Physical properties of a repeatedly used nonprecious metal alloy. J Prosthet Dent 1980;44:291-3.
18. Madani AS, Rokni SR, Mohammadi A, Bahrami M. The effect of recasting on bond strength between porcelain and base-metal alloys. J Prosthodont 2011;20:190-4.
19. Jochen DG, Caputo AA, Matyas J. Reuse of silver-palladium ceramic metal. J Prosthet Dent 1991;65:588-91.
20. Papazoglou E, Brantley WA. Porcelain adherence vs force to failure for palladium-gallium alloys: a critique of metal-ceramic bond testing. Dent Mater 1998;14:112-9.

**Corresponding author:**
Dr Zeynep Yesil Duymus
Atatürk University
25030 Erzurum
TURKEY
Email: zyesilz@hotmail.com

Copyright © 2015 by the Editorial Council for *The Journal of Prosthetic Dentistry*.

## Receive Tables of Contents by E-mail

To receive tables of contents by e-mail, sign up through our Web site at http://www.journals.elsevierhealth.com/periodicals/ympr.

### Instructions

Log on and click “Register” in the upper right-hand corner. After completing the registration process, click on “My Alerts,” then “Add Table of Contents Alert.” Select the category “Mosby” or type ***The Journal of Prosthetic Dentistry*** in the search field and click on the Journal title. The title will then appear, and having already completed the Registration process, you may add tables of contents alerts by accessing an issue of the Journal and clicking on the “Add TOC Alert” link.

You will receive an e-mail message confirming that you have been added to the mailing list.

Note that tables of contents e-mails will be sent when a new issue is posted to the Web site.