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RESEARCH ARTICLE

EFFECT OF REPEATED FIRINGS ON METAL CERAMIC BOND STRENGTH OF Co-Cr ALLOY FABRICATED BY DIRECT METAL LASER SINTERING AN IN-VITRO STUDY

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Abstract

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Purpose: The bond strength of metal ceramic restorations places a key role for the longevity of the prosthesis which could be affected by the fabrication technique and the number of firings. The current research evaluates the effect of repeated firings on bond strength of metal ceramic systems with copings fabricated from two processing techniques, lost wax technique through induction casting and direct metal laser sintering.

Materials and Methods: 21 metal ceramic bars will be fabricated using Direct Metal Laser Sintering (Group DMLS) and 21 using conventional lost wax technique (Group Cast). Each sample will have a dimension of 25x3x0.5mm respectively. In the center of each bar, a 1.1mm thickness of porcelain will be fused onto an 8x3mm rectangular area. Each group is further subdivided into 3 subgroups which are subjected to repeated firings (3, 5, 7) and the bond strength is measured with positioning of the samples on a Universal Testing Machine.

Results: Group ANOVA and Post Hoc Tukeys test showed comparison of overall bond strength of ceramic samples fabricated using DMLS & Casting subjected to different Firing was done and the difference in mean was statistically significant ($p<0.05$).

Conclusion: The DMLS group showed slight superior bond strength properties when compared with Cast group.

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Introduction:-

Metal-ceramic restorations are still considered the preferable choice for fixed dental restorations, due to their high strength and superior aesthetic appearance. The selection of the appropriate dental alloy and its processing to produce an acceptable metal-ceramic bond is one of the key elements influencing the success of these restorations.

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Co-Cr alloys are the best option for dental metal-ceramic applications due to their superior mechanical qualities, including high modulus of elasticity and great corrosion resistance[3].

Although the predominant fabricating technique of dental metal substrates is the casting, over the recent years the evolution of digital technology has developed new techniques of construction, such as Stereolithography (SLA), Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) as well as Hot pressed technique. The high performance, good aesthetics, and high density of SLM produced products indicate that SLM may have a significant capacity for use in the fabrication of dental restorations[10].

DMLS crowns have greater bond strength between metal and ceramic than conventional techniques due to their reduced porosities and finer grain size with greater surface roughness leading to better mechanical interlocking. The DMLS technique for dental application has greater potential to substitute the traditional lost wax technique as it is more repeatable, accurate and less operator sensitive than the lost wax technique and the precision of dental crowns obtained is very good by microns order.

One common error by dental technicians is repeated firing due to errors to achieve a suitable form pattern in metal ceramic crowns. Studies have shown that microcracks in ceramic could be caused by condensation, melting, and sintering of the ceramics on metal because of coefficient of thermal expansion differences. Thus, repeated firings of restorations are inevitable. Studies have shown that repeated firings of porcelain decrease porcelain metal compatibility and subsequently decrease bond strength[7].

Although a number of mechanical tests can be used to evaluate the strength of a metal– ceramic interface, it is the Schwickerath crack initiation test (three-point bending test), first proposed by Lenz et al. that is promulgated in ISO 9693:1999(E)9 to determine the debonding strength of a metal– ceramic system [10]. In a three-point bending test, the upper portion of the specimen is under compression, the lower under tension, while the probe tips are in shear mode.

The present study evaluates the effect of repeated firings on bond strength of metal ceramic systems with copings fabricated from two processing techniques, lost wax technique through induction casting and direct metal laser sintering.

Materials and Methodology:-

42 Co-Cr discs of a uniform diameter of 3mmx25mmx0.5mm were fabricated of which 21, using the lost wax technique (LITHCAST CoCr metal pellets are used) (Fig 2) and 21, using direct metal laser sintering (3D Systems, LaserFormCoCr (C)) (Fig 3) powder is used. In the center of each bar, a 1.1-mm thickness of opaque and dentin porcelain (VITA ceramic is used) was fused onto an 8×3mm rectangular area (Fig 4).

They were subjected to repeated firings (3, 5, and 7), and the bond strength of these samples was measured by a 3-point bend test using the Universal testing machine.

Procedure for measuring bond strength:

Bond strength readings were obtained by using the Universal testing machine (Fig 5), which can mathematically describe the values of force (F) and surface area (SA). The current standards, ANSI/ADA Specification No. 38 (2000) and ISO Standard 9693 (1999), for evaluation of the metal–ceramic bond employ a three-point bending test, and the minimum acceptable bond strength with this test is 25 MPa. A supporting column with a 1 mm diameter and a 20 mm span was used at each end of the specimen to support it during testing. The samples were placed on the device symmetrically, and the crosshead speed was adjusted to 1.5 mm/min, which loaded the force in the middle of the bar until breakage occurred (Fig 6).

The force at which initial debonding occurred is taken as F. The total surface area of metal to ceramic 3x8mm is taken as SA.

Bond strength of that particular sample is calculated by using the formula:

$$\text{Bond strength} = \frac{\text{Force (F)}}{\text{Surface Area}}$$

Fig. 1:- Wax pattern fabricated using putty index.

Fig. 2:- Wax patterns with sprue attached.

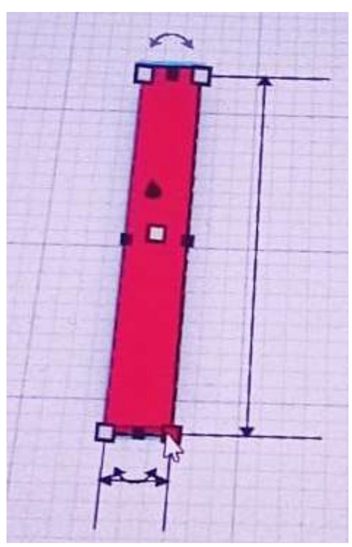


Fig. 3:- 3D format for metal discs.

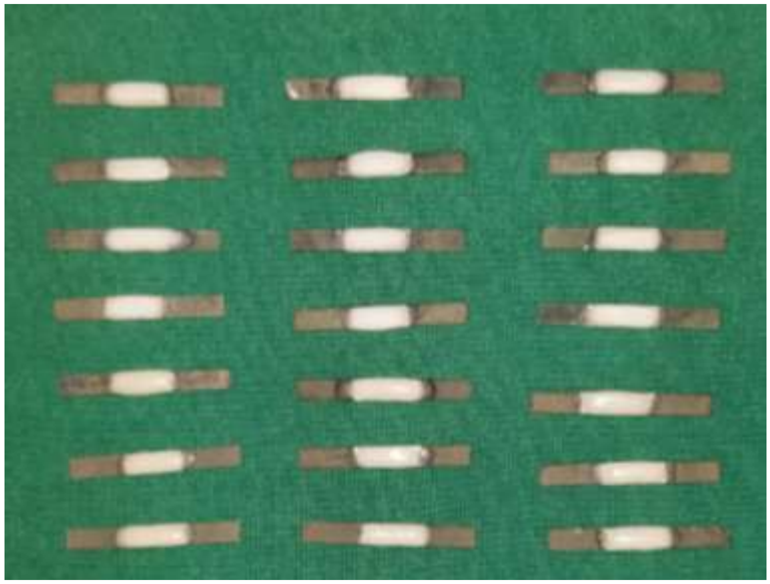


Fig.4:- Metal-ceramic samples after repeated firings

Fig. 5:- Universal testing machine.

Fig. 6:- 3 point bend test.

Results:-

The data were subjected to Statistical Analysis using IBM SPSS Version 21. Descriptive and Inferential statistics for the two groups, i.e., conventional and DMLS groups, and three subgroups, i.e., 3rd, 5th, 7th, firing groups, were tabulated in tables and graphs.

To compare within Group ANOVA with Post Hoc Tukeys was applied.

All tests were applied keeping Confidence interval at 95% and (P>0.05) was considered to be statistically significant.

Table 1:- Mean bond strength of the ceramic samples Fabricated using DMLS to different firings.

DMLS Bond Strength					
	N	Minimum	Maximum	Mean	Std. Deviation
3 Firing	7	28.83	34.52	32.1271	1.91742
5 Firing	7	28.04	31.62	29.9271	1.38056
7 Firing	7	24.94	28.98	27.6300	1.33362
Total	21	24.94	34.52	29.8948	2.39752

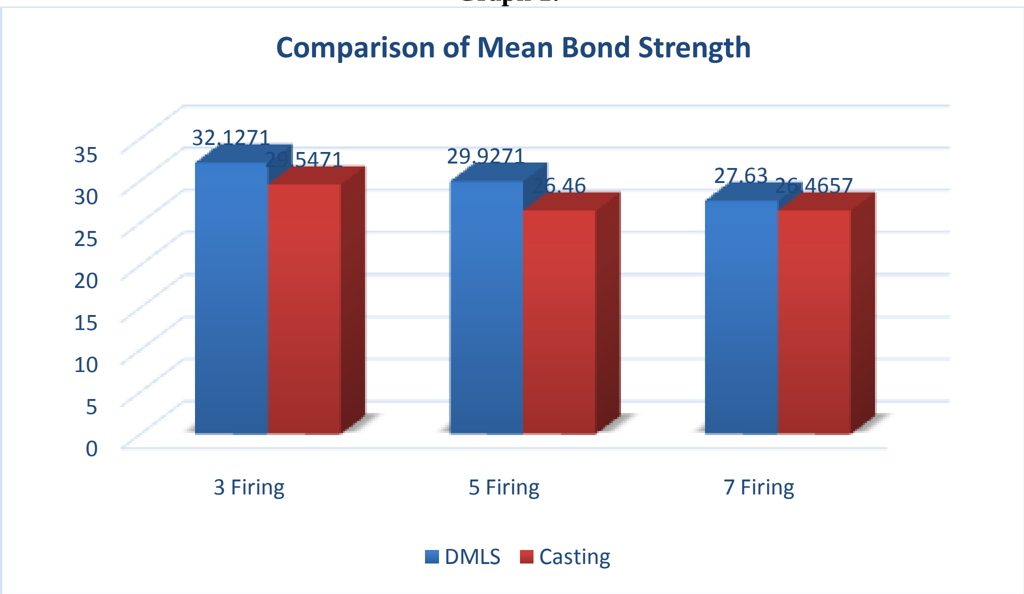
Table 2:- Mean Bond Strength of Ceramic Samples Fabricated using Casting subjected to different Firing.

Casting Bond Strength					
	N	Minimum	Maximum	Mean	Std. Deviation
3 Firing	7	26.91	32.95	29.5471	1.89825
5 Firing	7	24.16	28.92	26.4600	1.69981
7 Firing	7	23.39	29.16	26.4657	1.84919
Total	21	23.39	32.95	27.4910	2.27889

Table 3:- Comparison of Overall Bond Strength of Ceramic Samples Fabricated using DMLS & Casting subjected to different Firing.

ANOVA					
Bond Strength					
	Sum of Squares	df	Mean Square	F	P Value
Between Groups	175.861	5	35.172	12.217	.000
Within Groups	103.639	36	2.879		
Total	279.501	41			

Graph 1:-



Discussion:-

The present study evaluated the effect of repeated firings on the metal-ceramic bond strength of copings fabricated from two different processing techniques (Lost wax technique and Direct metal laser sintering).

Excellent fracture resistance of metal-ceramic restorations is one of the main reasons for its use in fixed dental prostheses. Dental prosthesis restorations must be strong to survive in the constantly varying biological conditions of the human oral cavity (temperature, pH, chemical changes), which are influenced by various chewing pressures. More particularly, during chewing, multi-axial stresses emerge in dental restorations. Thus, ensuring protection from the failure of dental restorations requires selecting the appropriate materials and manufacturing methods [(2)].

Achieving good bond strength between the metal and ceramic is the prime requisite for its long-term use[(5)]. Chemical, mechanical, and thermal methods can obtain optimal bond strength. In addition, processing variables in porcelain firing are also possible for improper bond strength, including firing temperature and repeated firings.

Although chemical bonding was responsible for metal–porcelain adherence, evidence exists that mechanical interlocking also provides the adhesion. Lavine and Custer[(6)] found that surface roughness increased the bond strength compared with non-roughened castings due to an increase in surface area, thus improving wettability because of the diffusion of the porcelain particles into the metal–porcelain interface.

McLean and Sced[(9)] tested the effects of pre-oxidation, surface roughness, and pickling of the substrate after undergoing oxidation, and discovered that sandblasting and degassing before porcelain application achieved the best bond strength. In this study, sandblasting of the samples with 50 µm aluminum oxide particles was done.

42 samples were fabricated in the present study, with ceramic over metal copings with a total thickness of 1.6mm. Twenty-one samples from each group were molded into dimensions of 25×3×0.5 mm, following International Organization for Standardization (ISO) standard 9693:2012. In the center of each bar, a 1.1-mm thickness of porcelain was fused onto an 8×3-mm rectangular area[(7)].

With repeated firings in this study value of F decreased, resulting in decreased bond strength as the number of firings increased. But all the values obtained from the lost wax technique and DMLS are above the acceptable range. F values decreased as the firings increased, thereby reducing the bond strength in both lost wax and the DMLS technique.

Lucia Dent[(1)] investigated the mechanical and functional characteristics of DMLS compared to traditional casting. Also, Co-Cr specimens produced by DMLS show excellent bond strength and the absence of defects concerning traditional casting.

NecatiKaleli[(4)] compared the porcelain bond strength of cobalt-chromium (Co-Cr) metal frameworks prepared by using the conventional lost-wax technique, milling, direct metal laser sintering (DMLS), and laser cusing, a direct process powderbed system. All groups, except for laser sintering, exhibited adhesive and mixed type bond failure. Both of the laser sintering methods were found to be successful in terms of metal ceramic bond strength.

In the present study, the bond strength obtained was >25 MPa for the lost wax technique and DMLS and the results obtained were in accordance with the above 3 studies. This may be due to the similarities in dental alloy composition used in both fabrication techniques.

J. G. Stannard et al[(8)]. concluded that the repeated firing of porcelain would practically lead to a decrease in porcelain metal compatibility and a subsequent decrease in bond strength. This study determined the effect of repeated firings on the planar shear bond strength of two compatible porcelain-to-metal systems.

The findings of the present investigation indicate that, as the force values decreased with repeated firings, so did the strength in both groups. The results obtained in the present study were in accordance with the above analysis. Repeated firing will lead to increase in crystallization, crack formation there by leading to a failure.

Limitations of this study:
Static loading was used in the study; however, dynamic loading is required to accurately represent the intraoral environment.

Results may be more accurate if the geometry of the samples utilized is similar to the geometry used in clinical settings.

A better understanding of metallic surface properties, porcelain adhesion to metal, cohesive failure of ceramics, and the effect of repeated firings on bond strength must be investigated further.

Conclusion:-
The following conclusions were drawn within the constraints of this in-vitro study.

With the increase in the number of firings the amount of debonding force is reduced thereby reducing the bond strength in both the groups.

Fabrication techniques (DMLS and Lost wax technique) have no significant effect on bond strength of metal ceramic restorations after being subjected to repeated firings.

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