Marginal Discrepancy of Cobalt Chromium Metal Copings Fabricated with Three Different Techniques

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Abstract: Background: production of metal ceramic restoration with accurate marginal fit has been challenged with development of CAD-CAM technique. This study compared the marginal discrepancy of Co. Cr. Metal copings fabricated with three techniques: A-Conventional casting, B- Castable CAD-CAM wax and C- Direct CAD-CAM milling techniques. And see the effect of ceramic firing on the last group. **Method:** A master Brass die model was milled to represent preparation for porcelain fused to metal crowns of upper central incisor with a deep chamfer finish line design. For each group, 20 copings were made, the standardization procedure of the wax patterns of the group A were done through using split mold, for groups (B and C), the standardization of wax was done through the software of the CAD-CAM, followed by casting procedure of group A and B using Cobalt Chromium metal, while group C had been milled directly using Ceramill Sintron blank. The marginal discrepancy was evaluated using travelling light microscope from four aspects Buccal, Mesial, Lingual and Distal. The ceramic addition was accomplished for the Direct CAD-CAM milling group, and the discrepancies were measured again. **Result:** The mean vertical marginal discrepancy for groups A, B, and C was 25.250µm, 25.090µm, and 10.262µm respectively. Difference of vertical marginal discrepancy between group C and other two groups was highly significant ($p<0.001$) whereas it was non-significant between group A and B ($p>0.05$). **Conclusion:** Minimum marginal discrepancy can be produced using Direct CAD-CAM metal milling.

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Key Words: CAD-CAM, Vertical Marginal discrepancy, Cobalt Chromium, Direct metal milling technique.

1. Introduction:

Despite the development and growing use of all ceramic systems, ceramic-fused-to-metal (CFM) fixed dental prostheses (FDP) are still considered a good option due to their mechanical strength, also presenting significantly less clinical failures as opposed to all-ceramic ones **(Craig and Powers, 2002).**

Marginal integrity is one of an important element in evaluating the success of any restoration, and minimizing the marginal gap is necessary because an increase in this gap results in an increase in cement dissolution, thus increasing the potential for microleakage **(Shiratsuchi et al, 2006).**

This process has been shown to develop recurrent marginal carries and effect on the periodontal health **(Suarez et al, 2003).**

During the 20th century, both dental materials and dental technologies for the fabrication of dental devices progressed.

Remarkably **(Mörmann et al, 1989)**. Since laboratory work still remains to be labor-intensive and experience-dependent, a new sophisticated processing technology called computer aided design and computer-aided manufacturing (CAD/CAM) has been introduced into dentistry.

Nowadays (CAD/CAM) technology allows the fabrication of better fitting fixed partial dental prostheses of metal ceramic restoration using hard machining blocks than those made with the traditional lost wax techniques (**Almasri et al, 2011).** But still the soft machining metal block not be tested yet. So this study compared marginal discrepancy of soft milling metal block with conventional casting and castable coping from CAD-CAM wax and study the effect of ceramic firing on vertical marginal discrepancy of direct milled Co. Cr. metal copings.

2. Material and Methods:

The following materials and equipments were used in the study:-

1-Die spacer (Pico-Fit set No. 1954-0400, Renfert, Germany).

2-Modeling wax for dipping wax technique (GEO Dip orange No. 482-3200, Renfert, Germany).

3-Die lubricant (Picosep No. 1552-0030, Renfert, Germany).

4-Phosphate bonded investment (Cobavest, YETI, Germany).

5- Asbestos free casting ring liner (Keravlies Dentaurum, Germany).

6-Cobalt chromium bonding alloy (Girobond NBS Ceramill systems, Amann Girrbach, Germany).

7-Presintered cobalt chromium blanks for CAD-CAM machine (Ceramill sintron system, Amann Girrbach, Germany).

8-Wax blanks for CAD-CAM machine (Ceramill systems, AmannGirrbach, Germany).

9-Dental porcelain veneering material (VMK Master, VITA Zahnfabrik, Germany).

10-Jelenko Dental surveyor (Dentarium, Germany)

11-Dental turbine (Alegra, W&H co., Austria).

12-Split Mold (a wax caliper device) (custom made).

13-Electric wax heater (Renfert, Germany).

14- CAD CAM system (Ceramill systems , AmannGirrbach , Germany).

A-Ceramill Map 300 (scanner)

B- Ceramill Mind (construction software)

C- Ceramill Motion (milling machine).

D-Ceramill Argotherm (sintering furnace).

15-Centrifugal casting machine (Degussa, Germany).

16- Screw holding device (Custom made).

17-Travelling light microscope (Mitutoyo S/N 000079, Japan).

Fabrication of Metal Die:

The Brass die model was mounted to metal ring by using dental stone to be stable during the preparation, and then the assembly was mounted to the base unit of the surveyor. This Die model has the shape of central incisor. A dental surveyor was used for the preparation which done by a high-speed turbine (Alegra, W&H co.) that was attached to the vertical arm of the surveyor with a specially designed cross-like pipe holder to keep the bur vertical to the finishing line and parallel to the longitudinal axis of the die and to eliminate the undercuts and ensure proper degree of axial tapering. The bur used in the preparation was coarse type diamond round ended, tapered fissure bur, followed by smoother torpedo diamond bur; the preparation was finished with similar tungsten carbide bur **(Subhy and Zakaria, 2005)**. After the completion of axial preparation, incisal finishing was done with oval shaped diamond bur, the incisal edge was reduced to 1.5 mm below the estimated incisal level of the final crown (**Bass and Kafalias, 1989**), then the die was smoothened with sandpaper and polished with pumice in a lathe brush then with rouge to gain smooth dished surfaces so that no interference with the seating of the metal copings could occur later. The completed die was 7mm in length, 5-6 mm in width and minimal (8) degree of convergence, with deep chamfer finishing line all around with a depth of 1 mm.

Group A (conventional casting technique):

Two coats of die spacer give approximately 25 microns thickness was applied to the surface of the die except the finishing line **(Grajower et al, 1989).** The standardized wax pattern was fabricated by dipping the die into an electric wax heater filled with molten dipping wax (type II inlay wax) at 89◦ c, for developing a uniform, thin initial coping with 0.5 mm thickness of wax on the die **(Shillingburg et al, 1997)**, the cervical wax was added so that thickness and height were 1mm at the finishing line, wax wire (gage 2.5mm) was attached to the mid area of the incisal edge of the pattern forming sprue.

The split mold is a steel mold framework which was turned into two halves used to facilitate getting mold using stone for wax pattern standardization of its thickness to be 0.5 mm thickness with attached sprue for producing further 20 standardized wax patterns of group A. Produced pattern was kept in a water container, later wax patterns would be invested using investing ring lined with a single layer of asbestos free ring liner (1mm thickness), casted using The Co-Cr. (Girobond NBS) Alloy according to manufacturer instructions and finished without touching the margins.

Group B (Castable coping of CAD-CAM wax patterns):

The die was fixed to stone base to be stable during scanning procedure, Ceramill powder applied on the die to get off luster, the die-base assembly loaded to the table of the CAD-CAM scanner and scanned by using Ceramill map 300 with a full automatically (Optical) scanning method.

Designing of wax pattern was made by using CAD software (Ceramill Mind) with the following criteria: thickness of wall was 0.5 mm, and thickness of cement gap was 25 micrometers (**Boening et al, 2000),** starting from 0 mm at the finishing line, and determination of the connectors' location to be away from the finishing line. Loading the wax block to CAM unit for milling procedure of the wax patterns, later they invested and casted and finished similar to group A.

Group C (Direct CAD-CAM milling copings):

The optical scanner scanned the die-base assembly; Three-dimensional image was displayed on the computer monitor. Ceramill 3D InLab Software was used to design the crown with the following information, thickness of wall will be 0.5mm, and thickness of cement gap will be 25 micrometer, starting from 0 mm at the deep chamfer finishing line. Ceramill sintron® Co-Cr block mounted to the Ceramill motion (Milling unit) for dry milling, crown was removed from Ceramill sintron® Co-Cr block and sintered using Ceramill Therm (sintering furnace) according to manufacturer instructions.

Each coping was kept in a plastic container, which was recognized and numbered. The copings were replaced on the mounted die to measure the marginal fitness.

Porcelain veneering on group C

Before porcelain application, the finishing of the metal coping included only sandblasting with 50-µm aluminum oxide to eliminate contamination followed by ultrasonic cleaning. There was no need for oxidation firing according to the manufacturer's instruction.

Opaque material was applied, with brush using porcelain (VITA VMK Master) with CTE range (13.8 - 15.2) $10^{-6} \cdot K^{-1}$, Firing of opaque layers was done into two stages; wash bake and opaque firing, this was done according to manufacturer's recommendations, the final opaque layer of porcelain was approximately 0.3 mm thick.

Opaque layer wetted with a small amount of the liquid and a bead of body porcelain built the veneer to anatomic contour with body porcelain slightly oversized to compensate for shrinkage, then dried and fired as intermediate 1st Dentine firing. The incisal layer was applied in the same manner and overbuilt in the restoration as described for body porcelain, then dried and fired as 2nd Dentine firing according manufacturer's instructions. The final firing cycle was done through auto glazing using porcelain furnace that was raised to its fusion temperature and maintained for a time before cooling.

Measurement of the marginal discrepancy:

Predetermined areas were marked on the metal die in the centre of the buccal, lingual, mesial and distal surfaces. Each coping/crown was seated on the metal die using a holder that applied a standard force to seat the copings/crowns on the metal die. The vertical marginal discrepancy between the metal die and coping/crown was measured on each of the four surfaces at the marked sites with a travelling light microscope. All measurements were executed by the same operator and each site was measured 3 nonconsecutive times. Mean value of these measurements was used for the statistical analysis. ANOVA and LSD test were carried out for obtaining the results.

3. Results:

Results related to the fabrication techniques:

The mean vertical marginal discrepancy for groups A, B, and C was 25.250µm, 25.090µm, and 10.262µm respectively. The mean of vertical marginal gaps, standard deviations, minimum and maximum values for all groups are shown in **Table 1.** Analysis of variance (ANOVA) test was performed among the tested groups and shown very highly significant differences at $P \leq 0.001$, **Table 2**. Difference (significant/non significant) among the three groups on all the four surfaces is shown in **Table 3.**

There was a very highly significant difference between group C and the other two groups ($P \leq 0.001$), while there was non significant difference between group A and group B ($P \geq 0.05$).

Result related to effect of firing cycles of the porcelain:

The mean vertical marginal discrepancy and standard deviation for Group C before and after porcelain veneering are shown in **Table 4.** Difference (significant/non significant) between the marginal fit of the copings before and after adding the veneering porcelain are shown in **Table 5.**

The Student paired t-test revealed a very highly significant difference in the marginal fit of the copings after the addition of veneering porcelain at 5% significance level ($P < 0.001$).

Table 1: The Descriptive statistic for each tested group (vertical marginal discrepancy).

Groups	N	Mean	SD.	Min.	Max.
Conventional casting	19	25.250	3.858	18.00	32.00
Castable CAD-CAM wax	20	25.090	3.850	19.25	34.00
Direct CAD-CAM milling	20	10.262	1.496	8.00	13.00

Table 2: ANOVA test for mean marginal gaps among the groups.

S.O.V	SS	df	MS	F	P- value	Sig.
Between Groups	2937.4	2	1468.7	138.8	.000	VHS
Within Groups	592.2	56	10.5			
Total	3529.7	58				

Table 3: LSD test for mean marginal gap between groups.

Groups		P-value	Sig.
Conventional casting	Castable CAD-CAM wax	.879	NS
Castable CAD-CAM wax	Direct CAD-CAM milling	.000	VHS
Direct CAD-CAM milling	Conventional casting	.000	VHS

Table 4: The Descriptive statistic of group C (before and after veneering).

	Mean	N	Std. Deviation
Before porcelain veneering	**10.262**	**20**	**1.496**
After porcelain veneering	**19.500**	**20**	**2.360**

Table 5: Student paired t-test of the marginal fit of group C.

	Mean	Std. Deviation	t	df	P-value	Sig.
before porcelain veneering - after porcelain veneering	-9.23	3.07	-13.4	19	.000	VHS

Fig 1.Fabrication of the Die

Fig 2. Wax pattern production

Fig 3.Wax block milling

Fig 4. Sintering furnace (CeramillArgotherm)

4. Discussion:

Discussion of Method:

Using Cobalt Chromium (Co.Cr.) alloy which are Nickel, Beryllium, and Carbon free as non allergic, non toxic and non brittle alloy was recommended (**McGinley et al, 2011).**

The fit is typically measured by the gap at the margins. Although margin gaps can be measured under different conditions, the method of vertical marginal discrepancy (defined by **Holmes et al,** ***1989)*** was used in this study because this measurement included different situations with only vertical measurements of (a) overextended coping, (b) underextended coping, and (c) where finish line of die is aligned to edge of the coping margin.

Evaluation of the marginal discrepancy of crowns depends on factors such as: measurements of cemented or not-cemented crowns, storage time and treatment (such as aging procedures) after cementation, kind of abutment used for measurements, kind of microscope and enlargement factor used for measurements (**Beschnidt and Strub, 1999).**

When measuring the marginal gap after cementation, the same number of teeth or metal dies as that of restoration sample is needed. On the other hand, only one tooth or die is needed if the measurement is done without a luting agent **(Pak et**

al, 2010). Some investigators**,** found a significant increase in the marginal discrepancy after cementation **Beschnidt and Strub, (1999) and Kern et al, (1993)**. These results, however, varied according to the luting agent. The marginal fit was, therefore, measured without cementation and on one brass die for a more sophisticated variable control in this study. Several investigators had used metal master models; the advantage of this model is standardized preparation that lacks wear during the manufacturing processes and measurements (**Balkaya et al, 2005).**

The fabrication of restorations with CAD/CAM require a preparation criteria including distinct finish lines and avoidance of parallel surfaces, undercuts and sharp angles (**Luthardt et al, 2001**), this was done during brass die preparation using the dental surveyor. The designing procedure included determination of the connectors' location to be away from the finishing line, this was done for all the copings in first and second groups so that it did not disturb the marginal fitness during later grinding procedure. There are many finish-line preparations, but the shoulder, shoulder-bevel and deep chamfer are mostly used as finish lines for metal ceramic restoration **(Rosenstiel et al, 2006).**

The deep chamfer preparation was selected because it meets the requirements for all metal ceramic preparations (**Witkowski et al, 2006).**

Sandblasting has been evaluated as a useful mean to get rid of the traces of investment; in this study only cleaning in the tap water with an active bristle was used in order to overcome marginal damage that occurred during air abrasion of dental casting (**Felton et al, 1991).**

During porcelain veneering of the 3rd group, the application of porcelain was made 1 mm away from the finishing line because it needed only to see the effect of the porcelain firing cycles on marginal discrepancy and to maintain the accuracy of marginal fit readings by minimizing the contamination of the internal walls.

Discussion of Results:

In the present study, the measurements of marginal fit exhibited mean vertical discrepancies in the range of (**8 -34** µm). Marginal fit of restorations that range from 25 to 40 microns has been suggested as a clinical goal **(Alkumru et al, 1992**) and marginal gap of 100 µm is reported as the maximum clinically acceptable gap size in metal ceramic restorations **(Boening et al, 2000**), (**Gassino et al, 2004).** According to previous studies, the results were within clinically acceptable limits.

The present marginal discrepancy a highly statistical significant difference in marginal discrepancy between the Direct CAD-CAM milling group and the other two groups. This confirmed that the CAD/CAM technique provided more precision than the conventional metal ceramic technique, avoiding the errors inherent in the casting process as reported by **Persson *et al* at 2008** and **Gonzalo *et al* at 2009**. In addition the expansion and contraction properties of the various materials used in the fabrication of first and second, combined with the complex fabrication steps of the casting process, made the achievement of the minimum gap of a cast coping considerably difficult (**Sulaiman et al, (1997 and Gonzalo et al, (2009).**

Although there was only one study by **Ortorp *et al* at 2011**, came in disagreement with our results and the explanation of different findings may be due to using hard milling technique rather than soft milling, cementation of the specimens, using three unit fixed dental prostheses not single crown and using different measuring methods.

The result of this study showed a non significant difference in the marginal gap of Castable CAD-CAM wax group compared to Conventional casting group, the explanation of that may be related to the high melting temperature of CAD-CAM wax blank compared to modeling wax that usually used with casting procedure. The using of the high melting wax blank was necessary to avoid distortion of wax patterns during milling procedure of the second group.

The mean marginal discrepancy value before porcelain application was the lowest for the Directly milled copings and showed a highly statistical significant difference following porcelain application, the explanation of this can be related to some factors; firstly, to a possible alteration of the infrastructure of the metal, but studies related with adaptation of metal-ceramic crowns show that mismatches proceeding not from the distortion of the infrastructure exists, but from ceramic contamination in the internal surfaces of the copings, injuring the sitting of the prosthesis **(Gemalmaz and Alkumru, 1995) and Campbell et al, 1995).**

Also this difference may be explained by the fact that during the porcelain veneering procedure, particles of porcelains melt and gather to fill up voids and the resulting contraction of the porcelain mass causes a compressive force on the coping result in medial displacement of the axial wall of the coping, which would produce tighter fit and incomplete seating (**Weaver et al, 1991).**

The deformation of the coping under the stress of contracting porcelain is spread around the whole circumference of the margin. Some investigators thought that reduction in the resilience of the metal because of the rigidity of porcelain result in outward and upward displacement of the marginal area **(Anusavice and Carroll, 1987).** This could be true if the finishing line was feather edge rather than deep chamfer.

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