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RESEARCH ARTICLE

COMPARING THE MARGINAL AND INTERNAL FIT OF METAL COPINGS FABRICATED BY THREE DIFFERENT TECHNIQUES.AN *IN VITRO* STUDY

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ABSTRACT

Background: Marginal and internal fit play an important role in determining the longevity of the restoration. Several fabrication techniques have evolved in recent times, but little emphasis was advised to the fit of the restoration. **Purpose:** The aim of the study is to compare and evaluate the internal and marginal fit of Cobalt-Chromium copings fabricated by computer aided milling/computer aided designing, direct metal laser sintering and conventional casting method**. Material and methods:** A master metal Die was designed using CAD software and milled using Ni-Cr alloy. 3D printer was used to design a customized special tray for making impressions of master die. A total of 15 working dies were duplicated from the master metal die. The study included three groups of 15 samples in each. Group A copings were fabricated using conventional method, group B copings were fabricated using CAD/CAM procedure and group C included 15 copings fabricated using DMLS procedure. The silicone replica technique was used to measure the marginal and internal fit and these sections were visualized under stereomicroscope. Values were tabulated and statistical analysis was done using R- Software. The Kruskal Walis test was used to compare between groups. **Results:** Marginal and internal fit of all the groups were within the clinical acceptable range (<120μm) and DMLS group showed least when compared to other groups. **Conclusion:** Both DMLS and CAD/CAM procedures resulted in producing lower discrepancies compared to Conventional group, however, further research and refinement in designing aspect is required in order to produce more precise restorations.

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INTRODUCTION

Fixed partial denture is considered to be the standard treatment for replacement of missing teeth as it enhances patient's comfort, masticatory ability, and self-image (Harish, 2014) Attaining accuracy in fit of cast metal restoration is a major factor in determining the success of the restoration (Rai *et al.,* 2017). Poor internal fit of a cast restoration increases the thickness of the cement and therefore affects the stability of restorations (Harish, 2014; Lisa, 2015) Thus, minimizing crown marginal and internal gap is a vital goal for the longevity of the cast restoration. Metal ceramics are widely used materials forfabricating cast restorations and fixed partial dentures (Carreira, 2007). Most commonly used base metal alloys were Nickel chromium (Ni-Cr) and Cobalt chromium (Co-Cr). Earlier, Nickel chromium alloys were commonly used, however issues concerning the toxicity of nickel and beryllium restricted the usage.

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The present trend is to use Co-Cr alloys, which are more biocompatible (Lisa, 2015). Methods such as venting, axial grooves, die spacer application are used to reduce the hydraulic pressure between the cement and cast (Hoang *et al.,* 2015) When compared to other techniques, it is safe to use die spacer as it does not harm the metal surface and also provide internal space for the luting agent (Fattahi *et al.,* 2015). Thus, die spacer application technique is most predominantly used in fixed partial dentures for several years (Hoang, 2015). Evaluation of the marginal fit is performed either qualitatively or quantitatively. Qualitative assessment is completed by direct visualization and sense of touch. For quantitative assessment, using a microscope in high magnification would be the most effective option to measure the gap, which includes Scanning electron microscope (SEM) and optical stereomicroscopy (Fattahi, 2015). Silicone replica impression technique is widely used for evaluating marginal and internal discrepancies. Compared to other techniques, this technique is considered to be more beneficial because there is less chance of damage to the sample and abutment, which makes it a non- invasive method (Trifkvoic, 2012). Various methods used to fabricate cast restorations have a direct impact on the longevity of the restoration.

Despite several advances in investing material, alloy composition and casting machines, fabrication using conventional casting procedure is extremely technique sensitive and discrepancies are inevitable (Harish *et al.,* 2014). Amongst the steps involved, wax pattern fabrication is the most crucial and depends on the skill of an individual. However; technological advancements have led to more sophistication and accurate techniques like Computer aided designing and Computer aided manufacturing (CAD/CAM), which includes both milling and Direct metal laser sintering (DMLS) procedure (Gunsoy, 2016; Vojdani, 2013). The present study was planned to compare and evaluate the internal and marginal fit of (Co-Cr) copings fabricated by computer aided milling/computer aided designing, direct metal laser sintering and conventional casting method. Very few studies were done in the past comparing all three techniques. Therefore, emphasis was given to determine whether fabrication technique has an influence on the marginal and internal fit of cast restoration.

MATERIALS AND METHOD

Metal master die fabrication: For master die replication, mandibular first molar was selected. With the help of CAD software (Exo-cad design software, Germany) (Figure 1), a wax pattern was prepared with circumferential chamfer finish line of 1mm, occlusal reduction of 1.5mm and 6-degree axial inclination was designed and milled on the metal die using Co-Cr alloy to simulate natural prepared tooth.

Impression making: A custom tray was fabricated to make the impression of the master die. In order to maintain uniform pressure while making impressions, the metal master die was accommodated in the lower half of a customized box which was fabricated using 3D printing (CoLiDo 2.0+ 3D Printer, Macau) (Figure 2). Double mix elastomeric impression technique was used for making impressions (Figure 3) which were then poured in die stone (Kerr, Denmark). The procedure was repeated 15 times to obtain fifteen stone dies of similar dimensions.

Study Groups: Fifteen metal copings were fabricated for each group on these stone dies and divided into three groups depending upon the technique used for fabrication as group A conventional method, group B Computer aided designing and Computer aided manufacturing (CAD/CAM) procedure, group C Direct metal laser sintering (DMLS) technique.

Co-Cr Coping fabrication

Metal coping manufacturing using Conventional casting method: Conventional copings were prepared by lost-wax technique in a centrifugal induction casting machine (BegoFornex, Germany) using Co-Cr alloy (Argeloy Np, China). Die spacer (Marc Die spacer, India) was applied on 15 working dies. Die spacer was applied for a total of two coatings with uniform brush strokes in one direction, followed by which second coating was applied in order to achieve a uniform thickness of 25 microns.Inlay casting wax (Kerr, Denmark) was used to fabricate wax patterns. A uniform thickness of 0.5 mm was maintained throughout and measured with the help of wax gauge. Prefabricated wax sprues (Sigmadent, India) were attached on top of each pattern at 45 degrees. Surfactant (Prime dental products, India) was sprayed. to the wax patterns to decrease the surface tension and to ensure complete wetting of the patterns with the investment material. The wax patterns were then invested using investment material (Wirovest, Bego, Germany), which was vacuum mixed. The casting ring was then filled with investment material under mechanical vibration and allowed to set for 1hour. Then wax burn-out procedure was carried out in Muffle furnace (Technico, India) till the temperature is about 760°C-800°C for 45 minutes. Followed by which casting was done using Bego induction casting machine, then the castings were divested, cleaned and air abraded with 110-micron alumina particles in a sandblasting unit (Mini sab, Israel) at 0.4 mPa pressure. Sprues were cut using silicon carbide disks and copings were finished.

Metal coping fabrication using CAD/CAM: 15stone dies were scanned with a 3D scanner (Roland LPX 250, North America). These scanned dies were then used to design the copings using CAD software. Similar to conventional casting, the thickness of the metal coping was maintained at 0.5 mm and internal space of 25µm by setting a fixed parameter using the CAD software (Exo-cad design software, Germany). The data relevant to the completed design was saved and executed to the milling machine (Roland DWX-51D, North America) using Co-Cr alloy (NPX super crown and bridge alloy, USA)

Metal coping fabrication using Direct metal laser sintering: The same CAD data used for Group B were fed into DMLS machine (EOSINT M100, Germany) and 15 laser sintered Co-Cr copings were fabricated using rapid prototyping technology in which a high precision, high energy laser was used to melt Co-Cr powder (EOSSP2 alloy, Germany) corresponding to the design. The laser sintering machine worked on a movable platform by sintering the cobalt chromium alloy powder at a rate of 1.6mm^3/s to form a uniform layer. Subsequent layers were added and adjoined to fabricate complete coping.

Marginal and internal fit evaluation: A non-destructive silicone replica technique was used. For all the metal copings in three different groups, a quarter of the interior was filled with light body silicone (Virtual Refill, Ivoclarvivodent, USA) and the coping was immediately placed on the master metal die. Uniform pressure of 50 N was placed and maintained for 2 minutes. The coping along with the light body silicone film was then reinforced with heavy body silicone impression material (Virtual Refill, Ivoclarvivodent, USA). This resulted in a combination of light and heavy body silicone replica to be sectioned. Light body silicone layer was measured to determine the marginal and internal gap. Using a blade, the silicone replica was divided into 2 sections along the buccal/lingual direction. These sections were visualized under stereomicroscope (Magnus MSZ Series, India) (Figure 4).Fifteen circumferential sites on the sliced specimen were measured.

Statistical analysis: Values of three groups didn't follow a normal distribution. Since the data failed to possess a normal assumption, an alternative nonparametric test was used termed as KruskalWali's test. R software is used to analyse the data. Statistical significance was defined as $P<0.05$.

RESULTS

Mean values of all the samples were calculated and compared. In group A samples (Table 1), mean value at the margin was 96.8 ±SD21.21, mean value at the axial wall was 28.17±SD8.73, at the occlusal surface was 113.84±24.72,

Table 1. Shows the values of fifteen samples fabricated using Conventional method

S.NO	Marginal	Axial Wall	Occlusal
1	75.58	33.23	77.53
2	127.81	23.35	122.01
3	112.06	47.85	179.81
4	81.28	27.11	125.82
5	81.38	19.48	119.42
6	71.63	20.19	96.7
7	82.38	20.85	102.88
8	81.15	19.97	100.83
9	91.6	34.38	98.27
10	85.93	28.33	87.66
11	116.35	20.89	98.24
12	90.88	29.24	123.7
13	137.75	20.61	128.9
14	125.36	39.79	137.07
15	90.95	37.33	108.89
Mean	96.8	28.17	113.84
SD	21.21	8.73	24.72

Table 2. Shows the values of fifteen samples fabricated using CAD/CAM procedure

S.NO	Marginal	Axial Wall	Occlusal
1	26.87	7.34	42.07
2	28.4	8.75	38.01
3	39.86	11.17	51.84
4	15.96	11.72	30.42
5	32.5	12.54	59.97
6	81.96	18	80.05
7	17.16	4.92	16.12
8	20.86	11.8	26.66
9	21.3	16.7	40.92
10	27.04	6.35	43.3
11	31.02	13.81	45.62
12	37.23	5.11	71.48
13	33.31	7.84	41.75
14	39.1	18.01	54.6
15	31.21	9.7	55.99
Mean	32.25	10.92	46.58
SD	15.63	4.35	16.58

Table 3. Shows the values of fifteen samples fabricated using DMLS procedure

S.NO	Marginal	Axial Wall	Occlusal
1	19.44	8.93	34.12
2	22.08	5.99	39.38
3	23.62	3.24	35.46
4	24.43	5.54	30.08
5	26.93	7.25	38.47
6	46	17.96	76.2
7	26.5	8.08	48.93
8	26.82	7.12	41.96
9	28.47	8.43	40.06
10	27.38	8.74	34.73
11	28.81	8.7	40.8

Table 4. Shows the values of pair wise comparison

	Procedure		
	DMLS &Conventional	DMLS & CAD/CAM	Conventional &CAD/CAM
Marginal	0.000000039	0.8	0.0000000735
Axial	0.000000039	0.65	0.000000039
Occlusal	0.000000039	0.85	0.000000077

whereas, in group B samples (Table 2), values were 32.25±SD15.63 at the margins; 10.92±SD4.35 at the axial wall, 46.58±16.58 at the occlusal surface. In the case of group C samples (Table 3), values were 27.56±SD5.98, 9.13±SD3.95, 42.87±10.84 respectively.

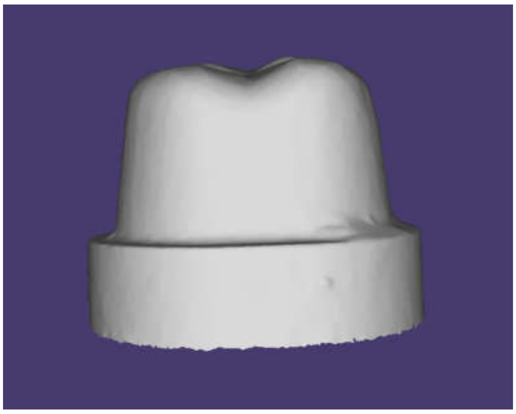

Figure 1. Designing master metal die using exo-cad software

Figure 2. Master metal die seated inside special tray. Special tray fabricated using 3D Printer

Figure 3. Impression made using heavy body and light body impression material

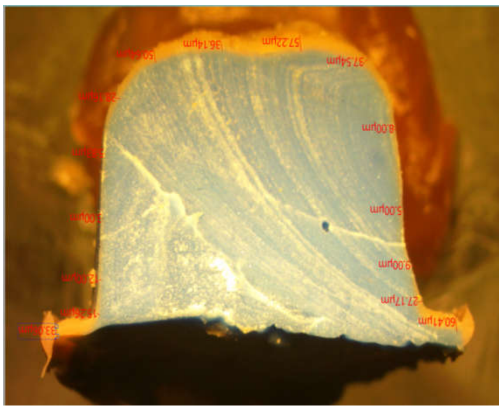

Figure 4: Specimen visualized under stereomicroscope×100.

In order to avoid bias in the results, a second observer analysed the data for all three groups and reported that there was no statistically significant difference in the values. (Table 4) shows comparisons between the three groups. When comparing group A and group C, probability value was 0.000000039 which was considerably less than the probability limit of 0.05. Therefore, it is evident that there was a significant difference between DMLS and Conventional group. When comparing group B and group C, probability values were 0.8, 0.65, 0.85, these values were not less than 0.05, therefore it depicts that there was an insignificant difference between DMLS and CAD/CAM groups. When comparing Group A and Group B groups, probability values were 0.000000073, 0.000000039, 0.000000077 which were considerably less than probability limit of 0.05, therefore it is evident that there was a significant difference between CAD/CAM group and Conventional group. Values obtained using DMLS technique showed the lowest discrepancies on intergroup comparisons and highest was noticed with the conventional group along all the tested surfaces.

DISCUSSION

A cast metal restoration with accurate marginal and internal fit is considered to be the primary requisite in determining the success of the restoration. A clinical study conducted by McLean and Vonfraunhofer (1991) on 1000 restorations for a period of five years derived at a conclusion that 120µm was considered as the maximum acceptable marginal opening. Beyond this value, the fit of the crown was considered unacceptable. When describing a reference range for the internal gap, there were several misconceptions in defining the exact range. No clinical studies reported the range except in a study conducted by Quante et al. (2008) stated the acceptable range of internal discrepancy can lie within 60-250µm. Among the available materials used for metal ceramic restorations, most commonly used base metal alloys are nickel chromium (Ni-Cr) and cobalt chromium (Cr-Co) alloys due to their high corrosion resistance.

Nevertheless, the presence of nickel and beryillium in nickel chromium alloys limited its usage. Therefore, Co-Cr alloys are widely used, which are a lot congenial.[3] Obtaining precise marginal and internal fit is directly related to the fabrication technique employed. With the introduction of automated systems such as computer aided design/computer aided manufacturing (CAD/CAM) and DMLS, dentistry has witnessed a series of innovative developments. Conventional methods, which were regularly used, were surpassed with these advancements. However, disadvantages associated with these automated systems were often overlooked, which includes the precision of the scanner, 3D software used, and the precision of the machined used.[13] Hence, the present study was conducted to compare the groups using fit as a reference to determine whether there is a correlation between fabrication technique and fit of the cast restoration. Even though, studies were conducted previously comparing all three groups. These studies differed in several aspects such as the type of alloy used, sample size, measurement technique, coping or fixed partial denture fabrication, die spacer thickness used, clinically acceptable range values. Considering all these aspects, the present study was designed to overcome all these shortcomings. In one of the studies by Carrieria et.al (2007) stated that the lowest marginal discrepancy was seen when two layers of die spacer was used.

In a study conducted by Anna et.al (2006)[14] stated that best marginal and internal adaptation to cast metal crowns was attained when the die spacer covered the entire preparation except 0.5mm short of the finish line. Hoang et.al (2015)[6] in his study stated that an ideal spacer thickness of 25µm, which simulates the film thickness of type I Zinc phosphate cement was considered to be standardized value. Considering the same, in the present study die spacer thickness of 25 µm was used for all three groups. Various methods were used for measuring marginal and internal fit. The direct measuring method in which the gap was measured directly with the help of a microscope after the prosthesis was placed on the tooth model followed by sectioning it. The Silicone replica technique in which the thickness of the light body silicone was measured with the help of a microscope. A Qualitative technique such as visual examination was not considered a reliable method because they are mostly dependent on the dexterity of the observer (Kim Ki, 2013). A study by Laurant et al. (2008) has shown the efficacy of silicone replica using two brands. The study revealed that irrespective of the brand used for replica technique both types equally simulated cementation technique. Habib et al. (2008) revealed that the film thickness of silicone impression material was similar to the thickness of glass ionomer cement and replica technique was considered to be a reliable technique in reproducing film thickness. Considering these facts, the present study was conducted using the silicone replica technique.

The number and site of measurements used to determine the marginal and internal gap on the sectioned samples also varied among studies (Vojdani, 2013; Habib, 2008; Cooney, 1981; Groten, 1997; Kim, 2017; Kim, 2018). Measurement location varied, ranging from 4 to more than 100 sites for measurement. Lovgren et al. (2017) et al stated that assessment points were divided into the marginal, axial and occlusal surface. The present study was conducted in congruence with this study to evaluate the marginal gap, adaptation to axial wall and occlusal surface. This technique was chosen for the present study because of equal distribution of points at all measuring areas so that values can be read easily without confusion. Therefore, this method was beneficial when compared to other techniques.

The results of the present study were in congruence with a study conducted by Lovgren et.al (2017)[22] For DMLS group, the mean marginal gap was 53±SD19, at the axial wall was 45± SD 20 and at the occlusal surface was 79± SD 8. Conventional group, the mean marginal gap was 104± SD 33, at the axial wall was 99± SD 15 and at the occlusal surface was 87± SD 30. A similar study conducted by Gunsoy et.al (2016)[9] resulted in the lowest discrepancy for DMLS group with the mean marginal gap of 51.6± SD 11, at the axial wall 61.9± SD 14.17 and at the occlusal surface was 88.6± SD 20.65 and highest for conventional group with mean marginal gap of 84.55± SD 18.56, at the axial wall 87.02± SD 19.24, and at the occlusal surface was 101.5± SD 25.78). Harish et.al (2014)[1] reported that DMLS group produced the lowest discrepancies at all measured areas when compared to the conventional group. Mean values for DMLS group were at the marginal gap with 02.15± SD 17.27 and the internal gap with 107.6± SD 10.98. Conventional group with the marginal gap of 176.5± SD 25.82 and the internal gap of 187.09± SD 11.47. Among the three groups, efficiency of DMLS method is mainly attributed to rapid solidification of cobalt chromium powder that occurs in incremental stages, thus minimizing shrinkage of the alloy as a result discrepancies are minimized. One of the major drawbacks associated with a CAD / CAM group lies in designing and milling. It is the limit of finite resolution during designing, which leads to edges that are slightly rounded and therefore the fabricated prosthesis doesn't have an accurate fit. Moreover, scanning procedure, processing the data, milling parameters, actual milling process causes significant amount of destruction to the prosthesis, which leads to discrepancies. Despite several advances in investing materials, alloy composition, casting machines, and procedures, casting procedure as a whole is always considered to be technique sensitive, and discrepancies occur (Harish, 2014; Lisa, 2015). Problems associated arise due to distortion of wax patterns, setting expansion of investment, casting shrinkage of alloys, insufficient metal flow, and die spacer application (Rai, 2017). Wax alone has several disadvantages because of its properties such as elastic memory and high coefficient of thermal expansion. Moreover attaining a precise fit of cast metal restorations is directly related to the experience and skill of an individual (Gunsoy, 2016). The values obtained for all the groups in this study were within the clinically acceptable range (120µm) for the marginal gap as stated by McLean and von Fraunhofer (1971) and clinically acceptable range for the internal gap as stated by Quante et.al (2008). However, samples were not subjected to thermo cycling. All samples were evaluated under ideal situations, which may not reflect daily clinical situations. Fabrication technique and its influence on the fit was only evaluated, there are ample chances, which can impact other variables of cast restorations. Thus, further in vivo studies focussing on simulating clinical conditions is essential before being clinically conclusive. Moreover, further research is warranted in improving automated computer-aided milling and DMLS systems.

Conclusion

Within the limitations of the study, marginal and internal fit of all groups were within the clinical acceptable range (<120µm). Marginal and internal fit values of DMLS group were least when compared to other groups and highest values were recorded for the conventional group. Out of all tested groups, the best fit was found along the margins and a large gap was noticed in the occlusal surface for all the groups.

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