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The Comparison of Vertical Margin Discrepancy in Casting Fabricated With Metal Ring, Ringless and Metal Ring With Hygroscopic Expansion Investment Systems

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Abstract

Background: The use of casting ring to produce accurate casting has been challenged with the introduction of a ringless casting technique. This study compared the vertical margin discrepancy of castings fabricated with the ringless technique, conventional (ring and liner) technique and conventional technique with hygroscopic expansion investment systems.

Objectives: The current study aimed to determine and compare the mean values of vertical margin discrepancies of castings in three investing procedures: the ringless technique and conventional investing technique.

Materials and Methods: In the first step, 39 coping wax patterns for Porcelain fused to metal restoration (P.F.M). With chamfer finish line were fabricated on the metal die and then divided into three groups of 13. The first group used conventional investing (with ring and liner), the second group used the ringless technique and the third group used the conventional ring technique with liner and hygroscopic expansion. All groups were invested using Thermovest phosphate bonded investment. Then wax patterns were cast with Ni-Cr alloy (super cast). Castings were divested, cleaned and seated on the metal die after minimal internal surface adjustment. The vertical margin discrepancy was measured in four sites: on the buccal, lingual, mesial and distal surfaces of the die. Castings were measured on an optical microscope. The vertical margin discrepancy in each group was used for statistical analysis.

Results: After statistical evaluation, the following results were obtained: the mean vertical margin discrepancy for conventional investing was 156.72 ± 64.67μ; for the ringless technique it was 117.3 ± 26.77μ; and for the conventional metal ring technique with hygroscopic expansion it was 96.15 ± 38.31 μ. There is a significant difference between castings of the conventional investing technique and the ringless and ring plus hygroscopic expansion techniques ($P < 0.001$). No significant difference was found between the ringless and ring plus hygroscopic expansion techniques ($P = 0.183$).

Conclusions: The castings fabricated from the ringless technique with non-precious alloy are acceptable. This investing system is useable for the fabrication of fixed restorations.

Keywords: Ringless Investment System, Dental Casting, Vertical Margin Discrepancy, Hygroscopic Expansion

1. Background

The great importance in the investing of wax pattern is the fact that the molten used alloy for dental restoration shrink upon solidification, this problem caused casting will be that much smaller (1-5).

However, if the restoration is a crown, this shrinkage may prevent it from seating completely on the tooth preparation, resulting in a gap between the margin and finish line. This gap can create a plaque-retentive area that leads to cavities which ultimately harms the tooth and the work done for the restoration (1, 2, 4, 5).

Other factors that affect the accuracy of castings for restorations include the precision of the tooth preparation, impression and working cast (1, 2, 4, 5).

There are four methods used to produce an expanded mold that compensates for metal shrinkage: 1) setting expansion of the investment, 2) hygroscopic expansion, 3) thermal expansion of the investment and 4) wax pattern expansion (1, 2, 4, 5).

In the conventional investing procedure, the metal ring restricts the setting and thermal expansion of the investment, forcing the expansion inward toward the mold, resulting in a distortion of the casting. For this reason, a resilient liner is placed on the inside of the metal ring to permit the expansion and easier removal of the investment and casting from the ring later (1, 2, 4-7).

Other methods use a split plastic casting ring that offers no resistance to the setting expansion. The

plastic ring is removed before the invested pattern is placed into the oven (1, 4, 5). Another method is a ringless technique, which allows for setting and thermal expansion, but the mold is more prone to cracking. An additional method uses hygroscopic expansion (2, 5, 8, 9).

In this study, we compare the accuracy of the casting obtained from three methods: the conventional ring technique, the ringless technique and the conventional ring technique with hygroscopic expansion. We will determine whether the ringless technique - a simple technique that uses low-cost materials can produce restorations with favorable accuracy.

2. Objectives

The purpose of this study is to determine and compare the mean values of vertical margin discrepancy in castings using three investing procedures: the ringless technique, the conventional investing technique and the conventional investing technique with hygroscopic expansion.

3. Materials and Methods

The following materials and equipment were used in the study:

1. Acrylic teeth; Ivoclar Vivadent, Germany
2. Acryle for fabrication temporary crown; GC. Corporation Tokyo, Japan
3. Ni-Cr alloy: super-cast, La Cienega, U.S.A.
4. Polysiloxane impression material; Speedex, Colten-Swiss
5. Inlay wax, Kerr, Berlin, Germany.
6. Investment material; phosphate bonded, Thermovest; Kerr, Berlin, Germany.
7. 2.5 mm gage sprue
8. 3 cm diameter metal and plastic ring
9. Vacuum mixer, Whip mix, Louisville, USA
10. Optical microscope, Zeiss microscopy, Jena, Germany.

An acrylic first mandibular right molar (Ivoclar Vivadent, Germany) was randomly selected. It was prepared for a full porcelain fused-to-metal restoration with a chamfer finish line. The acrylic tooth was then invested on a phosphate-bonded investment, cast with Ni-Cr alloy, and in this way fabricated a metal die (Figure 1).

A coping pattern was fabricated on the metal die using acrylic material thatproduce a temporary crown. The margin was then sealed by conventional casting wax (Figure 3). Finally, to fabricate similar wax patterns, an impression was picked up from the acrylic coping by polysiloxane material (Speedex) and produced polysiloxane index (Figure 3).

To make the same manner of fabrication wax pattern to produced similar wax pattern the lubricated metal die was placed on the index which was filled with the melting inlay wax. After the inlay wax was set, the metal die was separated from the silicon index and in this way produced similar wax pattern. The pattern was sometimes formed on the metal die and sometimes formed in the silicon index. The margins were then sealed by conventional casting wax to prepare the wax pattern for investing. This ultimately produced 39 wax patterns (Figures 3 and 4).

The 39 copings were divided into three groups of 13. The first group was invested using Thermovest phosphate-bonded investment 60 g/11.5 mL pure liquid for all group) with a metal ring of 3 cm diameter and cellulose paper liner. For all groups, the paper liner was wetted for one minute, according to the manufacturer's recommendations. The liner was placed 3 mm from the each side of the ring. For prepared investment in all groups, the powder and liquid (60 g/11.5 mL for was spatulated for 15 seconds, then thoroughly mixed using a vacuum mixer for 20 seconds before vibrating into the casting ring.

The second group was prepared for the ringless technique using a 3 cm (plastic ring with 3cm diameter without liner). The third group was prepared for the metal ring and hygroscopic expansion technique and was invested similar to the first group, except that in order to obtain hygroscopic expansion, after 14 minutes of primary setting the cylinders were plunged into the 100°F water house for 60 minutes.

In the ringless technique, the plastic ring removed after 10 minutes of primary setting. The silicon base former was removed after 60 minutes in all groups.

For burnout, the cylinder was placed on the cool kiln and was heated to 350°C over a period of 30 minutes. After this period, the temperature was increased automatically up to 860°C for a period of 30 minutes, after which burnout was performed throughout and the mold was prepared for the injection alloy. To pour the Ni-Cr alloy, it was melted by torch immediately (less than 30 seconds after removing the cylinder from the kiln) and placed on the casting machine. The Ni-Cr alloy was centrifuged in the mold. The cylinder was cooled at room temperature. The casting was removed and cleaned from the investment and sandblasted using only macroscopic disturbing nodule in placement coping eliminated by low speed bur. Each casting was seated on the metal die for a measurement of the vertical discrepancy (distance between margin and finish line). All measurements on the metal die were made using an optical microscope at a magnification of 80X (Figures 5 and 6) looking at predetermined points on a middle surface of buccal, mesial, lingual and distal sites.

The metal die was then mounted in the stone base to facilitate the next step (Figure 2).

The mean value of this measurement was used for the statistical analysis; ANOVA and Tukey tests were carried out to obtain the results.

4. Results

The mean vertical margin discrepancy for all groups was 123.39 μm. The mean vertical margin discrepancy for the group using the conventional ring technique was 156.72 ± 82.86; for the ringless technique it was 117.3 ± 45.25 μm; and for the technique using the conventional ring with hygroscopic expansion technique the mean vertical margin discrepancy was 96.14 ± 42.33.

The mean vertical margin discrepancies at the buccal, lingual, mesial and distal sites are outlined in Table 1. The ANOVA test detected differences between three groups ($P < 0.001$).

The Tukey test showed that there was significant differences between group 1 (casting produced with conventional technique; ring and liner), group 2 (ringless technique) ($P = 0.003$), and group 3 (conventional technique with hygroscopic expansion) ($P < 0.001$), but no significant difference between the ringless technique and the conventional technique with hygroscopic expansion ($P = 0.183$) (Table 2).

According the results obtained, both the ringless technique and the conventional technique with hygroscopic expansion have high accuracy in investing. Furthermore, the Tukey test in the comparison of the accuracy of different surfaces in the three methods of casting showed that (Table 1) there was no significant difference on the lingual surfaces of castings in the all three methods ($P = 0.146$), but there were significant differences observed on the other surfaces between the casting methods.

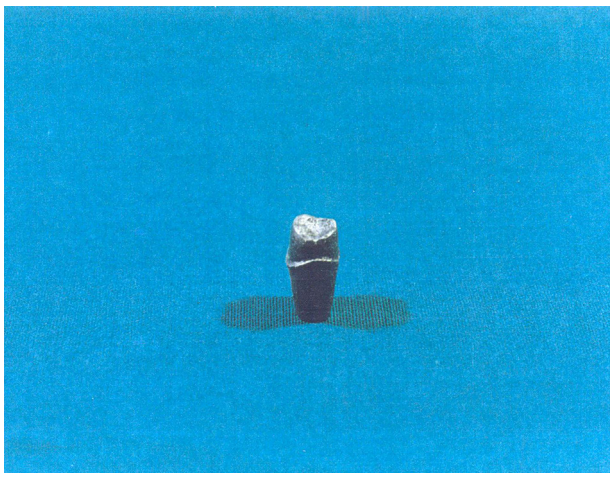

Figure 1. Metal Die After Polishing

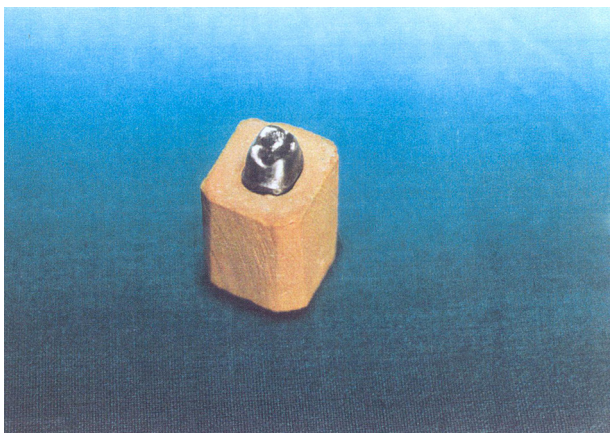

Figure 2. Metal Die on the Stone Base

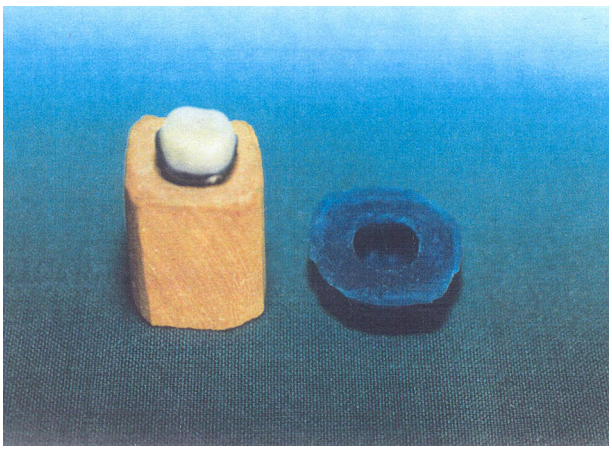

Figure 3. Polysiloxane Index Fabricated on the Acrylic Pattern

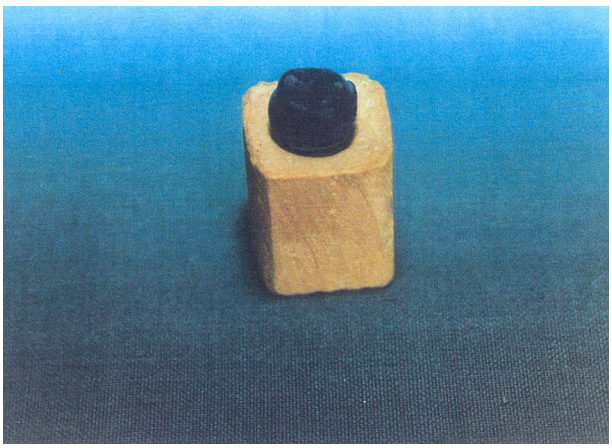

Figure 4. Wax Pattern Fabricated on the Metal Die

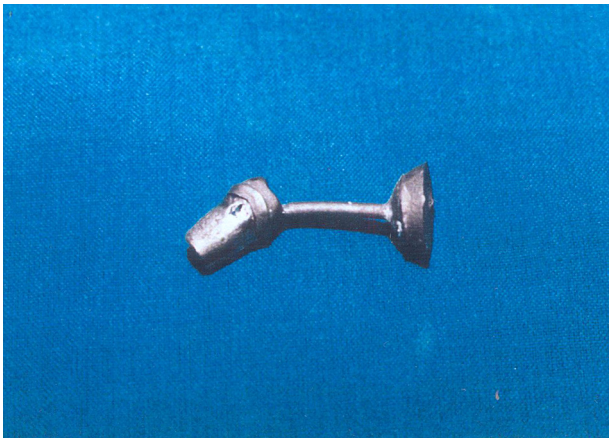

Figure 5. Coping on the Metal Die Removed From the Stone Base to Increase the Precision of the Measurement.

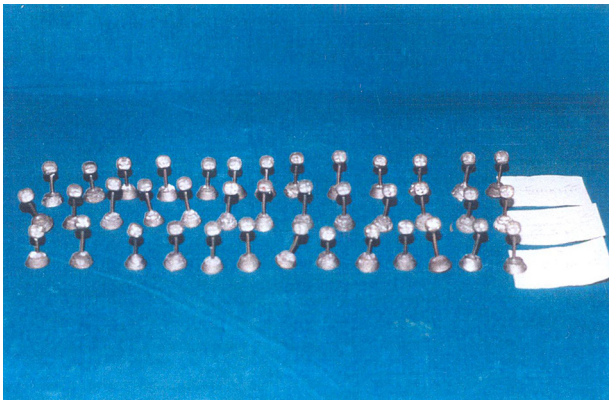

Figure 6. Three Groups of 13 Coping

Table 1. Vertical Margin Discrepancy Between Die and Casting Measured at Buccal, Lingual, Mesial, and Distil Surface[a]

Surface	Conventional Technique	Ringless Technique	Conventional Technique with Hygroscopic Expansion	P Value[b]
Buccal surface	184.61 ± 1.11	150 ± 50.0	92.3 ± 40.03	0.005
Lingual surface	161.53 ± 68.17	134.6 ± 37.55	126.92 ± 52.50	0.146
Mesial surface	134.61 ± 80.06	88.46 ± 29.96	84.61± 42.74	0.026
Distal surface	146.15 ± 66.02	96.15 ± 32.03	80.76 ± 43.49	0.015
Mean value	156.72 ± 82.86	117.30 ± 45.25	96.14 ± 42.33	< 0.001

[a]Data are presented as (mean, μm ± SD).
[b]ANOVA test.

Table 2. Comparison Means Vertical Margin Discrepancy

Technique	Values[a]
Conventional technique, μm	156.72 ± 82.86
Ringless technique, μm	117.3 ± 45.25
Conventional technique with hygroscopic expansion, μm	96.14 ± 42.33

[a]Data are presented as mean ± SD.

5. Discussion

Although the ringless method is used in fixed and implant prosthetics and the precision of restorations depends upon the dexterity of clinicians and laboratory technicians, there is little research available on this technique in the literature (2, 5, 9).

The marginal accuracy of cast restoration is affected by the quality of preparation and impression, the working cast, the thickness of the die spacer, the quality of the wax that was used for the lost wax technique, whether appropriate compensation for the casting shrinkage of the alloy was used, the sprue design (length, shape and diameter), the casting ring (length, diameter and thickness), the thickness of the ring liner, the luting pressure, the surface roughness, the irregularities of cast restoration and different evaluating techniques (2, 5-7, 9, 10).

The studies of Lombardas et al. (2) showed that the ringless technique can make high accuracy restoration in fix prosthesis. The studies used semi-precious alloy, but in some countries non-precious alloy is used. The non-precious alloy is technique sensitive and results in higher shrinkage on setting (2.3%) than precious and semi-precious alloy (9).

In this study, the vertical margin discrepancy in the conventional ring technique, the ringless technique and the conventional technique with hygroscopic expansion were compared. The ringless technique, unlike the conventional ring technique, allows for thermal expansion. None of the molds used in the ringless technique cracked or fractured on their own during or after the casting because of the absence of the metal ring (2, 6, 7, 9, 11, 12).

To allow for this expansion in the conventional technique a soft liner is used (2, 5, 9). The ringless technique for investing and casting has been in use for many years for making the frameworks for removable partial dentures (2, 5). Yadav (5) performed a study that compared the marginal accuracy of all metal complete coverage crowns fabricated with ringless, split plastic ring and metal ring investment system, which found that accurate casting with better marginal fit can be produced with the ringless casting technique. Also, Shah et al. did a study (4) that compared the dimensional accuracy of castings fabricated with ringless and metal ring investment systems for implant supported fixed dental prosthesis. This study showed that ringless casting systems have higher marginal accuracy than ring investment systems, and can be recommended for use in fabricating implant supported fixed dental restorations. In this study, we compared the vertical marginal discrepancy of casting in the ringless technique, the conventional ring technique and the conventional ring technique with hygroscopic expansion. Throughout our study, the recommendations of the manufacturers were followed and the adjustment of the internal surface of casting was minimal (only macroscopic nodule). The high mean vertical margin discrepancy was achieved without the use of a die spacer, without adjustment in the internal surface of the casting and higher shrinkage of non-precious alloy than precious and semi-precious.

This study showed no significant differences between the ringless technique and conventional ring technique with hygroscopic expansion, but these techniques were significantly different than the conventional ring technique. According the results obtained, the ringless technique and the conventional technique with hygroscopic expansion have high accuracy in investing. Also, in all methods significant differences were observed at the mesial surfaces between the conventional ring technique and the conventional ring technique with hygroscopic expansion ($P = 0.032$). However, no significant differences at the mesial surfaces were found between the ringless technique and the conventional ring technique with hygroscopic expansion ($P = 0.918$), nor were they found between the conventional ring technique and the ringless technique. At the distal surfaces, significant differences were observed between the conventional ring technique and the conventional ring technique with hygroscopic expansion ($P = 0.014$). At the buccal surface, significant differences were observed between the conventional ring technique and the conventional ring technique with hygroscopic expansion ($P = 0.009$), as well as between the conventional ring technique and the ringless technique. In this study, as in the Lombardas et al. study, no liner was used in investing (2). However, using a liner or paper cylinder instead of a plastic cylinder, had the effect of increasing setting expansion. In this study, due to the decrease of the hygroscopic expansion effect on the total investment expansion, pure liquid was used to determine pure hygroscopic expansion.

Since in the laboratory or clinical, to increase the dimensional accuracy of casting with stone die or tooth the internal surface is adjusting by fit checker; in the end of this study one casting of each group was adjusted on the internal surface after the original measurement and measured vertical margin discrepancy.

This adjustment showed that the conventional ring technique with hygroscopic expansion had a minimal margin discrepancy (30 μm). A greater marginal discrepancy was seen with the conventional ring technique (80 μm), and the ringless technique yielded a medium marginal discrepancy (50 μm).

The result of this study showed that the ringless technique could be a greater investment expansion that produces casting with minimal internal interference with metal die and ultimately with teeth.

On the other hand, with practice, hygroscopic expansion on the ringless group can increase casting accuracy. Although the results of this study support the study by Lombardas et al. (2) and Yadav (5) for the use of ringless technique, the conventional metal ring investing technique is well documented, proven to produce acceptable casting and should not be abandoned. Further studies should be carried out to substantiate these results.

To conclude, the ringless technique produced acceptably accurate casting with a better marginal fit. It is a simple and less time consuming technique. Therefore, it is recommended for routine use in fixed prosthodontics.

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Footnotes

Authors' Contribution: Mahmood Sabouhi: guide Prof and tips how to do laboratory works, measurement, and writing the thesis. Morad Hediyatipanah: writer and performance the laboratory procedure (wax pattern fabrication, investing procedure and measurement of vertical margin discrepancy).

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