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Original Research Article

Evaluation of marginal accuracy of nickel chromium copings fabricated from three different fabrication techniques: an in vitro study

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ABSTRACT

Aim: The purpose of the study was to compare the marginal accuracy of Ni-Cr copings made by four different pattern forming methods, using inlay casting wax and pattern resin in the conventional manner, inlay wax patterns by CAD & milling and resin patterns made by a 3 dimensional printing (3DP) technology.

Materials and Methods: A total of 40 test samples of Ni-Cr cast copings were made out of 10 patterns of each group using inlay casting wax, pattern resin, inlay wax by CAD and milling and from pattern resin by 3D printing technology. Each cast coping was seated on the stainless steel die and was evaluated for both vertical and horizontal marginal gaps using a translating tool makers microscope. The vertical marginal gap data was analyzed by use of Kruskal Wallis Test followed by Mann Whitney U Test and the horizontal marginal gap data was analyzed by using ANOVA followed by Tukey honestly significantly different (HSD) tests.

Results: 3D printed resin pattern copings showed better results of marginal adaptability.

Conclusion: Marginal fit of the Ni-Cr cast copings fabricated from the patterns prepared from inlay casting wax, pattern resin, CAD milling and 3 dimensional printing (3DP) technology were in the clinically acceptable range for longevity of restorations.

1. Introduction

Precise marginal adaptation (fit) of the restoration is necessary to achieve better mechanical, biological and aesthetic prognosis.[1,2] The marginal fit of castings basically relies on accurate tooth preparation and impressions, fabrication of acceptable patterns, precision castings with careful finishing and cementation procedures.[3,4] The conventional method of pattern fabrication uses inlay casting wax. Other techniques available for pattern formation include CAD milling, rapid prototyping technique with 3D printing method, stereolithography(SL), selective laser sintering(SLS) and polyjet etc.[5] Nickel chromium (Ni-Cr) base metal alloy was chosen for its wide use, high yield strength, susceptibility, the strain hardening, high modulus of elasticity, greater hardness, greater resistance to sag deformation, low specific gravity and porcelain to metal bonding ability.[6]

Many studies has been conducted in the past focusing on the vertical marginal discrepancy of Ni-Cr alloy copings.[2–4,7,8] However very few studies have reported on both horizontal and vertical marginal discrepancies. The present in vitro study was conducted to comparatively evaluate the marginal fit of Ni-Cr copings made by four different pattern forming methods using inlay casting wax, pattern resin in the conventional manner, wax patterns using CAD milling and resin patterns made by 3 dimensional

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printing (3DP) technology.

2. Materials and Methods

A standardized custom-made stainless steel master die (Figure 1) was made simulating the shape and dimension of tooth preparations resembling a maxillary first molar as recommended by Ushiwata O et al.[4] The Tooth preparation section of the stainless steel master die was made with the following dimensions: 9mm in cervical diameter, 5mm in height, Axial reduction of 1.2mm, Rounded axial line angles,135 degree chamfer finish line and a axial wall taper of 12 degrees.12 degree taper of axial wall was used for ease of removal of the patterns. The first cylindrical section [C1] of the metal die was contiguous to tooth preparation finish line with 5mm height and 9mm diameter. The cylindrical section[C2] was 30mm in height and 25mm in diameter. The lateral surface of cylindrical section was equally divided into 8 parts for measurements of marginal discrepancy of copings (Figure 1). Dental stone dies were prepared from the custom made stainless steel die to obtain patterns with the milling machine and three dimensional printing technology as the 3Shape D700 scanner could not scan the stainless steel die because of its shiny surface. A customized stainless steel former (Figure 1) was fabricated, such that the former could be accurately positioned over the stainless steel die. The stainless steel former was greater in dimension in comparison with the die by 0.5 mm uniformly. This space helped to obtain the patterns of a uniform thickness of 0.5 mm by conventional bulk building technique employing wax or resin.

2.1. Preparation of patterns for fabrication of Ni-Cr cast copings

2.1.1. Preparation of wax pattern (Figure 2)

The customized stainless steel die assembly as described previously was used to obtain standardized patterns for all the test specimens employed in this study. Die spacer (Han Dae Chemical Co.) of 28μm was applied on the die. Then a fine coat of die lubricant/ separator (Han Dae Chemical Co.) was applied. The inlay casting wax (Bego, Germany) was melted and filled in the stainless steel former and was pressed on the stainless steel die. The stainless steel die and former assembly were held together for 1 minute with finger pressure. The die was then separated from the former and the wax pattern obtained. The excess wax was trimmed using a PKT carver number 2. A uniform thickness of 0.5mm was checked throughout the coping using a wax calliper. In this manner a total of 10 wax pattern copings were made and assigned as group1 (G1) and numbered.

2.1.2. Preparation of resin patterns (Figure 2)

The customized stainless steel die and former as described previously were used. Die spacer of 28μm and a fine coat of die lubricant was applied. The auto-polymerizing pattern resin was mixed and placed in bulk in the stainless steel former and was pressed on the stainless steel die. The die former assembly was held together for 3minutes with finger pressure. After the resin set, the pattern was removed carefully from the die former assembly and carved back to the finish line. Pattern was checked for thickness 0.5mm with the wax calliper. A total of 10 pattern resin copings were obtained and grouped as group2 (G2) and numbered.

2.1.3. Preparation of wax pattern by CAD and milling (Figure 2)

The customized stainless steel die was duplicated using non aqueous elastomeric impression material and a customized acrylic tray and the impression thus obtained was poured in die stone. The die thus obtained was scanned using a 3Shape D700 scanner (3Shape Dental System,Copenhagen K, Denmark). Designing of the coping was done using the default set parameters for a coping thickness of 0.5mm on the CAM bridge software and was transferred to the milling unit (Roland JW X10 milling unit). For milling Inlay wax blocks(Ferris File A Wax) were used. A total of 10 wax patterns were obtained, numbered and grouped as group3 (G3).

2.1.4. Preparation of resin pattern by 3dimensional printing technology (3DP) (Figure 2)

The resin patterns were prepared with 3 dimensional printing technology using 3Shape D700 scanner for scanning the die stone die and a Projet HD 3000 printer for fabricating the patterns. The material used was epoxy resin containing reacting diluents. The die was scanned ,designed and the design created was transferred to the 3D printer (rapid prototyping machines). A total of 10 resin patterns were obtained, grouped as group4 (G4) and numbered.

2.2. Casting procedure

All the test pattern copings were invested individually using graphite free phosphate bonded investment material (Bellosun, Bego, Germany) and Individual castings were made from Ni-Cr alloy (Bellabond plus, Bego, Germany). The cast copings were devested, sandblasted, finished, polished and the internal surface inspected under magnification, relieved of all nodules with a round carbide bur and steam cleaned.

2.3. Measurement of marginal Gap

All the test samples of cast copings of Group 1, Group 2,Group 3 and Group 4 were evaluated for both vertical and horizontal marginal gaps employing a translating tool makers microscope TM-500 (Mitutoyo, Tokyo, Japan) .

2.3.1. Measurement of vertical marginal gap

Each cast coping was seated on the stainless steel die with finger pressure. The vertical marginal discrepancy was determined as the maximum distance between the preparation margin on die and the most apical part of the casting margin in a plane parallel to the long axis of the preparation on die. It was measured microscopically, at 150x magnification, under a translating tool makers microscope TM-500 which has a sensitivity of 2μm. Marginal gaps were measured to the nearest micron on each cast coping at the 8 predetermined reference points on the stainless steel die separated by 45 degrees (fig.3). The measurements thus obtained were tabulated and statistically analyzed.

2.3.2. Measurement of horizontal marginal gap

Each cast coping was seated on the stainless steel die with finger pressure. The horizontal marginal discrepancy was determined as the maximum distance between the margin of the tooth preparation on die and the most apical part of the casting margin, in a plane perpendicular to the long axis of the preparation on die. It was measured microscopically at 150x magnification under TM-500. Marginal gaps were measured to the nearest micron on each cast coping at the 8 predetermined reference points on the stainless steel die separated by 45 degrees (Figure 4). The measurements thus obtained were tabulated and statistically analyzed.

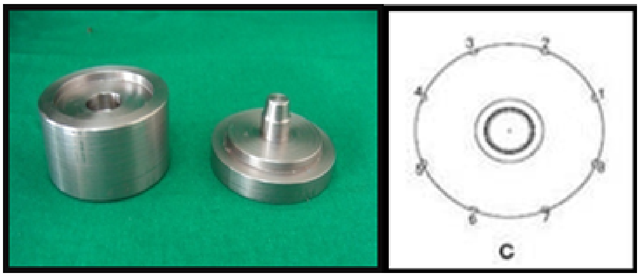

Fig. 1: Stainless steel die and stainless steel former assembly and Occlusal view of die with 8 reference points

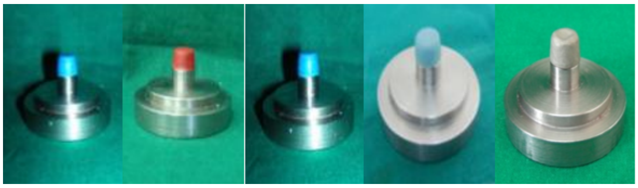

Fig. 2: Inlay wax pattern, Resin pattern, CAD milled wax pattern, 3D printed resin pattern and metal coping seated on die respectiveley

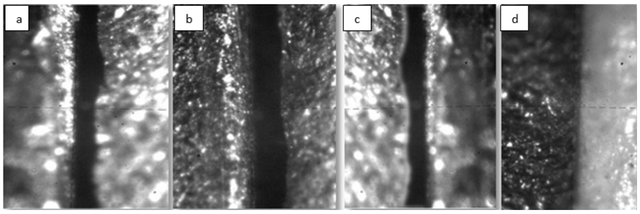

Fig. 3: Vertical marginal gap of Ni-Cr copings observed under 150x magnification using a translating tool makers microscope obtained from: a: group1, b: group2, c:group 3, d:group 4

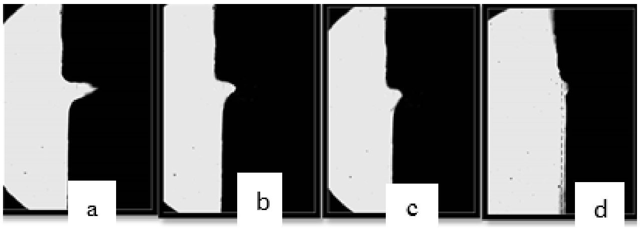

Fig. 4: Horizontal marginal gap of Ni-Cr copings observed under 150x magnification using a translating tool makers microscope obtained from: a: group1, b: group2, c:group 3, d:group 4

3. Results

Tables 1 and 2 shows the mean and standard deviation of group 1,2,3 and 4 for vertical and horizontal marginal gap respectively. The basic data obtained in this study shows a mean vertical marginal gap of 39.44 microns for inlay casting wax (Group 1), 66.06 microns for pattern resin (Group 2), 28.63 microns for CAD milled wax patterns (Group 3) and 10.69 microns for 3D printed resin patterns (Group 4). A mean horizontal marginal gap of 54.88 microns for inlay casting wax (Group 1), 28.25 microns for pattern resin (Group 2), 26.38 microns for CAD milled wax patterns (Group 3) and 25.69 microns for 3D printed resin patterns (Group 4). The vertical marginal gap data was analyzed by use of Kruskal Wallis Test followed by Mann Whitney U Test (Table 3) and the horizontal marginal gap data was analyzed by use of analysis of variance(ANOVA) followed by Tukey honestly significantly different (HSD) tests (Table 4).

4. Discussion

The vertical marginal gap of all the 40 copings obtained by four different pattern forming methods showed (G4<G3<G1<G2). There is a statistically significant difference between group 1 and group 2, group 1 and group 4, group 2 and group 3, group 2 and group 4 and group 3 and group 4. However differences between group 1 and group 3 were found to be statistically insignificant. The horizontal marginal gap of cast copings obtained from inlay casting wax group (G1), showed a statistically significant difference with group 2 (G2), group3 (G3) and group4 (G4) (G1>G2,G3,G4). But there is no statistically significant difference between group 2 and group 3, group 2 and group 4, and group 3 and group 4.

Table 1: Mean vertical marginal gap and standard deviation of group 1,2,3 and 4 (Kruskal Wallis Test).

	N	Mean	Standard deviation	Minimum	Maximum
Group 1	10	39.4375	18.05530	12.50	65.00
Group 2	10	66.0625	16.33804	37.50	99.38
Group 3	10	28.6250	5.91314	22.50	43.75
Group 4	10	10.6875	1.29937	8.75	12.50

Table 2: Mean horizontal marginal gap and standard deviation of group 1,2,3 and 4 (ANOVA).

	N	Mean	Standard deviation	Minimum	Maximum
Group 1	10	54.8750	9.26414	39.38	86.25
Group 2	10	28.2500	8.35830	17.50	45.63
Group 3	10	26.3750	7.05140	16.25	36.25
Group 4	10	25.6875	7.92461	15.00	41.25

Table 3: Mann Whitney U Test (Dependant variable: Vertical marginal gap)

	Z	P
Group 1 vs Group 2	-2.797	0.005
Group 1 vs Group 3	-1.060	0.289
Group 1 vs Group 4	-3.717	<0.001
Group 2 vs Group 3	-3.705	<0.001
Group 2 vs Group 4	-3.788	<0.001
Group 3 vs Group 4	-3.790	<0.001

Table 4: Tukey HSD (Dependant variable: Horizontal marginal gap)

(I) Group	(J) Group	Mean Difference (I-J)	P
Group 1	Group 2	26.6250	<0.001
	Group 3	28.5000	<0.001
	Group 4	29.1875	<0.001
Group 2	Group 3	1.8750	.971
	Group 4	2.5625	.930
Group 3	Group 4	.6875	.998

The reason for the high vertical marginal gap (66μm) in the case of pattern resin could be due to its high polymerization shrinkage. This coincides with the study conducted by Iglesias et al[2] in which he had mentioned that marginal discrepancy of acrylic resin was 40μm or greater for bulk build up technique. The vertical marginal discrepancy determined in this study of the cast copings fabricated from the inlay casting wax patterns was 39.44μm. This was in acceptance with the study conducted by Mc Lean et al which concluded that after the casting, marginal gaps ranged from 40 to 61.5μm.[2] The vertical marginal discrepancy of cast copings fabricated from epoxy resin patterns obtained by 3 dimensional printing (3DP) technology in this study is 10.69μm. The probable reason for this low vertical marginal gap could be due to its good dimensional stability. The software compensates for the polymerization shrinkage and increased precision without any chance for manual or technical errors during the pattern fabrication.

The results of this study had shown mean vertical marginal discrepancy of 10 to 66 μm were in the range of clinically acceptable level and in consensus with those of White SN, Dedmon, Mc Lean and Van Fraunhofer, Hung, Christensen, Gulker et al, Schwartz et al.[9] The mean horizontal marginal gap evaluated in this study ranges from 25 to 55μm which coincides with Dedmon's study which had shown the least clinically acceptable horizontal marginal gap of 93 μm.[10]

However there are a few limitations in this study. The laboratory testing cannot exactly reproduce the clinical situation. In this study, the marginal discrepancy was measured without permanent cementation of the cast copings and it could potentially affect the marginal adaptation. Sorensen[11] (1990) introduced a standardized method for determination of marginal adaptation of crowns like direct view, cross sectional view, impression technique, explorer and visual view. This study used direct view to evaluate the vertical and horizontal marginal discrepancy. The direct view method is convenient, easy, and rapid because the crown is retrievable, unlike the cementation, embedment, and sectioning method, which causes destruction of the crown. The results from this study encourage further research with different pattern forming materials and techniques and the need to identify the factors that facilitate better marginal fit of cast restorations.

5. Conclusion

Within the limitations of this study, it was concluded that three dimensional printing (3DP) technology of coping fabrication showed significantly better marginal fit than that of cast copings fabricated from CAD milled wax patterns, inlay casting wax patterns and the pattern resin patterns.

6. Conflict of Interest

There are no conflicts of interest in this article.

7. Source of Funding

None.

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