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EVALUATION OF MARGINAL FIT AND INTERAL FIT OF METAL COPINGS FABRICATED BY THREE DIFFERENT TECHNIQUES- AN IN VITRO STUDY

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Abstract:

Statement of problem: *An optimal marginal and internal fit plays an important role in the longevity of a restoration. Increased marginal gaps can cause bacterial and biofilm adherence. Also, poor internal fit can lead to decreased retention and resistance form. There are various techniques available for the fabrication of restorations. All these techniques have their own pros and cons. In regards to these problems, the present study was conducted to find out whether the manufacturing technique has any influence on the marginal and internal fit of copings.*

Aim: *The aim of this study was to evaluate and compare the internal and marginal fit of Co-Cr copings fabricated by three different techniques namely, conventional lost wax technique, 3D resin printing technique and CAD/CAM milling technique.*

Materials and methods: *A stainless steel master model and a custom tray were fabricated. Totally 30 impressions were made and poured with die stone to obtain 30 die specimens. The specimens were grouped into three groups. Group 1- conventional lost wax technique, group 2- 3D resin printing technique and group 3- CAD/CAM milling technique. Co-Cr copings were fabricated using the respective technique. For evaluating the internal fit, weighing technique was followed. The cross-sectional technique was followed to assess the marginal fit.*

Results: *There was statistically significant difference between the different groups in terms of internal and marginal fit. The CAD/CAM milling technique showed better marginal and internal fit compared to the other two techniques. The 3D resin printing technique showed better results than the conventional technique but was not statistically significant.*

Conclusion: *Within the limitations of this present study, the results drawn suggests the use of CAD/CAM milling technique and the 3D resin printing technique for fabricating restorations in routine dental practice.*

Key words:* *marginal fit, internal fit, cobalt-chromium alloy, coping, scanning electron microscope.

Introduction

Metal ceramic restorations are one of the most sought out options for fabricating full-coverage crowns and fixed partial dentures[1]. An accurate marginal and internal fit of cast restorations plays a vital role in the longevity of the restoration.[2] The precision of fit of a restoration is determined by two criteria: the marginal and the internal fit. The marginal fit provides a proper seal and an uniform internal fit provides an appropriate cement space which is necessary for good retention and resistance of the restoration.[3] Holmes et al defined the internal gap as the measurement between the axial wall of the prepared tooth and the internal surface of the casting, while the same measurement at the margin is called marginal gap.[4]

McLean and Fraunhofer in 1971, after clinically examining 1000 metal ceramic crowns, reported that marginal discrepancies up to 120μm were acceptable.[5]

Initially, gold alloys were considered as the material of choice for the fabrication of metal ceramic restorations. But the increased cost of the gold alloys led to the use of base metal alloys as an alternative.[6] Ni -Cr alloys have been commonly used for making metal copings. But they also have their own limitations, due to increased oxide formation and biocompatibility issues of nickel and beryllium, they can cause allergic reactions in many patients. Co-Cr alloys can be considered as a good alternative to Ni-Cr alloys due to their better biocompatibility, mechanical properties, corrosion-resistance and also cost efficiency.[7]

The conventional technique of fabrication employs the lost wax technique, which was introduced by Taggart in 1907. But certain properties of wax like, distortion, thermal sensitivity and high coefficient of thermal expansion can make it a less desirable option.[8] Resins can also be used to overcome the limitations of conventional wax patterns. Resins can offer strength, rigidity, and dimensional stability if immediate investment is not possible. But polymerization shrinkage can be an issue with the use of resins.

The CAD/CAM manufacturing systems have been introduced for fabricating prosthesis in order to overcome the disadvantages of the conventional casting system. It was introduced for dental applications over 20 years ago to prepare ceramic inlays and veneers, and several studies have presented favourable reports.[9] It includes both the additive technique and the subtractive technique.

There are various techniques to evaluate the marginal and internal fit of restorations. One among those is the cross-sectional method. In this method, the prosthesis is cemented onto the die and then cut. It is then measured for marginal and internal gap using an optical or electronic microscope.[10] Various other techniques have been described in the literature. Some of them are the direct visualization technique under microscope, replica technique and weighing technique. Also, clinical evaluation methods using explorer and scoring, micro-CT and 3D analysis can be used for evaluation of the restorations.[11]

Even though different methods are available to measure the fit of a restoration, there is no clear consensus regarding the optimal fit. Therefore, the purpose of this in vitro study was to evaluate the influence of the different fabrication techniques on the marginal and internal fit of restorations.

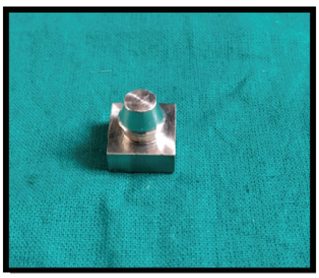
Fig 1. Stainless steel master die

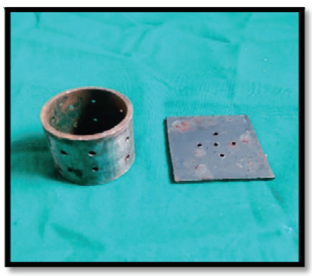
Fig 2. Custom made impression tray

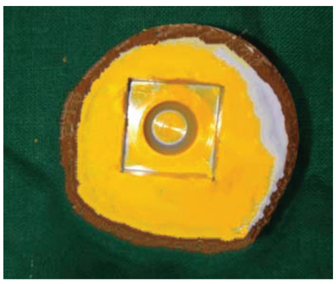
Fig 3. Single stage impression of the masterdie

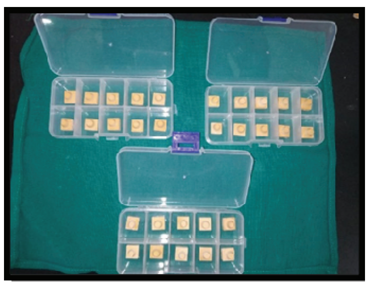
Fig 4. Grouped die specimens

Materials and methods

Fabrication of master die:

A stainless-steel die was fabricated using the CNC (computer numerical control) milling machine *(fig 1)*. This master die was used for the standardized production of copings. The master die replicated the form of a prepared premolar tooth. It had a 16-degree total occlusal convergence (TOC), 6mm height, 5mm diameter and a 360-degree chamfer finish line.[12]

Fabrication of custom-made impression tray:

For making the impressions of the master die,a custom-made stainless-steel impression tray was fabricated (fig 2). The custom tray was in a hollow cylindrical shape with 2.5cm length and 3cm diameter. One side of the custom tray was covered with a square shaped stainless-steel plate. Holes were made on the outer surface of the cylindrical custom tray and on the stainless-steel plate. These holes aided in mechanical retention of the impression material and also provided an escape way for the excess impression material.

Obtaining the die stone models:

Impressions of the stainless-steel master die were made with addition silicone impression material (GC Flexceed, GC India Dental Pvt Ltd, Medak, India) (fig 3) using single-stage technique. The die was placed on a flat surface and the custom tray with the loaded material was inverted onto it. The stainless-steel plate was placed on the upper side and firm pressure was given from above. A total of 30 impressions were made. Surfactant was sprayed into the mold cavity and type IV die stone was poured using a mechanical vibrator to obtain the die stone models. The dies were divided into three groups of 10 dies each (n=10), i.e., Group 1 (Conventional lost wax group), Group 2 (3D resin printing group) and Group 3 (CAD/CAM milling group) (fig 4). Impressions made for Group 1 were poured twice, because the same die cannot be used for coping fabrication and cementation as manual spacer application is needed. In case of the other two groups, cement space is created virtually, and the same die can be used for coping fabrication and cementation.

Fabrication of Co-Cr copings with the conventional lost wax technique:

One layer of die hardener (Yeti dental products, Germany) was applied on all of the 10 dies. Later, 2 layers of die spacers(Yeti dental products, Germany) were applied 0.5mm below the preparation. Each layer was about 15μm in thickness, so totally a 30μm thick spacer was applied. Each die was dipped into a wax pot containing molten inlay wax to obtain a wax pattern of 0.5mm uniform thickness, which was measured using a wax gauge (API wax gauge caliper, India). The wax patterns were viewed

Fig 5. Sprues attached to the crucible former

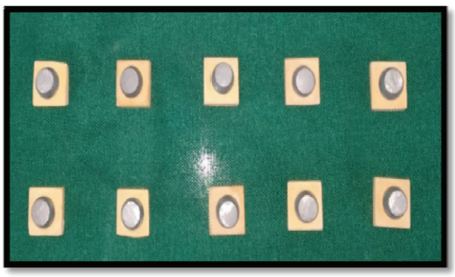

Fig 6. Copings fabricated from the conventional lost wax technique

Fig 7. Designing of the copings using CAD software

Fig 8. 3D printed resin patterns

under a magnification glass to assess for any discrepancy. Prefabricated sprues of 3mm diameter were attached to all the patterns(fig 5) and they were invested using phosphate-bonded investment material (Metavest,Germany) according to the manufacturer's instructions. After 30 minutes, burnout was done followed by casting with Co-Cr alloy (Wirobond C, Bego, Germany) in an induction casting machine (Fornax T, Bego). The investment was then bench cooled and divested. The copings were then sandblasted, trimmed and finished. (fig 6)

Fabrication of Co-Cr copings using the 3D resin printing technique:

10 master die stone models were scanned using an extraoral lab scanner (Medit-T, Medit corp, South Korea). Designing of the copings was done using a CAD software (Exocad, GmbH, Germany). (fig 7) The thickness of the copings was set at 0.5mm and an internal relief of 30μm starting from 0.5mm from the margin was given for the luting cement. The CAD data was sent to the 3Dresin printing system (Anycubic Photon, China). Printing of the pattern was done using a UDMA (Urethane dimethacrylate) based castable resin contained in a cartridge. After the printing was done, the resin supports were cut using a carborundum disc. The resin patterns were placed on the respective models(fig 8) after which the conventional steps like sprue attachment, (fig 9) investment, burnout, casting, divestment and finishing were done,(fig 10) similar to the conventional lost was technique.

Fabrication of the Co-Cr copings by the CAD/CAM milling technique:

10 dies were used to fabricate CAD/CAM milled Co-Cr copings. The dies were scanned by a 3D laser scanner (Shining 3D DS-EX). The STL data obtained was transferred to the CAD software (Exocad, GmbH, Germany) where the designing of the copings were done. (fig 11) The design included an internal relief for the luting cement. 30μm of internal relief was given starting from 0.5mm from

Fig 9. Sprues attached to the 3D printed resin patterns

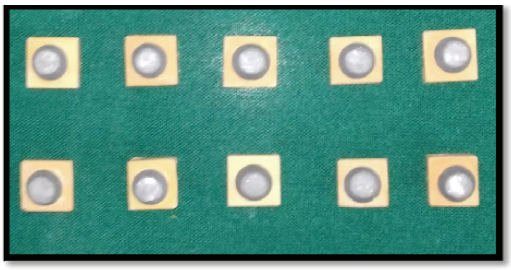

Fig 10. Copings fabricated by the 3D resin printing technique

Fig 11. Completed design of the copings using CAD software

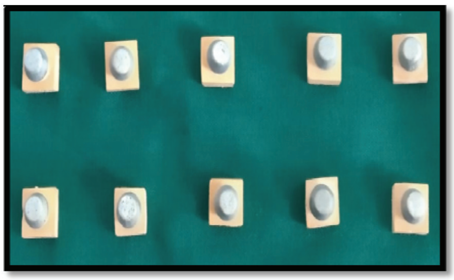

Fig 12. Copings fabricated by the CAD/ CAM milling technique

Fig 13. Modification of the 2kg weight with acrylic resin

Fig 14. Standardized pressure application for obtaining silicone replicas

Fig 15. Silicone cement space replicas

the margin. The thickness of the copings was set at 0.5mm. The data was sent to the CAD/CAM milling production unit (Dentium rainbow TM Mill, Dentium, South Korea), where a 5-axis milling of a solid Co-Cr disc was done. (fig 12)

Making a custom-made set up for cementing the copings:

To standardize the cementing force, a custom made set up was used. It consisted of a rectangular acrylic slab and a 2kg weight. A depression was created on the surface of the acrylic slab where the base of the die could fit in. A commercially available 2kg weight was used to apply pressure on the copings during cementation. The hole on the under surface of the 2kg weight was filled with self- cure acrylic resin and a depression was made (fig 13) which would fit onto the occlusal surface of the copings.

Volumetric evaluation of the internal fit:

Equal amounts of addition silicone light body base and catalyst (GC Flexceed, GC India) were mixed and loaded onto the intaglio surface of the copings and the copings were seated on their respective dies. To apply a cementing force, the custom-made acrylic slab was placed on the surveying table of a surveyor, the die along with the coping was placed on the depression in the acrylic slab. The 2kg weight was placed on the copings, by positioning the depression exactly on the occlusal surface. For additional support, two wax pillars were placed on either side of the acrylic slab. The 2kg weight was stabilized by lowering the vertical arm of the surveyor such that it contacted the surface of the 2kg weight (fig 14). This cementing force was maintained for 2 minutes until the material set.

The excess material was removed with an explorer and a No.13 bard parker blade. The coping was removed from the die with a slight twisting and rocking motion. Each silicone cement space replica was retrieved carefully. This procedure was done for all the 30 copings in total. The silicone cement space replicas were labelled and kept separately according to their group. (fig 15) Each cement space replica was weighed in a digital analytical weighing machine (Sartorius CP225D). An increased weight of the silicone cement space replica indicated a greater cement space and a subsequent decrease in the internal fit.

Cementing and embedding the samples:

After making the cement space replicas, the intaglio surface of each coping was cleaned. The copings were placed on their respective dies and inspected for any abrupt marginal gap before cementation. Type I GIC (GC Fuji, Japan) was used for cementing the copings. Manufacturer's recommendations were followed for mixing the cement. The same customized set up that was used for making the silicone cement space replicas was used for cementing the copings onto the dies. The excess material was removed using an explorer

Fig 16. Specimens embedded into clear acrylic

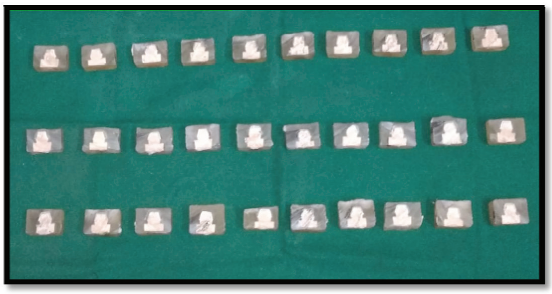

Fig 17. Specimens sectioned for SEM analysis

Fig 18. SEM imaging to measure marginal gap

immediately and carefully. Care was taken not to damage the margins of the die stone models. The cementing pressure was maintained for 5mins until the cement was set. After cementation the specimens were cleaned and embedded into clear acrylic resin poured into the putty impression of a cubic box. (fig 16)

Measurement of the marginal gap using the scanning electron microscope

After embedding, all the specimens were sectioned using an electronic saw (fig.17). The sectioned specimens were used to evaluate the marginal gap discrepancies. Since, the specimens were non-conductive, they were sputtered with gold-palladium (Au/Pd) using a sputter coater (Quorum, SC7620, Quorum Tech, United Kingdom) for 4 minutes to make them conductive and to obtain a good quality image. Analysis of the specimens to measure the marginal gap was done using a scanning electron microscope (Hitachi, S-3400N) at different magnifications of 50- 200x. The distance between the external edge of the metal coping and the margin of the die was used to measure the marginal gap discrepancy. (fig 18) All the 30 specimens were measured for marginal gap.

Statistical Analysis:

Data obtained were compiled systematically in Microsoft Excel 2010 spreadsheet. Statistical analyses were performed using a personal computer in IBM corp. Statistical Package for Social Sciences software for windows; version 20.0 (Armonk, NY). Both descriptive and inferential statistics were used. P value of < 0.05 was considered to be significant. One way ANOVA with Tukey's post- hoc test was used to compare the mean difference between the groups.

Table 1 : Distribution of the weight of silicone cement space replicas between groups using one way ANOVA test.

INTERNAL FIT	TIME LINE	(MEAN ± SD)	p value
	G1	0.035 ± 0.007	0.001
	G2	0.031 ± 0.007	
	G3	0.023 ± 0.002	

P value of < 0.05 considered as significant
G1- group 1, G2-group 2, G3- group 3

using one way ANOVA test.

Results:

The mean weight of the silicone cement space replicas for group 1 was 0.035± 0.007 g, for group 2 it was 0.031± 0.007 g and 0.023± 0.002 g for group 3. The mean weights of the silicone cement space replicas of the three groups were compared using one-way ANOVA test. A significant difference ($P < 0.05$)was seen among the three groups (table 1). The lowest mean weight of the silicone cement space replicas was seen in group 3, followed by group 2. Group 1 had the highest values.

Intergroup comparison of the weight of silicone cement space replicas was made using ANOVA with post-hoc (Tukey's HSD). There was no significant difference when group 1 and group 2 were compared. But there was statistically significant difference when group 3 was compared with group 1($P < 0.05$)and also with group 2 (table 2)

Table 2: Comparison of the weight of the silicone cement space replicas among each group using ANOVA with post-hoc (Tukey's HSD).

GROUP	TIMELINE	MEAN DIFFERENCE	P VALUE
G1	G2	0.004	0.322
	G3	0.01	0.001
G2	G3	0.007	0.029
	G1	-0.004	0.322
G3	G2	-0.007	0.029
	G1	-0.01	0.001

P value of < 0.05 considered as significant
G1- group 1, G2-group 2, G3- group 3

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Mean marginal gap forgroup 1 was found to be 48.50 ±7.9μm,49.60 ±9.7 for group 2 and 32.30 ±5.9 for group 3. A significant difference ($P < 0.05$) was found between the mean marginal gap of the three groups when they were compared using one-way ANOVA (table 3). Intergroup comparison of the mean marginal gap between the three groups was done using ANOVA with post- hoc (Tukey's HSD). No significant difference was seen between group 1 and group 2. There was statistically significant difference ($P < 0.05$)when group 1 and group 2 were compared with group 3. (table 4)

Discussion

The chief objective of prosthetic treatment is to rehabilitate the patient with a well-fitting restoration. The marginal and internal fit play an important role in the long-time survival of a restoration.[13] The fit of a cast restoration is the most important factor for it to be clinically acceptable.[8,14]

Table 3: Distribution of the marginal gap discrepancy of copings between the groups using ANOVA test.

	TIMELINE	(MEAN ± SD)	p value
MARGINAL GAP	G1	48.50±7.9	0.000
	G2	49.60 ±9.7	
	G3	32.30 ±5.9	
P value of < 0.05 considered as significant G1- group 1, G2-group 2, G3- group 3			

Table 4: Comparison of the marginal gap discrepancy between each groupusingANOVA with post- hoc (Tukey's HSD).

GROUP	TIMELINE	MEAN DIFFERENCE	P VALUE
G1	G2	-1.009	0.957
	G3	`16.20	0.000
G2	G3	17.21	0.000
	G1	1.009	0.957
G3	G2	-17.21	0.000
	G1	16.20	000
P value of < 0.05 considered as significant G1- group 1, G2-group 2, G3- group 3			

For the standardized production of copings, a custom-made stainless-steel master die was used. In some previous studies, tooth preparation for the specimens was done manually which can lead to incorporation of errors.[15,16] Many in vitro studies have assessed the effect of the margin configuration on the marginal fit of metal ceramic restorations. In an in vitro study by Kane et al, chamfer marginal design for CAD/CAM milled copings of posterior teeth models showed smaller marginal gap when compared to the shoulder margin design[6]. Thus, in this study, since a master model representing a posterior teeth preparation was used a chamfer margin was opted for the master model.[17]

The dimensions of the cement space were also standardized. Also, alloys containing Nickel have known to possess more sensitization potential, thus Co-Cr alloy was used for fabricating the copings.[15,16]

The ringless casting technique has shown to produce copings with improved fit when compared to metal ring casting. This is because, an equalized expansion of the refractory mold is achieved by the ringless casting technique.[18] Thus in this study, the ringless casting technique was followed.

The milling unit that was used in this study to fabricate CAD/CAM milled copings had a 5-axes milling function. The increase in the milling axes facilitates the milling of complex geometries also.3

Vojdani et al have suggested the use of a constant force of 20N as ideal for cementing the copings[8]. An object of 1kg equals to 9.80665 N of force. In this study a 2kg weight was used, which corresponds to 19.6133 N which is closer to 20N. Many studies in the literature have used finger pressure for cementing the copings on the dies.[7,13,17,19,15,16,20] It should be noted that though it simulates the clinical cementation of the copings, since finger pressure is variable, a standardized pressure cannot be applied on all copings.

Various techniques are available for the measurement of marginal and internal gaps, which includes the direct viewing, cross-sectional technique, silicone replica technique, weighing the light-body silicone and visual examination. Nawafleh et al have reported that for measuring the marginal gaps in CAD/CAM fabricated restorations, scanning electron microscope analysis was better than light microscopy.[21] Thus, in this study, the cross-sectional technique with subsequent scanning electron microscopy analysis was used to measure the marginal gaps.

The weighing technique used in this study are similar to that used in the studies by Joo Kim et al11 and Ucar et al[9].

In two separate studies by Al Saady et al[22] and Kocaagaoglu et al[23], the marginal fit for CAD/CAM milled copings was found to be better. The results of the present study agree with the above studies.

The results of the present study also support the study by Nesse et al[24] in the fact that CAD/CAM milled copings have better marginal as well as internal fit.

The results of this study are contrary to the results obtained by Farjood et al[25] in which the conventional technique was found to be better.

The poor marginal and internal fit of conventionally cast copings can be attributed to the accumulation of the manual errors in each step. Also, in the induction coil heating, due to the increased temperature some components of the alloy which have low melting point are lost, making the alloy more viscous. This can also affect the fit of copings.

According to Bhaskaran et al, vertical marginal discrepancy of 10-160 μm and internal gap of 81-136 μm were clinically acceptable. On the other hand, Moldovan et al[13] suggested that marginal misfit of 100 μm is considered good and 200-300μm is considered as acceptable. McLean and von Fraunhofer suggested 120 μm of marginal gap as clinically acceptable[27] and the marginal gap of the copings in this present study were within the clinically acceptable range. A clear consensus regarding the marginal and internal fit seems to be lacking.

Limitations of the Study

- It is an invitro study and the clinical conditions cannot be simulated.
- Gap discrepancies were measured only in the margins and not on other axial surfaces.
- The effect of ceramic layering on the fit of copings was not studied.
- Marginal and internal fit assessment was done only for a single coping. Long and short span bridges were not studied.

Conclusion

It is concluded that the Co-Cr copings fabricated by the CAD/CAM milling technique had the best marginal and internal fit, followed by the 3D resin printed copings and the conventionally cast copings. Thus, the null hypothesis that there will not be any statistically significant difference in the marginal and internal fit among the groups was rejected. Despite the increased marginal gap discrepancies in the 3D resin copings and the conventionally cast copings, the marginal gap values were within the clinically acceptable range.

Within the limitations of this present study, the results drawn suggests the use of CAD/CAM milling technique and the 3D resin printing technique for fabricating restorations in routine dental practice. Moreover, future studies with larger sample size and multiple measuring points are necessary to further support the adoption of newer techniques like the CAD/CAM milling and 3D resin printing.

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