



## Marginal Accuracy of Castings Fabricated with Ringless Casting Investment System and Metal Ring Casting Investment System: A Comparative Study

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### ABSTRACT

**Background:** The thermal expansion of the investment can be restricted by the metal casting ring because the thermal expansion of the ring is less than that of the investment. The ringless casting procedure is in use in clinical dentistry, though there is little scientific data to support its use in fixed partial dentures. In this study, marginal discrepancy of castings produced with the ringless casting technique and the conventional technique using the metal rings were compared.

**Materials and methods:** A total of 30 wax patterns were fabricated directly on a metal die. Optical stereomicroscope was used to measure the marginal discrepancy between the metal die and wax patterns. A total of 15 castings were invested using Bellavest T phosphate-bonded investment with the ringless technique and 15 were invested with the same investment with a metal ring; 30 castings were produced using a nickel-chromium ceramo-metal alloy. The internal surface of the castings was not modified and seated with finger pressure. The vertical marginal discrepancy was measured using an optical stereomicroscope at a magnification of 100×. The data obtained were statistically analyzed using students t-test (paired t-test and unpaired t-test).

**Results:** The castings of the ringless technique provided less vertical marginal discrepancy ( $240.56 \pm 45.81 \mu$ ) than the castings produced with the conventional metal ring technique ( $281.98 \pm 53.05 \mu$ ). The difference was statistically significant.

**Conclusion:** The ringless casting technique had produced better marginal accuracy compared with conventional casting technique. Ringless casting system can be used routinely for clinical purpose.

**Keywords:** Marginal accuracy, Phosphate-bonded investment, Ringless casting, Thermal expansion.

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### INTRODUCTION

The lost wax technique was made available to dentistry by William H Taggart in 1907. This process has been marked as one of the greatest steps achieved by the dental profession. However, Taggart was unable to overcome the problem of casting shrinkage that resulted in undersized restorations.<sup>1,2</sup>

For longevity and clinical success, the accuracy of fit of the cast restoration is essential; it gets affected by the impression, the working cast, the quality of the preparation, the quality of the wax, and the accuracy of the castings. It is mandatory to compensate for the shrinkage of the solidifying alloy by investment expansion.<sup>3-6</sup>

Higher melting temperature alloys could withstand the firing cycle of porcelain without noticeable distortion with the introduction of ceramo-metal technology and thus to the development and use of investments that could resist higher temperatures and higher stresses during casting.<sup>4,5</sup> The phosphate-bonded investments fulfill these requirements.

Initially the gypsum-bonded investments and phosphate-bonded investments were treated with the

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same techniques. As phosphate-bonded investment was a standard procedure, the need for the casting ring was not questioned.

The thermal expansion of the ring is less than that of the investment, hence the metal casting ring restricts the thermal expansion of the investment.<sup>1,3,7-9</sup> To compensate for this limitation, the liner was recommended.

Introduction of a ringless technique for removable partial denture frameworks challenged the use of the casting ring. Recently, the use of ringless technique has been extended for conventional fixed restorations and experimentally for implant-connected frameworks.<sup>3-5,10-15</sup> The high strength of the phosphate-bonded investment makes it possible to avoid the use of the casting ring.<sup>11</sup> The ringless techniques are easier, less expensive, and allow the natural setting expansion to take place without distorting the mold, and cleaner to work with and easier to divest.<sup>3,11-13</sup> Very few studies have compared the two casting techniques used for fixed restorations.

The purpose of this study was to compare the marginal accuracy of single full coverage restorations made with ringless casting investment system and conventional casting investment system.

## MATERIALS AND METHODS

To simulate a complete molar crown preparation a precisely machined brass master die was designed. The die had a 6° taper toward the occlusal surface from the finish line and measured 6 mm from the occlusal surface to finish line. Mounting of the metal die was done on a cylindrical base of 10 mm diameter and 20 mm length. For orientation of casting during seating a shallow axial groove was given. On the root stump near the cervical margin around the circumference of the die, four reference marks were scribed, one each on the buccal, lingual, mesial, and distal surfaces. These were used later as reference marks for the measurements. In order to make wax patterns of uniform dimensions, a counter-die with dimensions 1 mm larger than the master die was made<sup>16</sup> (Fig. 1).



Fig. 1: Master model with counter die



Fig. 2: Wax pattern on master die

The wax patterns were fabricated after applying a thin layer of die lubricant (Fig. 2). The counter-die was closed until the demarcated mark over the die to obtain a wax pattern of uniform thickness.<sup>16</sup> The margins were readapted and refined using wax carving instruments and divided into two groups, namely groups 1 and 2 with 15 wax patterns in each group.

*Group 1:* Representing metal ring with ring liner used for investing and casting.

*Group 2:* Representing ringless casting system used for investing and casting.

An optical stereomicroscope was used to measure the marginal discrepancy between the metal die and the wax pattern at predetermined areas that were marked on the metal die, on the buccal, mesial, lingual, and distal surfaces of the die (Fig. 3 and Table 1).

Groups 1 and 2 wax patterns were invested individually with individual casting rings.

*Group 1:* The first group was invested with Bellavest T (BEGO, Bremen, Germany) phosphate-bonded investment. A single layer of ceramic liner was adapted to the 1× casting ring and moistened by dipping in a bowl of water, and the excess water was shaken away. Bellavest T phosphate-bonded investment (60 gm of



Fig. 3: The marginal discrepancy between the metal die and the wax pattern was measured on an optical stereomicroscope

**Table 1:** Comparison of marginal accuracy between wax patterns and castings with and without rings (Metal – wax) in  $\mu$

	Conventional casting				Ringless casting			
	Wax	Metal	Different	p-value	Wax	Metal	Different	p-value
Buccal	10.28±7.78	301.65±77.22	291.38±72.13	<0.001	14.31±9.99	255.18±60.85	240.88±62.06	<0.001
Distal	12.02±8.43	278.61±64.78	266.59±62.35	<0.001	11.26±11.11	254.76±45.73	243.49±47.29	<0.001
Lingual	15.71±8.48	294.27±84.71	278.57±85.58	<0.001	15.23±9.65	242.47±43.85	227.24±42.46	<0.001
Mesial	16.87±8.75	308.25±93.46	291.37±90.18	<0.001	15.45±7.51	266.09±76.16	250.64±74.61	<0.001
Total	13.72±4.52	295.7±54.11	281.98±53.05	<0.001	14.06±6.36	254.62±45.66	240.56±45.81	<0.001

powder to 16 ml of 100% mixing liquid) was used for investment.

The investment powder and liquid were hand spatulated for 15–20 seconds to incorporate the powder.<sup>4-6</sup> Then the investment was mechanically vacuum mixed for 60 seconds. After placing the lined casting ring over the pattern, with the aid of vibration, the investment was poured down the side of the ring. The ring was filled slowly. The investment was allowed to set before proceeding with burnout.

*Group 2:* The second group was invested with Bellavest T phosphate-bonded investment according to the manufacturer’s recommendation, with a plastic ring of 1 X diameter, in similar manner to that of group 1. After 10 minutes of initial setting, the molds of the ringless group were removed from the plastic rings.<sup>8</sup> The investment was allowed to set before proceeding with burnout.<sup>6</sup>

According to the manufacturer’s instruction, burnout and casting procedures were carried out in an induction-casting machine using Wiron 99 (nickel-chromium metal ceramic alloy Bego).

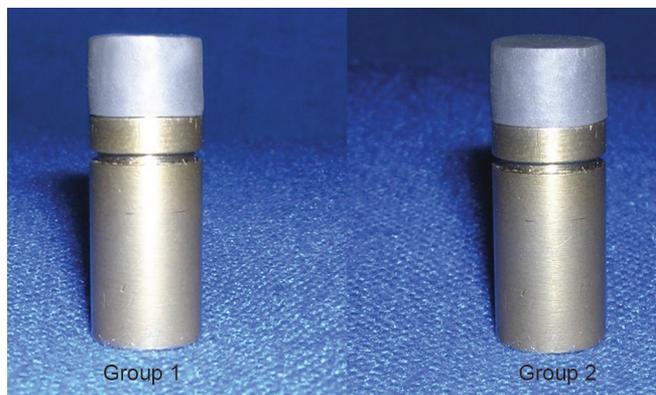
By divesting the investment, the castings were recovered. To remove the investment from the inner surface of the casting, burs were used such that a thin layer of investment was left behind. To remove the residual investment and oxide layer, sandblasting was done.

The recovered castings were seated onto the metal die under finger pressure (Fig. 4). Measurements were made at predetermined points that were marked on the metal die, at the buccal, mesial, lingual, and distal surfaces of the die (Fig. 5).

All measurements were executed by a single operator and the readings were tabulated and mean value of these measurements were used for statistical analysis. Student’s t-test (paired) was used to compare the means between castings and wax within the groups. Intergroup comparisons were made by unpaired t-test. For all the tests a p value of 0.05 or less was considered statistically significant (Tables 1 and 2).

**RESULTS**

The castings of the ringless technique provided less vertical marginal discrepancy ( $240.56 \pm 45.81\mu$ ) than



**Fig. 4:** Castings on master die



**Fig. 5:** The marginal discrepancy between the metal die and the casting was measured on an optical stereomicroscope

**Table 2:** Comparison of marginal accuracy between conventional and ringless casting system in  $\mu$

	Conventional casting (mean diff±SD)	Ringless casting (mean diff±SD)	Significance
Buccal	291.38±72.13	240.88±62.06	2.06 0.05S
Distal	266.59±62.35	243.49±47.29	1.14 0.26NS
Lingual	278.57±85.58	227.24±42.46	2.08 0.05S
Mesial	291.37±90.18	250.64±74.61	1.35 0.19NS
Total	281.98±53.05	240.56±45.81	2.28 0.03S

S: Significant; NS: Not Significant

the castings produced with the conventional metal ring technique ( $281.98 \pm 53.05\mu$ ). The difference was statistically significant.

## DISCUSSION

Precise marginal fit is essential for a successful cast restoration. Marginal fit of castings is one factor that leads directly or indirectly to secondary dental caries, adverse pulpal reactions, and periodontal disease. The marginal fit of castings relies on accurate impressions, perceptive tooth preparation, and precision casting. The accuracy of casting is subject to material volumetric changes occurring due to shrinkage of alloys. This shrinkage can be compensated by setting expansion, hygroscopic expansion, or thermal expansion of the investment.<sup>3-6,11</sup>

Traditionally, a metal ring is used to constrain and carry the investment mold during casting. To compensate for the shrinkage of the metal upon solidification, the setting and thermal expansion of the investment is necessary, which gets restricted by the metal ring.<sup>1,3,7-9</sup> In order to overcome this restriction for expansion, a ring liner is used.<sup>2,5</sup> The ringless technique for investing and casting has been in use for many years for the fabrication of frameworks for removable partial dentures.<sup>10,15</sup> Although the ringless casting technique is in use in fixed prosthodontics and implant prosthodontics, there are few investigations about the technique in the literature, and the accuracy of the casting depends on the skills of the technician and is clinically determined by the dentists. The method uses a paper or plastic casting ring and is designed to allow unrestricted expansion.<sup>11</sup> There are no scientific data to support the use of this technique. The high strength of the phosphate-bonded material makes it possible to abandon the use of the casting ring.<sup>3</sup> In this study, the marginal discrepancy of castings produced with the ringless technique and the conventional technique using the metal ring was compared.

In the study, the mean marginal discrepancy of group 1 wax patterns ranged from 5.80 to 19.94  $\mu$ , with total mean of 13.72  $\pm$  4.52  $\mu$ . The mean marginal discrepancy of group 2 wax patterns ranged from 3.92 to 26.84  $\mu$ , with a total mean of 14.06  $\pm$  16.36  $\mu$ . Following reasons can be attributed to this discrepancy.

The most serious problem that can occur during fabrication and removal of the pattern from the die is probably wax distortion. The thermal changes and relaxation of stresses that are caused by molding, carving, removal, occluded air in the wax, contraction on cooling, and the time and temperature of storage result in this distortion.<sup>5</sup>

The marginal discrepancies in wax patterns were found to happen in spite of utmost care. The wax patterns were fabricated directly on the metal master die in the present study. The heat from the molten wax gets rapidly dissipated, hence when the molten wax flows on a cool metal die, the wax immediately adjacent to

the die solidifies quickly. The previously congealed wax gets pulled away from the metal when the wax adjacent to the air which stays molten for a period solidifies and contracts.<sup>4</sup>

The mean marginal discrepancies of ring and ringless castings were compared using Student's (paired) t-test. Statistically significant differences were found between the mean marginal discrepancies of ring and ringless castings ( $p < 0.05$ ).

The recommended marginal opening is 50 to 75  $\mu$ . In the present study, mean marginal opening was 281.98  $\pm$  53.05  $\mu$  and 240.56  $\pm$  45.81  $\mu$  in groups 1 and 2, respectively, which could be due to a number of factors such as shrinkage of wax and alloy shrinkage, setting expansion, and thermal expansion. All these factors come into play for both groups 1 and 2 as the same procedures have been followed for both.

Phosphate investments are sensitive to changes such as the addition or removal of energy from the investment, or activities that affect the crystal growth. As a result, phosphate investments are sensitive to the preparation technique.<sup>13</sup>

Factors affecting the setting and thermal expansion:

- Restraining factors—rigidity of the pattern material, casting ring, and ring liner<sup>1-3,17-19</sup>
- Nonrestraining factors—mixing time, mixing liquid, mixing device, volume mixed, and storage time and condition<sup>17,20-22</sup>
- Heating rate<sup>23-26</sup>
- Environmental conditions.<sup>13</sup>

A comparison between horizontal and vertical expansion has shown significantly greater vertical expansion than horizontal expansion in the rigid ring and not significantly different expansions in the flexible ring. The use of a flexible ring offering little or no restriction to horizontal expansion is recommended to reduce mold distortion.<sup>1,9,19</sup>

The adjustment of the internal surfaces of the castings was not performed. Castings with any defects on seating surfaces were discarded, and no correction for seating was done.

In the present study, total mean marginal opening of group 1 castings was 281.98  $\pm$  53.05  $\mu$  and group 2 castings was 240.56  $\pm$  45.81  $\mu$ . The probable reason for these results might be due to (1) the marginal discrepancy of the wax patterns; (2) the castings binding more on the axial walls of the metal die as no die spacer was used; (3) the internal surfaces of the castings had no adjustments.<sup>3,4,27</sup>

The thermal expansion of the phosphate-bonded investment at 700°C is 1.2–1.75%. The thermal expansion of casting ring at 700°C ranged from 0.95 to 1.40%.<sup>1</sup> The difference between the thermal expansion of investment and casting ring confirms the restraining effect of the

casting ring used for conventional casting technique. Because of this restraining effect, the castings produced by conventional system bind more on the die, showing more marginal discrepancy.<sup>1,3</sup>

In case of ringless technique, there is unrestrained expansion of the investment. From the results and conditions of the study, a hypothesis can be made that more expansion of the investment is allowed with the ringless technique and so produces castings that bind less on the die.<sup>1,3,7</sup>

The results indicate that, within the conditions of the study, the castings produced by the ringless technique fit better than the castings produced by the conventional metal ring technique.

The ringless technique has certain advantages over the conventional casting technique:<sup>3,11-13</sup>

- Allows unrestricted thermal expansion
- Smaller marginal discrepancy
- Easier to work
- Cleaner to work
- Easier to divest
- Health hazards of liners are avoided<sup>28</sup>
- Allows natural setting expansion to take place without distorting the mold.

The study was made to test the “new” ringless technique that was proved to be also acceptable in terms of fit accuracy. The results of this study support the clinical use of this technique for fixed restorations.<sup>29,30</sup>

Further investigation should be conducted to determine the use of ring-free technique for the fabrication of implant-supported prosthesis.<sup>31</sup>

## CONCLUSION

- The vertical marginal discrepancies of the castings in ringless investment technique for the buccal and lingual surface were significantly less than that of the conventional investment technique.
- There was no significant difference in the vertical marginal discrepancy within the same group.
- Statistically significant differences in the total mean vertical marginal discrepancy were found between the ringless and conventional investment technique.
- The ringless technique has shown better fit when compared with the conventional technique.
- The castings produced with ringless technique were clinically acceptable and can be used routinely for clinical purpose.

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