Original Article

A Comparison of the Marginal and Internal Fit of Cobalt- Chromium Copings Fabricated by Two Different CAD/CAM Systems (CAD/ Milling, CAD/ Ceramill Sintron)

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KEY WORDS
Marginal and Internal fit;
CAD/CAM;
Ceramill Sintron;
Base Metal Alloy;

ABSTRACT

Statement of the Problem: Marginal fitness is the most important criteria for evaluation of the clinical acceptability of a cast restoration. Marginal gap which is due to cement solubility and plaque retention is potentially detrimental to both tooth and periodontal tissues.

Purpose: This *in vitro* study aimed to evaluate the marginal and internal fit of cobalt-chromium (Co-Cr) copings fabricated by two different CAD/CAM systems: (CAD/ milling and CAD/ Ceramill Sintron).

Materials and Method: We prepared one machined standard stainless steel master model with following dimensions: 7 mm height, 5mm diameter, 90˚ shoulder marginal finish line with 1 mm width, 10˚ convergence angle and anti-rotational surface on the buccal aspect of the die. There were 10 copings produced from hard presintered Co-Cr blocks according to CAD/ Milling technique and ten copings from soft non- presintered Co-Cr blocks according to CAD/ Ceramill Sintron technique. Marginal and internal accuracies of copings were documented by the replica technique. Replicas were examined at ten reference points under a digital microscope (230X). The Student's t-test was used for statistical analysis. $p< 0.001$ was considered significant.

Results: Statistically significant differences existed between the groups ($p< 0.001$). The CAD/milling group (hard copings) had a mean marginal discrepancy (MD) of 104 µm, axial discrepancy (AD) of 23 µm and occlusal discrepancy of 130 µm. For CAD/ Ceramill Sintron group, these values were 195 µm (MD), 46 µm (AD), and 232 µm (OD). Internal total discrepancy (ITD) for the CAD/milling group was 77 µm, whereas for the CAD/Ceramill Sintron group was 143 µm.

Conclusion: Hard presintered Co-Cr copings had significantly higher marginal and internal accuracies compared to the soft non-presintered copings.

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Introduction

Metal ceramic crowns remain the most commonly used method for fabricating full coverage restorations [1] and they are considered standard treatment for restorative dentistry. The conventional technique for fabricating a metal substructure is the lost wax technique and the use of various alloys for casting. [2]

Advantages of wax in the traditional method are convenient manipulation, ability to form a precise shape and complete removal from the mold by heat. [3] The fabrication of a wax pattern is the most critical step in making porcelain fused to metal (PFM) crowns. The quality of this time-consuming task depends on the skill of the technician. [4] Zeltse *et al.* [5] have found that removing a wax pattern from a mold with a shoulder margin caused a 35µm average gap in margin area, prior to investing. In addition, due to the color of the wax pattern and its glossy surface, small defects could be difficult to identity. [3] Undesirable properties of wax include delicacy, thermal sensitivity, elastic memory and a high coefficient of thermal expansion (CTE). [6]

Currently, the introduction of different CAD/CAM systems, has led to improved quality of full coverage restorations. It is possible to fabricate wax patterns made from castable materials and omit the numerous limitations of the conventional wax up technique. [7-8]

Advantages of CAD/CAM systems include the production of higher and more uniform- quality restorations by using commercially formed blocks of material, standardization of restoration shaping processes as well as reduced production costs and time. [9] Another advantage is the potential accuracy that may result from omission of waxing, investing and casting fabrication steps used in the conventional method. [6]

Despite the above advantages, CAD/CAM systems have introduced some additional steps to the fabrication process that may result in inaccuracies, such as scanning, software design, milling and material processing. [6] Beuer *et al.* [10] have reported that the sintering process, scanning procedure, the processing of the collected geometric data, calculation of milling parameters, and the actual milling process are factors that affect fitting accuracy of restorations.

CAD/CAM technology can be divided into three categories according to the technique used: subtractive technique from a solid block, additive technique by applying material on a die (a combination of additive and subtractive CAM approaches), and finally additive technique by using solid forms fabrication (SFF) or rapid prototyping (RP). [9-11]

Base metal alloys are used extensively in dentistry due to their favorable chemical and physical properties as well as their high cost-efficiency. [12] Two different approaches to CAD/CAM processing have been reported for these alloys, additive, which uses laser sintering, and subtractive, on massive, costly milling machines from end-strength material (hard presintered blocks). Only a few CAD/CAM systems for the dental laboratory are designed for processing of materials milled in the final densely-sintered stage like hard presintered cobalt-chromium (Co-Cr) blocks. These CAD/CAM systems are associated with high acquisition and maintenance costs. The development of a soft non-presintered Co-Cr material (Ceramill Sintron; AmannGirrbach, Koblach, Austria) allows this alloy to be processed in-house on desktop milling machines with reduced manufacturing time and costs. The processing steps are quite comparable to those of pre-sintered zirconia. The soft Co-Cr blank is processed in a material pre-state by dry milling. The material contains adhesive agents such as organic binders and is milled in a “green state”. Subsequently, the milled reconstruction must be sintered to full density in a special, high-temperature sintering furnace under an argon protective gas atmosphere at 1300 °C. During the sintering process, the organic binder burns out and the metallic powder particles are sintered (caked) without creating a fused phase. This leads to a decrease in volume of approximately 10%. According to present knowledge, the soft Co-Cr base metal alloy appears to be suitable for long-span fixed dental prostheses (FDPs) of up to four units.

The fit of any restoration is determined by its marginal and internal fit. [6] A good marginal and internal fit is an important factor for the long- term success of full coverage restorations. [13] Metal ceramic crowns are still the most widely used material for fabricating crowns and fixed partial dentures. Although new CAD/ CAM techniques (CAD/Milling, CAD/ Ceramill Sintron) have been introduced to fabricate metal copings, there is no data available regarding the fit of metal copings produced by these methods.

Therefore the purpose of this *in vitro* study was to evaluate the marginal and internal fit of Co-Cr copings fabricated with two different CAD/CAM systems; milling from hard presintered Co-Cr blocks (CAD/ Milling), and milling from soft non-presintered Co-Cr blocks (CAD/ Ceramill Sintron). The null hypothesis was that no significant differences would be found in marginal and internal fit of metal copings fabricated with these two CAD/CAM systems.

Materials and Method

For this *in vitro* study, we prepared one machined standard stainless master model with a height of 7 mm, diameter of 5mm, 90˚ shoulder marginal finish line with 1 mm width, 10˚ convergence angle (5˚ for each axial wall) and antirotational surface on the buccal aspect of the model. (Figure 1)

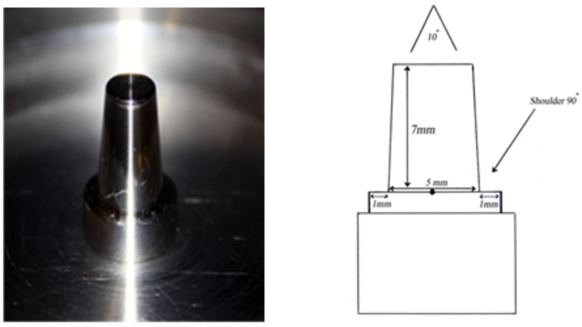

Figure 1: Master model

In order to achieve scannable surfaces, we covered the stainless steel model with scan spray (Arti-Scan CAD/CAM Spray; Bausch Gmbh & Co. KG, Koln, Germany).

After scanning the master model, we fabricated the copings. In the CAD/Milling system, presintered hard Co-Cr blocks (CORITEC Co-Cr disc; imes-icore GmbH, Germany) were used for fabricating ten metal copings. In the CAD/ Ceramill Sintron system, ten metal copings were fabricated from non presintered soft Co-Cr blocks (Ceramill Sintron blanks; Amann Girrbach, Germany).

For preparation of the Ceramill Sintron specimens, soft non-presintered Co-Cr blocks have been used and milled in the green state (Ceramill Motion 1; AmannGirrbach). The wax like texture of this materials results in minimal tool wear and effortless milling in the dry mode. Subsequently, all specimens were sintered under an inert gas (Argon 4.6) in a special argon furnace (Ceramill Argotherm, AmannGirrbach) according to the manufacturer's instructions. After sintering, copings were allowed to cool to room temperature.

In the CAD/Milling group, hard presintered Co-Cr blocks were placed in the holder of milling machine (CORITEC 450i, imes-icore GmbH Im Leibolzgraben, Germany) and milling of blocks was done by special burs in 5 axes. Since these copings were in the final densely-sintered stage, no sintering process was necessary. All copings were designed with a thickness of 0.5 mm; the cement space was set to 40 µm with no space at 0.5 µm from the margin. (Figure 2)

Figure 2a: CAD/Ceramill Sintron, **b:** CAD/Milling copings.

Replica technique

In order to register marginal and internal gap, silicone replicas were fabricated. 20 samples of these replicas were made for both CAD/CAM copings. The copings were filled with a light body A-silicone **(**Elite HD+; Wash Material Light Body, Zhermack, Italy), placed on a standard master model and a force of 20N was applied, verified by dynamometer. This thin blue silicone layer represented the gap width between the inner surface of the coping and master model surfaces. After the light body silicone was set, coping was removed from the model. This thin blue colored silicone film in the coping was stabilized by injecting a heavy orange-colored body A-silicone material (Elite HD; Tray Material Heavy Body, Zhermack, Italy).

The replica was removed and segmented with a razor blade in the mesiodistal and buccolingual directions. (Figure 3)

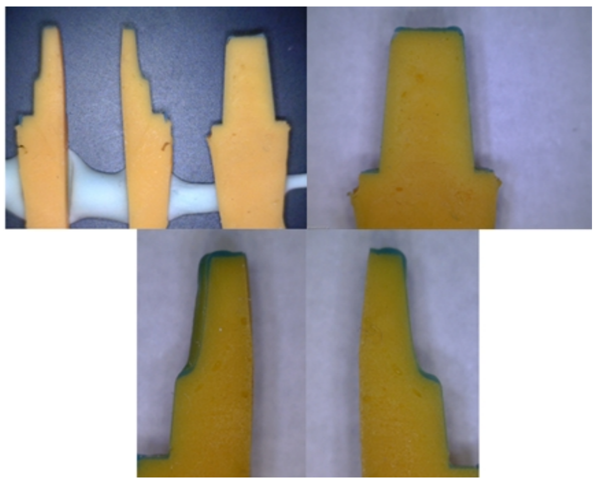

Figure 3: Replica samples show the intersections of the samples prepared for microscopic investigation.

Gap measurement

Four cross sections for each coping were adjusted horizontally on modeling clay in order to obtain a parallel orientation to the microscope plate and to achieve a rectangular observation. The blue colored silicone layer which represented the discrepancy between the master model and the inner surface of the restoration was ex-

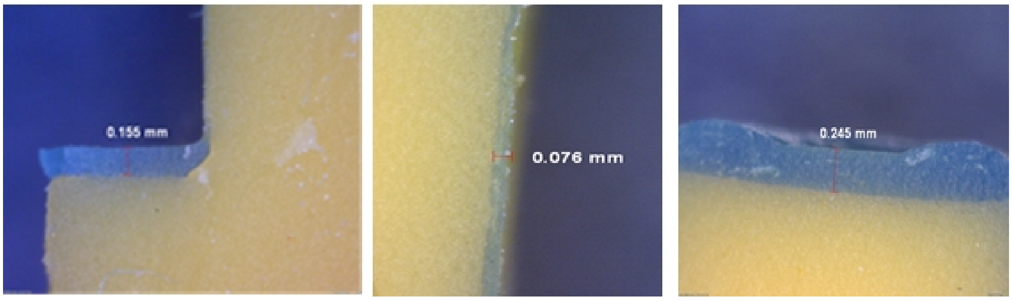

Figure 4: Locations of the discrepancy measurements at **a:** marginal discrepancy (MD), **b:** axial discrepancy (AD), **c:** occlusal discrepancy (OD).

amined at 230X magnification using a digital microscope (AM413FIT Dino-Lite Pro; Dino-Lite, Taipei, Taiwan) with a corresponding digital camera and software. At each cross section the following landmarks were measured; marginal discrepancy (MD) according to the study of Holmes *et al.*, [8] where the width was measured as the perpendicular distance from the internal surface at the margin of the restoration to the marginal region of the die , axial discrepancy (AD) which represented the distance between the die and inner surface of the crown at the middle of the axial wall, occlusal discrepancy (OD) or center occlusal discrepancy(COD) which represented the distance between the die and inner surface of the crown at the center of occlusal surface. In order to measure the above mentioned gap spaces, ten points for each coping were considered. (Figure 4)

The Student t-test was used for statistical analysis between the two groups. SPSS version 18.0 (Chicago, IL, USA) was employed for data analysis. The data of the two techniques were tested for statistically significant differences at $p< 0.001$.

Results

The means and standard deviations for marginal MD, AD, OD and ITD for both groups are summarized in Table 1.

The results showed significantly higher marginal and internal fit in the CAD/Milling group (hard copings) compared to CAD/Ceramill Sintron group (soft copings). The bar plat diagram (Figure 5) shows the median values, both 25 and 75% quartile and the outlier of the two systems at the different regions. The values for MD, AD, OD and ITD showed significant differences between two groups ($p< 0.001$).

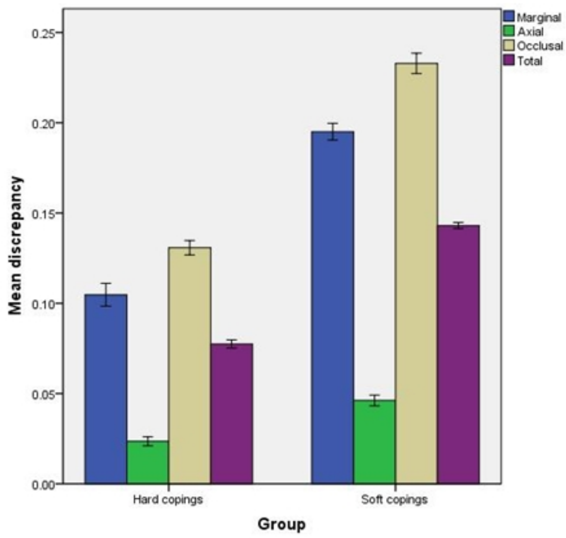

Figure 5: Bar Plot Diagram at marginal discrepancy (MD), axial discrepancy (AD), occlusal discrepancy (OD) and internal total discrepancy (ITD) for both groups.

Discussion

The aim of this *in vitro* study was to compare the marginal and internal fit of metal Co-Cr copings fabricated by two different CAD/CAM systems. (CAD/Milling and CAD/ Ceramill Sintron) The results support the rejection of the null hypothesis, as there were significant differences in marginal and internal fit between the two systems. The CAD/ Ceramill Sintron group had signifi-

Table 1: The Mean ± SD of marginal and internal fit (μm)

Groups / Regions	Hard copings (CAD/milling)	Soft copings CAD/Ceramill Sintron	P value
MD (Marginal Discrepancy)	104 ± 3	195 ±2	<0.001
AD (Axial Discrepancy)	23 ± 1	46 ± 1	<0.001
Occlusal Discrepancy (OD)	130 ± 2	232 ± 2	<0.001
ITD (Internal Total Discrepancy)	77 ± 1	143 ± 1	<0.001

cantly lower marginal and internal fit in all measured areas compared to the CAD/Milling group. (Table 1)

We chose the absolute MD for measuring the marginal gap, because it is most critical due to cement solubility. [14] There are several basic methods used to measure marginal and internal gaps; direct view (external microscopic examination), cross-sectional technique after cementation and embedding (internal microscopic examination), impression technique (internal replica approach), weighing the light-body additional silicone, and explorer and visual examination. [6, 15]

In the present study, impression technique (replica method) was used for evaluating marginal and internal fit, which is accepted as a reliable and noninvasive method for measuring marginal and internal fit. However the impression replica technique has its constraints and inherent errors such as difficulty in identifying the crown margins and finishing lines, tearing of the elastomeric film upon removal from the crown and mistakes in sectioning plane which eventually would lead to overestimated measurements. [6]

Marginal fitness is the most important criteria for evaluation of the clinical acceptability of a cast restoration. [16] Marginal gap is due to cement solubility and plaque retention which is potentially detrimental to both tooth and periodontal tissues. [14, 17] Minimal marginal gaps results in less gingival irritation, cement dissolution, recurrent carries and marginal discoloration. [18-19] Many studies have been conducted to represent the maximum clinically-acceptable marginal gap width. Bhaskaran E *et al.* [20] stated that vertical marginal gap ranged between 10 and 160 µm and internal gap ranged between 81 and 136 µm were clinically acceptable. However, Moldovan *et al.* [21] reported 100µm to be good and 200-300 µm to be acceptable for marginal misfit. We reported marginal misfit of 104 µm for CAD/Milling group and 195µm for CAD/Ceramill Sintron group. Therefore, according to these results, both systems have clinically acceptable marginal discrepancies.

The internal gap was defined as the perpendicular distance between the framework and the abutment teeth. It is the misfit of the coping at the occlusal/ incisal and axial surfaces. [22-23]

Apart from the mechanical properties of the material used, the internal fit also has a practical aspect. If too much space is lost as a result of large occlusal discrepancies, the intercuspal clearance available for veneering would be reduced, [24] which consequently can affect the strength of a crown-cement system. Therefore, the internal fit should be uniform to avoid compromising either the retention or resistance of the crown and should also provide an appropriate luting space. [25]

Theoretically, the internal space necessary for cement is 20to 40µm as reported by Fransson *et al.* [26] However, according to Martins LM *et al.* study, [27] the practical range for clinical acceptability of internal fit seems to be approximately 50 to 100µm. Beuer *et al.* [28] have reported that a 50µm space in the chamfer area is expected to result in better seating at the margin area. The current study had clinically acceptable results of 23 µm for the internal gap in the CAD/Milling group and 46 µm for the internal gap in the CAD/Ceramill Sintron. In this study, occlusal and marginal gap were significantly greater than the axial gap, a finding that agreed with previous studies. [17, 29]

In clinical practice, natural teeth show a large variation because of their age and individual structure, thus causing difficulties in obtaining standardized abutments. Therefore, we have used the standardized stainless steel master model to measure the marginal and internal fit. To normalize the measurement, all procedures for both groups were standardized with the exception of the CAM procedures. For calibration, we used a standard stainless steel master model, an almost equal cement space of 40 µm, uniform coping thicknesses, and the same CAD system for both systems.

It has been demonstrated that marginal fit is significantly dependent on the type of CAD/CAM system used. [30] In the present study, the CAD system was the same for both groups, whereas the CAM system was the subtractive method in both groups. In one method, copings were fabricated from hard solid presintered Co-Cr blocks and in the other method; copings were milled from soft non-presintered Co-Cr units after which they were sintered in an Argotherm furnace.

The subtractive method of manufacturing has some limitations since the precision fit of the inside contour of the restoration is dependent on the size of the smallest usable tool for each material of a system .If the cutting tool is larger in diameter than some parts of the tooth preparation, the CAD system will face a problem of cutting or not cutting the parts, which consequently results in decreased internal fit precision or inferior marginal properties. [11, 24]

Most cutting tools are incapable of cutting sharp internal angles which results in an increased marginal gap. In order to avoid this problem, a spacer parameter has to be chosen in the CAD/CAM system, or the fit of the crown has to be corrected by the technician, using a handpiece, during the laboratory fitting procedure. Both procedures can induce wider internal gaps. [24] Gonzalo *et al.* [24] have shown an internal space of 50µm provided a high precision of fit for restorations. Similarly, a larger cement space has been considered for CAD/CAM or CAM groups in several studies. [22-23, 31] In the present study, cement space for all copings were 40µm according to manufacturer instructions.

According to a number of studies, veneering significantly impacts the MD of PFM crowns. In the present study; however, we have measured the adaptation of copings without veneering in order to limit variations that affect MD. Moreover, the copings principally define the overall fitness of veneered crowns. [32-33]

Depending on the type of cement, marginal discrepancies of castings may increase from 15µm to more than 55µm through cementation compared to the same casting seated without medium in the luting gap. [34] However, marginal discrepancies of castings seated with a light-bodied silicone indicator paste are comparable to those of the same casting cemented with zinc phosphate cement. [35] Thus, although not evaluated in the current study, it can be assumed that the marginal discrepancies of the cemented restorations will be in a similar range as measured with the silicone indicator paste. Limitations of the current study included the *in vitro* setting which might not reflect conditions in daily clinical practice. The use of human teeth would be ideal for simulating clinical procedures. In addition, we have not subjected the copings to thermo mechanical cycling, that is a factor that affects long- term marginal fit of the crown.

Conclusion

Within the limitations of this study the following conclusions may be drawn:

1- The marginal and internal discrepancy of the CAD/ Milling system was lower compared to CAD/ Ceramill Sintron.

2- CAD/Ceramill Sintron, as a new technology in the CAD/ CAM system, is easy to use due to the wax like texture of blocks and minimal tool wears.

3- Marginal discrepancy, occlusal discrepancy and axial discrepancy of both systems are clinically acceptable.

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Conflict of Interest

The authors of this manuscript certify that they have no conflict of interest.

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