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Evaluation and Comparison of the Internal Fit and Marginal Accuracy of Cobalt-Cromium Alloy Copings Fabricated Through Cad-Cam Milling and Direct Metal Laser Sintering Technology- An In Vitro Study

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ABSTRACT

Introduction: Dental prostheses necessitate physiologic constancy, strength sufficient biocompatibility, for the occlusal load, an aesthetic comparable to the colour and shape of real tooth, to accurate fit to the abutment.

Objectives: The aim of this study was to evaluate and compare the internal fit and marginal accuracy of Co-Cr copings fabricated through CAD-CAM milling and Direct Metal Laser Sintering technology (DMLS) by using stereomicroscope.

Methods: A total no of 40 Co-Cr Copings were fabricated and were divided in two groups. Group a: 20 Co-Cr copings fabricated by CAD-CAM. Group B: 20 Co-Cr copings fabricated by DMLS technology. Copings of both group were evaluated and compared for internal fit and marginal accuracy by stereomicroscope. Data obtained was analysed using Statistical package for social sciences (SPSS v 21.0, IBM).

Results: The result of the study showed that the internal fit and marginal accuracy was less in CAD CAM Co-Cr Copings when compared with DMLS technology.

Conclusion: It could be concluded from the study that Copings fabricated with CAD-CAM have less discrepancy in internal fit and better marginal accuracy when compared with DMLS Technology.

Key Words: CAD-CAM, Co-Cr Copings, Internal fit, Marginal accuracy

INTRODUCTION

Dental prostheses necessitate physiologic constancy, strength sufficient biocompatibility, for the occlusal load, an aesthetic comparable to the colour and shape of real tooth, to accurate fit to the abutment.[1] Furthermore functional and aesthetic outcome, longevity is another factor for their success. Longevity, whether from a biologic or mechanical standpoint, is directly related with the quality of marginal and internal fit.[2]

Passive fit has been well-defined as "the optimum marginal fit of superstructures to abutments that determines the absence of bone tension without the occlusal load" and is measured a essential factor for the long-term success of dental implant restorations.[2] The lack of passive fit may increase the risk of biomechanical failure, including framework distortion or ceramic detachment due to inadequate stress dissipation.[2] Advances in computer-aided design and manufacturing (CAD-CAM) techniques in the last three decades have dramatically improved prosthetic devices machined directly in the dental clinic or laboratory[3]. Two types of CAD-CAM systems are frequently used today, which work either subtractive milling or an additive technique depending on three-dimensional (3D) printing.[3]

The manufacture of metallic restorations in the dental laboratory has conservatively been conceded out by the lost wax casting method.[4] Dental casting alloys can be allocated into base metal alloys and noble alloys such as nickel-chromium (Ni-Cr) and cobalt-chromium (Co-Cr) alloys.[4] Both Ni-Cr and Co-Cr alloys may be used for metal ceramic restorations, but Co-Cr alloys are preferred for patients known to be allergic to nickel.[4] However, Co-Cr alloys are difficult to manipulate in the dental laboratory because of the high melting range of the

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casting alloy with the need to heat to high temperatures before casting.[2] The use of cobalt-chromium (Co-Cr) alloys for crowns and fixed dental prostheses has increased largely because of their excellent mechanical properties and their lower cost than those using high-noble alloys.[4]

From past seventy years, conventional casting, recognised as lost-wax casting, was the prime method for manufacturing metallic dental restorations. However, the evolution of digital technology and the development of CAD-CAM procedures at the beginning of the 1970s set a landmark by introducing automated manufacturing processes. Until the early 1980s, most fabrication techniques of dental restorations were based on subtractive manufacturing, either by casting or milling.[5] recently, the introduction of additive manufacturing provided a completely new concept. CAD-CAM technologies have revolutionized prosthodontics by enabling new manufacturing methods and materials. A simple scanning procedure can directly generate a 3-dimensional cast of a dental impression or of the patient's mouth.[6]

Various additive techniques were developed to meet the requirements of rapid manufacturing (RM) and rapid prototyping (RP), [5] such as stereo lithography (SLA), [5] fused deposition modeling (FDM), [5] selective electron beam melting (SEBM) [5] or selective laser sintering (SLS).[5] Each technique was used for the manufacture of different dental materials, with SLS being the most increasingly used for the fabrication of dental restorations in prosthetic dentistry.[5] SLS is a procedure of manufacturing 3D parts, consolidating layers of powders of several materials (such as polymers, metal and ceramics), under the heat of a intensive laser beam, focused by the data provided by a CAD file.[5,6] CAD-CAM and direct metal laser sintering (DMLS) manufacturing systems have recently been introduced for fabricating metal frameworks for metal ceramic crowns to overcome the disadvantages of the casting method.[7]

Advantages of the MLS system include the ease with which it can be fabricated and eliminating a major disadvantage of the lost wax technique, i.e., the casting shrinkage.[8] SLM technology saves substantial construction time in the production of precision made products. With SLM, powder can be completely melted without much retained porosity; near full density objects with complex geometries can be produced.[9] SLM products exhibit higher density and improved corrosion and surface properties.[10] It is not clinically desirable that a crown should have a perfect fit with no marginal gap because there must be space for the luting agent.[11] The CAD-CAM production process uses either direct or indirect digitalization and enables the design, analysis, and additive or subtractive manufacturing of restorations with a computer.[12]

However, recent advances in technology, engineering, and materials have led to CAD-CAM systems that use highly accurate scanners and more sophisticated software to digitize the complex shapes required in dentistry.[13] This *in vitro* study was conducted to evaluate the internal fit and marginal accuracy of co-cr alloy copings fabricated through cad-cam milling and direct metal laser sintering technology.

MATERIALS AND METHODS

A total number of 40 samples (calculated using statistical software version) were prepared and divided into two groups depending upon the fabrication technique of Co-Cr alloy copings. A special stainless steel master metal die of cervical diameter of 8mm which includes 0.8mm of cervical margin, 5^0 of uniform taper and height of 6 mm was made. The die had orientation grooves parallel to each other and the base of the die also comprised two sleeves which gave anti rotational feature (Figure-1). The master die was cleaned with ethyl alcohol, distilled water and dried. Light and putty viscosity addition silicone impression material (Silagum™) was used to make 40 impressions of the master metal die. The light viscosity impression material was syringed around the master metal die, and the putty material was loaded into circumferentially metal ring assembly. Mould obtained from the master die.

The impression was poured in Type IV die stone (Ultrarock Kalabhai™) after 30 minutes. Working stone dies was carefully removed from the impression and examined for the presence of air bubbles or other defects. Now working stone dies will be removed from the impression after 1 hour and divided into 2 groups 20 of each and grouped as A and B. The working stone dies in group A will be numbered as A1 to A20 and in group B will be numbered as B1 to B20 (Figure 2).

The advance of a soft non-presintered Co-Cr material (Ceramill Sintron; AmannGirrbach, Koblach, Austria) permits this alloy to be handled in-house on desktop milling machines with reduced manufacturing cost and time. The processing steps are quite similar to those of pre-sintered zirconia. All copings were designed with a thickness of 0.5 mm; the cement space was set to 25µm with no space from the margin.

In the CAD/ Ceramill Sintron system twenty metal copings were fabricated from non presintered soft Co-Cr blocks (Ceramill Sintron blanks; Amann Girrbach, Germany). All working dies were laser scanned to obtain a 3D model on the computer. This 3D model on the computer was used to design a Co-Cr coping with the help of CAD-CAM milling technique (Ceramill motion 2 Amann Girrbach Australia ™). The soft Co-Cr blank was processed in a material pre-state by dry milling. The 20 Co-Cr coping were made from A1 to A 20 (Figure-3).

The material contains adhesive agents such as organic binders and is milled in a "green state". Subsequently, the milled reconstruction must be sintered to full density in a special, high-temperature sintering furnace under an argon protective gas atmosphere at 1300 °C. During the sintering process, the organic binder burns out and the metallic powder particles was sintered (caked) without creating a fused phase. This leads to a decrease in volume of approximately 10%.

The working dies of Group B (B1-B20) were scanned using optical scanner (3M ESPE lava scan TM). 20 metal coping were fabricated by Co-Cr metal alloy powder (EOS Co –Cr SP-2TM) by Direct Metal Laser sintering (Figure 3).

A laser beam was outlined over the surface of a securely compacted powder made of thermoplastic material. The powder was spread by a roller over the surface of a build cylinder. A piston moves down one object layer thickness to occupy the layer of powder. Excess powder in each layer helps to support the part during the build. Heat from the laser selectively melts the powder where it strikes under guidance of the scanner system.

The laser provides a concentrated infrared heating beam. The whole fabrication chamber was sealed and maintained at a temperature just below the melting point of the plastic powder.

The copings obtained were cemented on their dedicated working dies using glass ionomer cement. (GC Corporation TM). These specimens were then embedded in autopolymerizing acrylic resin in ring of stainless steel having dimensions 2cm in diameter and 2cm in height. The embedded specimen was then sectioned longitudinally in labio-lingual direction from the centre of the die using slow speed diamond cutting saw. This sectioned specimen will then be finished and polished to remove metal particles that adhered to cement region (Figure 4).

The internal gap width was measured using optical microscope i.e. stereomicroscope at resolution 40x at standardized areas (a) incisal/ occlusal surface (b) lingual axial surface (c) and labial axial surfaces (c). Each Co-Cr coping obtained from CAD-CAM milling procedure as well as direct metal laser sintering procedure was seated to respective working die using light finger pressure until resistance is obtained. The grooves on the die prevent rotation of the patterns and ensured correct seating . The vertical marginal discrepancy between the margin of metal coping and the cervical preparation line of the working die was measured at labial margin and lingual margin using a stereomicroscope at resolution 40x for group A and B (Figure 5).

RESULTS

`Data obtained was compiled on a Micro Soft Office Excel Sheet (v 2010) and was subjected to statistical analysis using Statistical package for social sciences (SPSS v 21.0, IBM) Normality of data was determined using Kolmogorov-Smirnov test and it was found that data did not follow a normal curve, hence non-parametric tests were used. Inter group comparison of all variables was done using Mann Whitney U test. For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%. The result of the study showed that the internal fit discrepancy on incisal/occlusal surface, labial surface and lingual surface is less in Co-Cr copings prepared by CAD- CAM when compared with DMLS technology. The marginal discrepancy is less on labial and lingual margin in Co-Cr copings prepared with CAD-CAM when compared with DMLS technology.

The average internal fit discrepancy on incisal /occlusal, labial and lingual surface of Co-Cr copings with CAD- CAM is 42.005 µm, 29.198 µm and 27.166 µm respectively and the average internal fit discrepancy on incisal /occlusal, labial and lingual surface of Co-Cr copings with DMLS technology is 67.887 µm, 35.58 µm and 34.741 µm respectively (Table 1).

The average marginal fit discrepancy on labial and lingual margin of Co-Cr copings with CAD-CAM is 34.347 µm and 35.515 µm and the average marginal fit discrepancy on labial and lingual margin of Co-Cr copings with DMLS technology is 39.381 µm and 39.656 µm (Table 2).

DISCUSSION

This study was conducted to evaluate and compare the internal fit and marginal accuracy of Co-Cr copings fabricated through CAD-CAM milling and Direct Metal Laser Sintering technology (DMLS). According to American dental association (ADA) specification no. 8 it should be within 25µm-40µm. McLean and Von Fraunhofer concluded in a 5-year clinical study of 1000 restorations that 120µm was the maximum acceptable marginal opening. Quante et al.[14] stated no standard protocol is available for evaluating the adaptation of dental restorations. This may result in to misconception and limits the evaluation of results from different studies. Marginal and internal gaps are generally being measured directly under a microscope after sectioning the embedded specimens into acrylic resins i.e. cross-sectional technique after cementation and embedding (internal microscopic examination).

The internal gap was defined as the perpendicular distance between the framework and the abutment teeth. In the present study the mean internal fit discrepancy at Incisal /occlusal surface is 42.00µm, mean internal gap at the labial axial surface is 29.19µm, and the lingual axial surface is 27.16µm in copings fabricated with CAD-CAM. Vojdani et al.[15] stated a study that had clinically acceptable results of 23 µm for the internal gap in the CAD/Milling group and 46 µm for the internal gap in the CAD/Ceramill Sintron.

There is a significant difference found out in the study within the limitations of this study in the internal fit and marginal accuracy. The internal fit with lowest value at incisal/ occlusal surface is 24.12 µm of CAD-CAM copings and highest value is 116 µm. The lowest value 24.27µm was found to be at labial axial and lingual axial surface and highest value found out to be 43.95 µm & 33.98 µm at labial axial and lingual axial surface respectively. Bhaskaran et al.[16] stated that vertical marginal gap ranged between 10 and 160 µm.

Marginal accuracy of CAD-CAM Milling (group A), the mean marginal gap at the labial margin is of 34.34µm and at lingual margin 35.51µm. Kim et al.[17] proposed in his study that the marginal internal gaps were 68.6 ± 11.9 µm, 49.2 ± 11.8 µm, and 81.1 ± 4.9 µm, for the casting, the CAD/CAM milled, and the laser sintered coping, respectively. the present study revealed that in the marginal accuracy the minimum value found out to be 22µm and maximum value to be 59.05 µm at labial marginal area. The marginal accuracy in lingual surface area is 24.27µm at low scale and 53.34µm at the higher scale. Kane et al.[18] stated that the mean marginal openings of the milled Co-Cr copings studied in his investigation were within the range (52 to 113 µm) considered clinically acceptable by most reports in the dental studies (<120 µm), therefore according to this system have clinically acceptable discrepancies.

In the Direct metal laser sintering technology (DMLS) Group B, the Mean Internal fit values of DMLS, at Incisal/occlusal surface of is 67.88µm, Mean labial axial surface is 35.58µm, and the mean lingual axial surface is 34.74µm. Lovgren carried out the study in which the mean axial space found out to be in LS coping 79 ±8 µm and the mean occlusal space in laser sintered coping was 125 ±30 µm[3], Oyague et al.[19] proposed study the mean (SD) vertical discrepancy (µm) Laser-sintered Co–Cr is 30.2µm.

Marginal accuracy of direct metal laser sintering technology (DMLS), the mean marginal gap of DMLS at labial marginal surface is 39.381 µm and mean marginal gap at lingual surface is 39.656µm, Zeng et al.[20] stated the mean marginal gap width values for SLM-fabricated copings were 36 µm, 37 µm, 38 µm, and 38 µm after the first, third, fifth, and seventh firings, the Mean marginal accuracy of the present study found out to be , 39.38 µm at labial margin , and at lingual margin is 39.65 µm.

In the present study the Group B (DMLS) the incisal /occlusal surface the minimum value is 29.12µm and the highest value was found out to be 200µm, Kim et al.[17] proposed a study the occlusal internal gap value was 133.5±22.8 µm in the laser sintered group.

In the present study the labial axial surface having the lowest value of a sample is 29.12 µm and highest value of a sample was 74.43. The lingual axial surface was found out to be 26.14 µm and 44.75 at the higher end of discrepancy, Harish et al.[21] study revealed that the internal fit among samples within laser sintered copings, the lowest discrepancy was 99 µm and highest discrepancy of 119 µm therefore assuming both the discrepancy are in clinical acceptable use.

The Marginal fit in the labial surface is 29.12 µm at lower side and 63.1 µm at the higher side, there is also a significant finding were seen in marginal fit in lingual area 29.12 µm at lower end and 97.2µm at higher end of a sample, Tamac E carried out a study in which the Mean measurement of adaptation discrepancy was 96.23 µm for DMLS.

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The effect of coping on crown and the abutment is important as the outcome of the treatment in long term will depend upon these changes. Unless these changes are accounted for while in internal fit and marginal accuracy, measuring the prognosis of a particular treatment, long term success could be seldom achieved.

CONCLUSION

Within the limitations of the study we conclude that; the Internal fit discrepancy values were less in CAD-CAM Milling samples as compared to Direct metal laser sintering samples, the Marginal accuracy values of both sample group were near but CAD-CAM milling group were having better marginal fit than DMLS group.

Conflict of interest: Nil

Source of funding: Self

Authors contribution

1. AM- Insvestigation
2. VK–Data collection
3. SK-Analysis
4. SP- Manuscript writing
5. NK- Manuscript writing
6. PN- Manuscript editing

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Table1: Internal fit discrepancy (μm)

	Incisal/ occlusalsurface	Labial axial surface	Lingual Axial surface
CAD CAM	42.005	29.198	27.166
DMLS	67.887	35.58	34.741

Table 2: Marginal accuracy discrepancy (μm)

	Labial Margin	Lingual margin
CAD CAM	34.347	35.515
DMLS	39.381	39.656

Figure 1: Fabrication of special stainless steel mould.

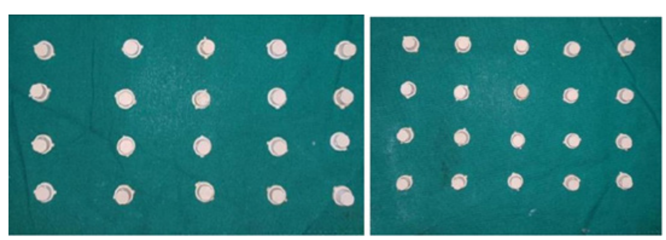

Figure 2: Working dies of group A and B.

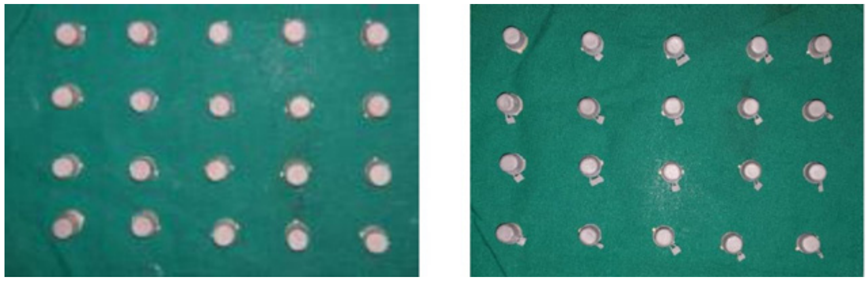

Figure 3: Co-Cr coping fabricated with CAD CAM and DMLS technology.

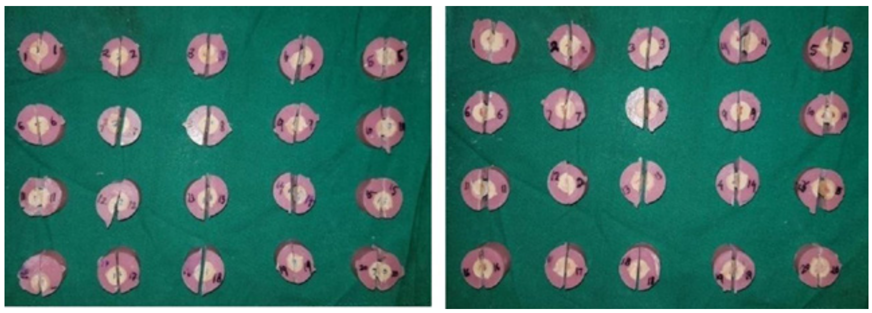

Figure 4: Sectioned Group A and B samples.

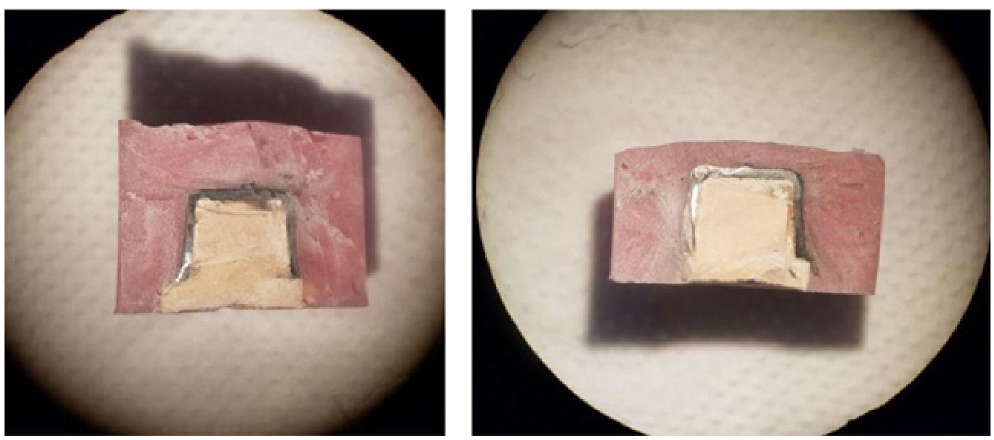

Figure 5: Mircoscopic view of samples through lens of stereomicroscope CAD CAM milled and DMLS sample.