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In Vitro evaluation and comparison of marginal fit of Cobalt-Chromium copings cast from resin patterns fabricated using CAD/CAM and 3D printing technology.

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ABSTRACT:
AIM: *To evaluate and compare marginal fit of Cobalt-Chromium copings cast from resin patterns fabricated using CAD/CAM and 3D printing technology.*
METHOD: *A dentoform right first mandibular molar was prepared to receive metal ceramic crown following tooth preparation guidelines and copings were fabricated. The crowns were divided into two groups, group I: copings casted from 3D Printed resin patterns (n=15), and group II: copings casted from milled resin patterns (n=15), each coping was investigated for marginal adaptation.*
RESULTS: *Group I (Copings casted from 3D Printed resin patterns) had higher marginal discrepancy as compared to Group B (Copings casted from milled resin patterns).*
CONCLUSION: *Marginal adaptation of copings casted from milled resin patterns is better as compared to 3D printed resin patterns.*
KEY WORDS: *CAD/CAM, 3D printing, milling, marginal adaptation, marginal fit, marginal discrepancy.*

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I. Introduction

Fixed dental prostheses range from single-tooth restoration to whole-mouth rehabilitation, restoring function, patient comfort, masticatory ability, maintaining the health and integrity of the dental arches, and, in certain situations, improving the patient's self-esteem by changing the appearance. The fixed prosthesis also provides appropriate occlusion, which improves TMJ orthopaedic stability; otherwise, poor occlusion leads to stomatognathic system disharmony and damage.[1]

Metal ceramic restorations are one of the most commonly adopted fixed restorations. This is partly due to advancements in dental laboratory restoration fabrication technology, and in part to a growing need for visually pleasing, long-lasting restorations. Metal-ceramic restorations combine metal's physical features, like stiffness and impact strength, with dental ceramic's aesthetic benefits, such as abrasion and strain resistance. The metal-ceramic restoration was referred to as a 'Ceramco Crown,' a 'Porcelain Veneer Crown,' and a 'Porcelain Fused to Metal (PFM) restoration.[2]

Restorations are now typically manufactured using CAD/CAM (Computer-Aided Design/Computer-Aided Manufacture) systems and 3D printing.[3] Patterns fabricated using CAD/CAM technology and 3D printing has a number of advantages, including a high production rate, coping quality control, reduced manpower and time to produce the patterns, and less finishing work on cast copings (due to the absence of irregularities in coping thickness) and dimensional accuracy control.[4]

The main objective of any prosthodontic treatment is to provide the patient with restorations or prostheses that are precisely fitting. The marginal gap and internal gap are critical factors in establishing the prosthesis' long-term success in fixed prosthodontics. Cast restoration is damaged by distortion of wax patterns-like shrinking caused by internal stress relaxation. Resins were suggested as a way to get around wax's inadequacies as a pattern-forming material. Resins provide dimensional stability, strength, and rigidity.[5] Frangibility, heat sensitivity, elastic memory, and a high coefficient of thermal expansion are all inherent properties of wax.4 Cement dissolution and microleakage are enhanced by increased marginal discrepancy of a crown. The vital pulp might be inflamed as a consequence of microleakage. Poor marginal crown adaptation increases plaque retention and affects the subgingival microflora composition, indicating the initiation of periodontal disease.[6]

Metal-ceramic restorations have traditionally been done with gold. However, as typical gold alloys become more expensive, base metal alloys are becoming more popular as a cost-effective substitute. For metal-ceramic restorations, nickel chromium alloys are the most popular base metal alloys. Cobalt-chromium (Co-Cr) is a metal ceramic restorative material that was created in response to concerns about the toxicity of nickel and beryllium.4 Because of its great mechanical strength, corrosion resistance, biocompatibility, and cost effectiveness, cobalt-chromium alloys are corrosion resistant and stable in biological environments and as novel alternatives.[7]

Numerous previous research investigated the marginal and internal fit of cast restorations made using various preparation designs, impression techniques, die preparation, spacer thickness, pattern fabrication, investment material, and conventional casting techniques. Only a few studies on the evaluation and comparison of marginal and internal fit of Cobalt-Chromium copings cast from resin patterns fabricated using CAD/CAM and 3D printing technology have been published.

II. Aim And Objectives

The aim of this study is to evaluate and compare marginal fit of Cobalt-Chromium copings cast from resin patterns fabricated using CAD/CAM and 3D printing technology.

III. Materials And Methodology

Ethical committee approval and study design -

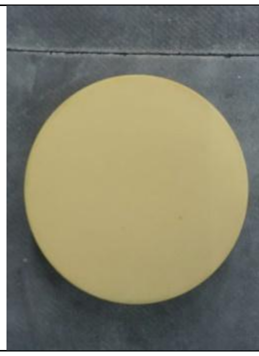
This study was carried out in the Department of Prosthodontics in 2019–2020. Ethics was granted by the Institutional Ethical Committee and research board approval. The study conducted according to the ethical standards given in the 1964 Declaration of Helsinki, as revised in 2013.

The sample size was calculated using the references of related articles, studies, reviews and sample size formula. The power of the study is less; thus, the sample size was taken as 30. The sample was divided into two groups, namely Group I and II. Each group was assigned 15 samples each.

Fabrication of samples-

Samples were made with 3D Printed and milled resin pattern as mentioned above to compare the marginal adaptation.

• Copings casted from 3D Printed resin patterns material (Anycubic, China) Group I - 15 samples. (fig. 1)
• Copings casted from milled resin patterns material (Amann Girrbach, Austria) Group II - 15 samples. (fig. 2)

	
Fig. 1. Copings casted from 3D Printed resin patterns (Group I)	Fig. 2. Copings casted from milled resin patterns (Group II)

Fabrication of die model-

A dentoform right first mandibular molar was prepared for a metal ceramic crown. (fig. 3) The prepared tooth was scanned (fig. 4) to fabricate 15 3D printed and 15 milled patterns. (fig. 5 & fig. 6)

Fig. 3. Prepared tooth for metal ceramic crown

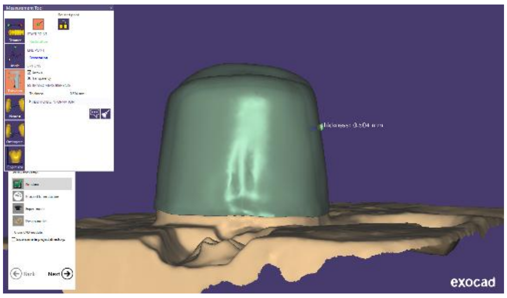


Fig. 4. Scanning of prepared tooth

Fig. 5. 3D printed resin patterns

Fig. 6. Milled resin patterns

Computer-Assisted Designing, 3D printing and Computer-Assisted Milling specimens –

In this study, 3D printed resin (Anycubic, China) were used to fabricate specimens for group I and PMMA resin blanks (Amann Girrbach, Austria) were used to fabricate specimens for group II, respectively. The master model of prepared tooth was scanned with intraoral scanner and virtual image was obtained. Design of prosthesis was done on obtained virtual image. The STL file was transferred to CAD program, and the specimens were designed and transferred to 3D printer and milling unit. The specimens were 3D printed in resin (Anycubic, China) and milled in PMMA (Amann Girrbach, Austria).

IV. Procedure Of The Study

An ivory tooth (mandibular right first molar 46) was selected for the preparation of the master model. The tooth was then prepared with a shoulder finish line of 1.5mm on the buccal aspect, a chamfer finish line of 0.5mm on the lingual aspect and an occlusal reduction of 2mm. Two vertical extensions were made on the buccal and lingual sides, respectively extending from margins downwards. This was done to guide the copings and assure their proper fit while measurement and a custom tray was fabricated with perforations to make the impressions of the prepared ivorine tooth. The impression was then poured into a Type IV gypsum product (die stone). The procedure was repeated and thirty impressions were made to obtain thirty stone dies of the same dimensions. 15 were used for Group I (copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns), respectively. The prepared ivory tooth was scanned and designed the patterns of uniform thickness (0.5mm) and cement space (50 µm) with the help of exocad software. 15 coping patterns were fabricated for each group viz. Group I (copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns) and immediately invested for casting. The metal copings were checked for initial fitting and then cemented commercially available Glass Ionomer Cement under 50N load with UTM (fig.7) for 10 minutes on respective dies. All the copings were sectioned longitudinally in a buccolingual direction using a circular saw (fig.8). A stereomicroscope (40x magnification) equipped with a computer was used to calibrate marginal fit.

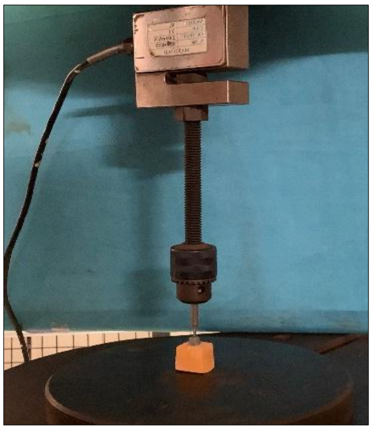


Fig. 7. Cementation of coping on respective die with 50N pressure with UTM

Fig. 8. Sectioning of the samples

For evaluating marginal fit (fig. 8 & fig. 9), the vertical distance between the most extended point of the coping margin and the external marginal line of the prepared tooth was used to evaluate the marginal gap. Two measurement points were made at the margins, i.e., the buccal margin (a) and lingual margin (b). A stereomicroscope (40x magnification) equipped with a computer was used to calibrate marginal fit.

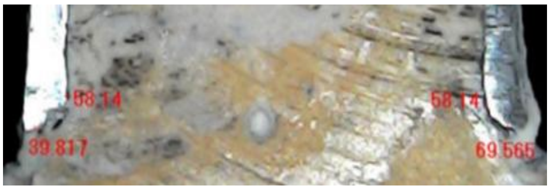


Fig.9 Measuring marginal adaption of Copings casted from 3D Printed resin patterns (group I) under stereomicroscope

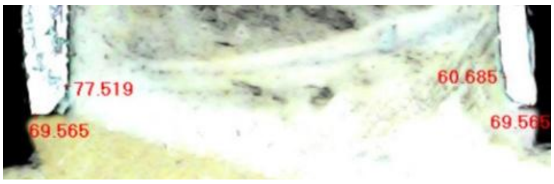


Fig.10 Measuring marginal adaption of Copings casted from milled resin patterns (group II) under stereomicroscope

V. Data Analysis

Statistical analysis was performed using Statistical Product and service solution (SPSS) version 16 for Windows (SPCC Inc, Chicago, IL). Descriptive quantitative data was expressed in mean and standard deviation respectively. Data normality was checked by Shapiro-Wilk Test. Inter group comparison of means between Group I (copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns) was done using STUDENT T-TEST. Confidence interval is set at 95% and probability of alpha error set at 5% Power of study set at 80%.

VI. Results

The marginal adaptation was recorded for each specimen. This raw data of the values obtained were compiled on MS- Excel sheet to get the mean and SD. The data were then statistically analysed.

Mean values and standard deviations (M±SD) of the marginal gap for both groups are shown in Figure. (Table 1 & Table 2, Graph 1) The average marginal gap for each group was: Group I (copings casted from 3D printed resin patterns) 66.85 µm and Group II (copings casted from milled resin patterns) was 49.43 µm. On comparative statistics of internal gap between Group I (copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns) respectively, there was found to be statistically significant difference ($p<0.001$) between both groups where Group I (copings casted from 3D printed resin patterns) had higher marginal gap as compared to Group II (copings casted from milled resin patterns).

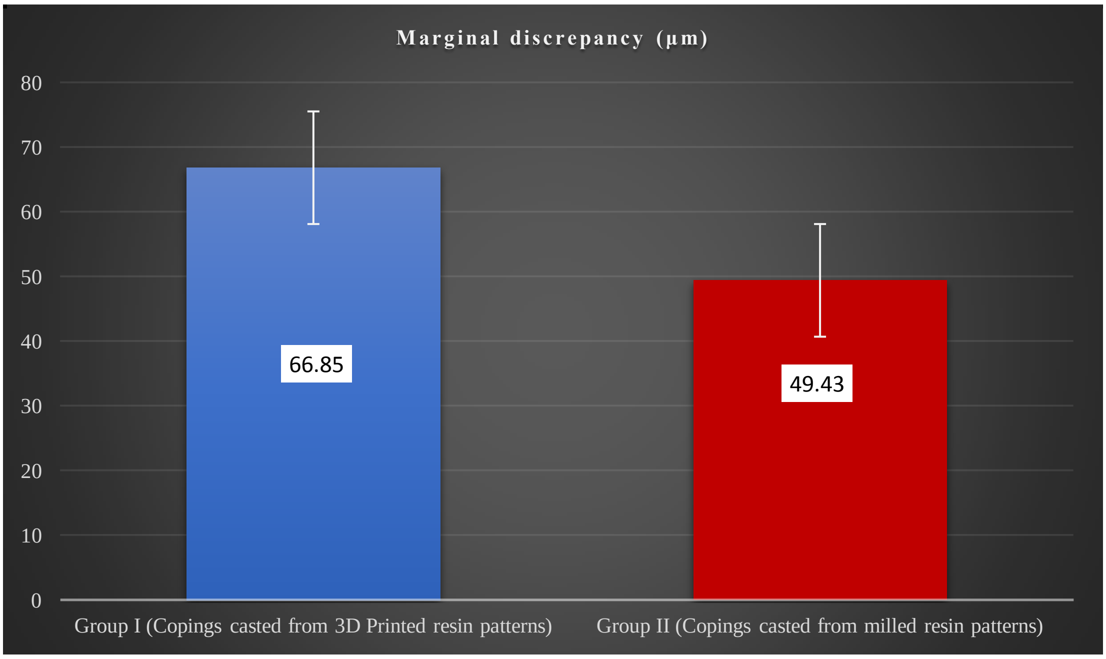
No.	Group I Copings casted from 3D Printed resin patterns		Group II Copings casted from milled resin patterns	
	a	b	a	b
1.	69.56	69.56	39.8	69.56
2.	64.5	61.5	45.3	50.6
3.	63.4	60.4	38.9	43.9
4.	67.8	70.3	55.8	50.6
5.	61.9	64.9	39.6	44.6
6.	62.7	65.7	47.3	52.3
7.	65.6	68.6	40.2	45.2
8.	66.3	69.3	41.5	46.5
9.	69.2	72.2	43.7	48.7
10.	63.8	66.8	58.2	53.2
11.	65.7	68.7	49.2	54.2
12.	69.4	72.4	53.2	58.2
13.	66.7	69.7	38.5	43.5
14.	62.9	65.9	61.2	56.2
15.	68.6	71.6	59.3	54.1
Total	988.06	1017.56	711.7	771.36
Mean	66.854		49.43533	
S. D.	3.26		7.66	
S. E.	0.59		1.39	
Minimum	60.4		38.5	
Maximum	72.4		69.56	

Table 1: Descriptive statistics of marginal discrepancy in Group I (Copings casted from 3D Printed resin patterns) and Group II (Copings casted from milled resin patterns) respectively

Marginal discrepancy (µm)	Mean	SD	Unpaired t test	p value, Significance
Group I (Copings casted from 3D Printed resin patterns)	66.85	3.26	t = 11.453	p < 0.001**
Group II (Copings casted from milled resin patterns)	49.43	7.66		

Table 2: Comparative statistics of marginal discrepancy in Group I (Copings casted from 3D Printed resin patterns) and Group II (Copings casted from milled resin patterns) respectively

****p<0.001 – highly significant difference**



Graph 1: Comparative statistics of marginal discrepancy in Group I (Copings casted from 3D Printed resin patterns) and Group II (Copings casted from milled resin patterns) respectively

On comparative statistics of internal gap between Group I (Copings casted from 3D Printed resin patterns) and Group II (Copings casted from milled resin patterns) respectively, there was found to be statistically significant difference ($p<0.001$) between both groups where Group I (Copings casted from 3D Printed resin patterns) had higher marginal gap as compared to Group II (Copings casted from milled resin patterns).

VII. Discussion

There have been numerous and diverse factors that influence the FPD's success. One element that determines the durability of the final prosthesis in the oral cavity is marginal integrity. Marginal fit influences the clinical acceptability and durability of cast restorations. The clinical importance of marginal fit to periodontal health and the reduction of recurrent marginal caries cannot be underestimated. A cast alloy crown can be considered an excellent fit in clinical terms if have enough axial tolerance to allow seating and if its margin fits the cavosurface line angle of the tooth preparation as determined by visual and tactile evaluation. The marginal fit of castings is largely dependent on precise tooth preparation, precise impressions, and accuracy of casting procedure. Prior to clinical acceptance, many approaches are widely employed to assess the marginal accuracy of cast restorations. Elastomeric materials and the use of a dental explorer are examples of this. There is, however, no agreement on what constitutes a clinically acceptable margin.[8]

Cemented crown margins should meet prepared tooth margins in perfect non-detectable junctions in the ideal situation. Clinical perfection is difficult to obtain and even more difficult to prove. As a result, the smallest marginal gap is nominally acceptable. There really is no single definition for the terms marginal gap and internal gap. "The perpendicular measurement from the inner surface of casting to the axial wall of preparation is called the internal gap," according to Holmes et al.9, who defined numerous gap definitions based on contour difference between the crown and tooth margin and the term "marginal gap" refers to the same measurement made at the margin. The retention will be affected if the internal space is increased. However, the distance between the restoration and the tooth preparation margin where both meet the oral environment is of primary concern, as gap measurement at the margin determines the fit.10-11

In this investigation, the maximum clinically acceptable marginal discrepancy was set at 120 µm, as proposed by McLean and von Fraunhofer.12 The amount of marginal discrepancies in both groups were within the clinically acceptable range.

All methods for both groups were standardized for the sake of comparability; a master model was used to scan the preparation, and identical cement spaces (50 µm) have been used. A static load of 50N was used for cementation, with the help of a Universal Testing Machine and the same investing and casting techniques were performed. All copings die assemblies were cut on exactly the same plane, and the axial points were determined.

Mean marginal fit (Discrepancy) for the study groups, i.e., Group I (Copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns) was 66.85 µm and 49.43 µm, respectively. In which Group II (copings casted from milled resin patterns) showed better marginal fit (lower marginal discrepancy) than Group I (Copings casted from 3D printed resin patterns).

Certain limitations of the study are as follows:

- The marginal and internal fit of copings after porcelain veneering were not defined.
- In this vitro study which could not simulate oral conditions, the marginal gap was evaluated by sectioning of the casted copings and internal gap was evaluated after sectioning which could resulted in minimal fit discrepancy, but this was common for all test samples.
- In this study the internal gap was measured 2 dimensionally, actually 3-dimensional evaluation of this gap would have yielded more accurate results regarding the space occupied by the luting agent.
- The scanner or milling unit used in the present investigation may be limited in its ability to reach the depths required of the master die in the shoulder design, or limitations may exist in the software for identifying the margins.

VIII. Conclusion

Within the limits of this In Vitro study, the following conclusions can be drawn:

- As Group II (copings casted from milled resin patterns) showed better marginal fit (lower marginal discrepancy) than Group I (Copings casted from 3D printed resin patterns).
- Since the results obtained in this study using Group I (copings casted from 3D printed resin patterns) and Group II (copings casted from milled resin patterns) were comparable and within acceptable limits, all of these Cobalt-Chromium copings casted from resin patterns fabricated using 3D printing and milled resin patterns can be considered for further clinical evaluation.

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