

# Comparative Analysis of Marginal Accuracy of Complete Crowns Fabricated by Using Ringless and Metal Ring Investment Systems: An *In Vitro* Study

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## ABSTRACT

**Aim:** To compare the vertical margin accuracy of lost wax castings produced by the conventional casting technique with all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system.

**Materials and methods:** A brass die assembly was used to fabricate standardized wax pattern crowns. A total of 100 wax patterns were made with both ringless and metal ring investment systems. Wax patterns were readapted and refined on the master die and divided into two groups, namely, group I and group II with 50 wax patterns in each group. Group I (ringless system) and group II (metal ring system) were further divided into subgroups having a sample size of 25 in each group. Each coping was invested and cast individually. The marginal discrepancy between the metal die and the castings were measured by a stereomicroscope and AutoCAD software 2013. Measurement was made on the facial area of the metal die.

**Results:** The resultant casts obtained from different casting systems show statistically significant difference found between the marginal discrepancies using metal ring and ringless castings system, and statistically nonsignificant difference was found between the marginal discrepancies using all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99) within the same group.

**Conclusion:** The marginal discrepancy for castings made with ringless casting system was less when compared to metal ring casting system, and there was no difference in marginal discrepancy when compared to all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99) within the same group.

**Clinical significance:** Marginal fit is influenced by several factors including type of crown, tooth preparation geometry, dimensional accuracy of impression materials, factors related to dental casting, type of cement, luting pressure, duration of cementation, and use of occlusal vents or die spacers.

**Keywords:** Dimensional accuracy, Metal ring system, Ringless system.

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## INTRODUCTION

From the earlier times, many efforts have been made to fabricate more accurate fitting castings with minimal marginal discrepancy.<sup>1</sup>

The success of any dental cast restoration depends upon the marginal adaptation (fit) of casting to the underlying tooth structure.<sup>2</sup> Accurately fitting cast restoration is essential for its success because there will be less plaque accumulation at the margins, thus providing better mechanical properties (retention and resistance), less cement space (fewer possibilities for leakage), and improved aesthetics.<sup>3</sup> The marginal fit of castings basically relies on perceptive tooth preparation, accurate impressions, precision castings with careful finishing, and cementation procedures.<sup>2</sup>

Ni–Cr alloys have been promoted for castings in place of the gold alloys.<sup>3</sup> Economic aspect plays a major role in the development of nonprecious alloys for removable frameworks; thus, cobalt and nickel base alloys became the alloys of choice for partial dentures. The use of base metal alloys for fixed restorations has increased dramatically since their introduction in the 1960s.<sup>4</sup>

The desire of dental patients for more cosmetic restorations is undeniable. With this revolution emerged the renaissance of porcelain as a useful material.<sup>5</sup> They are called porcelain fused to metal alloys which are composed of nickel (70–80%) and chromium (13–20%).<sup>4</sup> The use of the casting ring (conventional casting technique) was challenged with the introduction of a ringless technique.<sup>3</sup>

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Thermal expansion of the investment is restricted by metal casting ring because the ring expands less than that of the investment.<sup>2</sup>

Nowadays, ringless technique is routinely used for conventional fixed restorations due to high strength of the investment material.<sup>2</sup> The ring-less technique is easy to manipulate, inexpensive, and produces clinically acceptable castings.<sup>6</sup> The purpose of this investigation was to compare the vertical margin accuracy of lost wax castings produced by the conventional casting technique with all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system.<sup>1</sup>

## MATERIALS AND METHODS

### Materials Used in the Study

- Metal casting ring with crucible former (Bego, Germany)
- Cellulose ring liner 1 mm
- Plastic casting ring
- Phosphate bonded investment material (Bellasan powder and Begosol liquid, Bego, Germany)
- All metal alloy (WIRONIUM®)
- PFM alloy (WIRON®99)

A brass die assembly was used to fabricate standardized wax pattern crowns. A tooth preparation with 10° total axial wall taper was simulated in the master die. Height and occlusal diameter of the master die were 6 mm with 90° shoulder finish line of 1 mm width. A brass ring (spacer) 1 mm in height was made to fit on the shoulder of the die (Fig. 1). The die could be accurately positioned in a brass former that had an opening in the center 1 mm larger than the dye in all dimensions.<sup>7,8</sup> A shallow axial groove was made for orientation of casting during seating. One line was scribed on the facial area below the cervical margin of the die which was used later as reference for the measurements.<sup>7</sup> The wax patterns were fabricated after applying a thin layer of die lubricant. The counter die was closed until the wax hardens so that we get wax patterns of uniform thickness (Fig. 2).<sup>8</sup> The margins were readapted and refined using wax-carving instruments and divided into two groups, namely, group I and group II. Group I included 50 samples of ringless system. Group I consists of castings made with ringless system. It was subdivided into two subgroups of 25 samples each. Subgroup IA included PFM alloy and subgroup IB included all metal alloy. These subgroups were invested and cast with by using plastic ring of 2.5 cm in diameter. The wax patterns were sprued at 45° angle to the occlusal surface.<sup>9,10</sup> The wax patterns were positioned within 4–6 mm from the top of the investment and placed as close as possible to the center of the ring.<sup>9–12</sup> Each coping was invested individually in one ring each immediately after its fabrication. After 10 minutes of initial setting, the molds of the ringless group were removed from the plastic rings. The investment was allowed to set for 1 hour before proceeding with the burnout.<sup>13</sup>

Group II consists of castings made with metal ring system. It included 50 samples invested using the metal ring. Group II was further subdivided into two subgroups of 25 each. Subgroup IIA included PFM alloy and subgroup IIB included all metal alloy. These subgroups were invested and cast using metal ring of 2.5 cm in

diameter, and cellulose paper liner was wetted for 1 minute. Each coping was invested individually. The investment was allowed to set for 1 hour before proceeding to the burnout.<sup>13</sup>

Then, all the castings were placed in the burnout furnace at room temperature, and the temperature was raised to 815°C for 60 minutes.<sup>9,12</sup> After completion of the burnout, the casting procedure was carried out in an induction-casting machine using all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99). The castings were recovered by using the deflasking press. Burs were used to remove the investment from the inner surface of the casting with a thin layer of investment left behind. Sandblasting was done to remove the residual investment and oxide layer. The completed castings were seated on the metal die under finger pressure (Fig. 3). Measurement was made on the facial area of the metal die (Fig. 4).

## OBSERVATION AND RESULTS

All the castings were checked for its marginal integrity with finish line of the master die by stereomicroscope and AutoCAD software 2013. The readings were tabulated, and results were statically analyzed using SPSS software version 22. *p* value was set at <0.05. Intergroup comparison was done using analysis of variance (ANOVA) test and *post hoc* Tukey test.

Table 1 shows data obtained from all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system.

- Negative values in the range of marginal discrepancy indicate oversized margins, and positive values indicate undersized margins.

Table 2 shows:

- The mean marginal discrepancy of subgroup IA (Ringless PFM alloy) castings is 0.146 mm and standard deviation is 0.166.
- The mean marginal discrepancy of subgroup IB (Ringless all metal alloy) castings is 0.124 mm and standard deviation is 0.174.
- The mean marginal discrepancy of subgroup IIA (Ring PFM alloy) castings is 0.326 mm and standard deviation is 0.213.
- The mean marginal discrepancy of subgroup IIB (Ringless all metal alloy) castings is 0.312 mm and standard deviation is 0.203.

It has been observed that least value of marginal discrepancy found in all metal alloys (0.124 mm) with ringless system and highest value of marginal discrepancy found in PFM alloys (0.326 mm) with metal ring system.



Fig. 1: Brass metal die

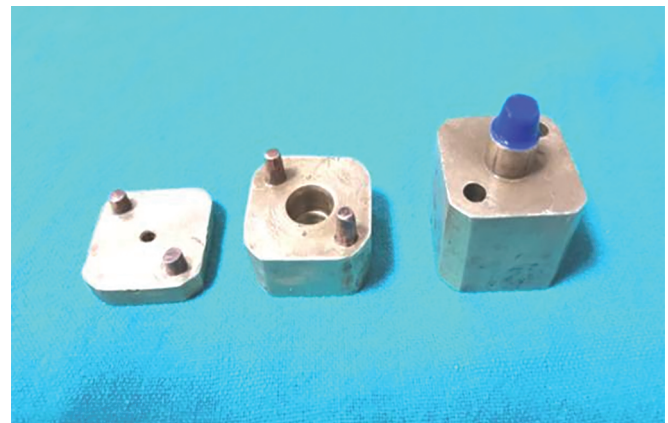


Fig. 2: Wax pattern on master die

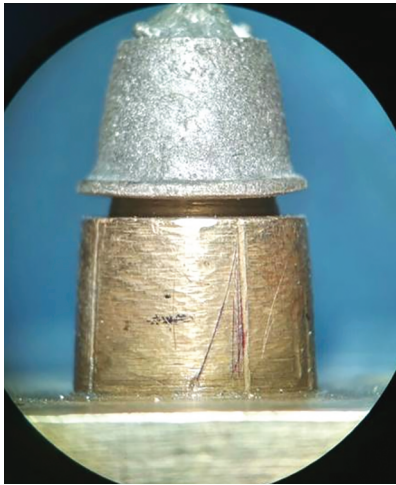


Fig. 3: Casting on the master die viewed under stereomicroscope

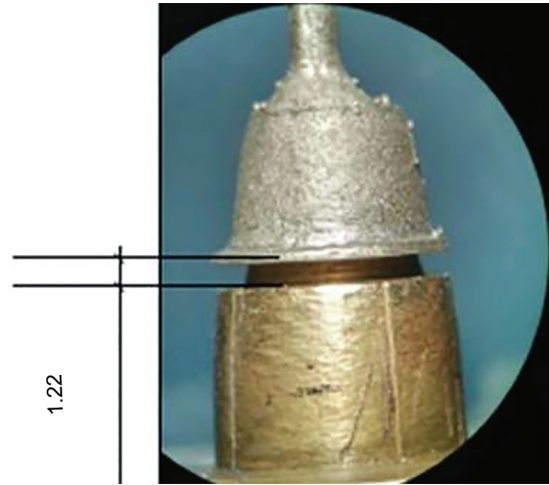


Fig. 4: Measurement of marginal gap using AutoCAD software

Table 1: Data obtained from all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system

S. no.	Ringless PFM mm (subgroup IA)	Ringless all metal mm (subgroup IB)	Ring PFM mm (subgroup IIA)	Ring all metal mm (subgroup IIB)
1	0.22	0.21	0.45	0.44
2	0.23	0.22	0.38	0.36
3	0.28	0.26	0.41	0.38
4	-0.11	-0.12	-0.01	-0.03
5	0.27	0.26	0.45	0.43
6	-0.09	-0.08	-0.09	-0.04
7	-0.08	-0.09	0.48	0.45
8	0.21	0.19	0.49	0.48
9	0.27	0.25	0.41	0.4
10	-0.13	-0.13	0.47	0.46
11	0.28	0.27	0.39	0.35
12	0.25	0.23	0.41	0.37
13	-0.08	-0.1	-0.01	-0.03
14	0.26	0.24	0.43	0.42
15	0.32	0.30	0.44	0.43
16	0.28	0.26	0.38	0.35
17	-0.07	-0.15	-0.02	-0.02
18	0.3	0.28	0.47	0.46
19	0.26	0.24	0.48	0.47
20	-0.05	-0.1	-0.09	-0.07
21	0.22	0.18	0.41	0.4
22	-0.08	-0.18	-0.02	-0.02
23	0.26	0.26	0.47	0.45
24	0.27	0.25	0.48	0.46
25	0.16	0.16	0.49	0.46

Table 3 shows that the mean marginal discrepancies of metal ring casting system and ringless casting system were compared using ANOVA test and *post hoc* Tukey test. There was statistically significant difference found between the marginal discrepancies using metal ring and ringless castings system, and no statistically significant difference found between the marginal discrepancies using all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99) within the same group.

Table 2: Comparison of mean marginal discrepancy in all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system

Groups	Mean	SD	Maximum	Minimum
Ringless PFM (subgroup IA)	0.146	0.166	0.32	-0.13
Ringless all metal (subgroup IB)	0.124	0.174	0.3	-0.18
Ring PFM (subgroup IIA)	0.326	0.213	0.49	-0.09
Ring all metal (subgroup IIB)	0.312	0.203	0.48	-0.07

Table 3: Mean difference in all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system

Groups	Mean diff	q value	p value	Status
Ringless PFM vs ringless all metal	0.022	0.568	0.900	Ns
Ringless PFM vs ring PFM	0.180	4.737	0.006	Sig
Ringless all metal vs ring all metal	0.188	4.947	0.004	Sig
Ring PFM vs ring all metal	0.014	0.358	0.900	Ns

## DISCUSSION

Fixed prosthodontics has become a major part of the current restorative dentistry. Various alloys and techniques have been introduced for casting of the fixed partial dentures. Ever escalating cost of gold has made a paradigm shift to the use of base metal alloys ever since their introduction to the profession over 50 years. Of all the base metal alloy systems, the most successful are Ni-Cr alloys because of their mechanical properties. Ni and Cr form the major components, and the balance of the composition includes Mo, Si, Fe, and Ce. The density of these alloys is one-half, modulus of elasticity is 2 to 2.5 times, sag resistance that is 9 times greater, yield strength that is approximately 20,000 p.s.i. greater, elongation values between 3 and 22%, and cost is one-fifth that of the gold alloy.<sup>13</sup>

Marginal fit of the castings is influenced by several factors, including type of crown, tooth preparation geometry, dimensional

accuracy of impression materials, factors related to dental casting, etc. Studies have shown that casting ring shape, diameter, and length affect the accuracy of castings produced because they affect the expansion of the investment. Although it produces clinically acceptable results, the metal ring restricts the expansion of the investment which compensates for the shrinkage of the metal on solidification. To overcome this restriction on expansion, a soft liner is used.<sup>6</sup> The asbestos liner that was in use for many years is not used these days, as it is carcinogenic. Reports have stated that asbestos fibers in the casting ring liners can cause asbestosis, bronchogenic lung cancer, or mesothelioma. Ceramic liners are used as a substitute.

The high-melting alloys are used to withstand the firing cycle of porcelain. This led to the use of investments that can withstand high temperatures and high stresses of casting. Phosphate-bonded investments were used as they fulfill these requirements.

The use of the casting ring was challenged with the introduction of a ringless technique for phosphate-bonded investments. The high strength of the material makes it possible to abandon the use of the casting ring. The ringless techniques are easier, less expensive, and give clinically acceptable castings. These findings are in accordance with the studies done by Shah et al.,<sup>6</sup> Alex et al.,<sup>2</sup> Muddugangadhar et al.,<sup>3</sup> and Lombardas et al.<sup>14</sup> which showed that ringless system of casting can be recommended for use in fabricating implant-supported fixed dental restorations.

This study was conducted to compare the vertical margin accuracy of lost wax castings produced by the conventional casting technique with all metal (WIRONIUM®) and PFM alloy (WIRON®99) using a metal ring and ringless system. In this study, the results showed that mean values for marginal gap of subgroup IA (RINGLESS PFM ALLOY) castings is 0.146 mm, subgroup IB (RINGLESS ALL METAL ALLOY) castings is 0.124 mm, subgroup IIA (RING PFM ALLOY) castings is 0.326 mm, and subgroup IIB (RING ALL METAL ALLOY) castings is 0.312 mm. The mean marginal discrepancies of metal ring casting system and ringless casting system were compared using ANOVA test and *post hoc* Tukey test. There was a statistically significant difference found between the marginal discrepancies using metal ring and ringless castings system, and statistically nonsignificant difference was found between the marginal discrepancies using all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99) within the same group. Several investigations reported that marginal gaps in cast crowns of up to 74  $\mu$ , 104  $\mu$ , or 120  $\mu$  are considered to be clinically acceptable.<sup>7</sup> This could be due to an array of factors, such as setting expansion, thermal expansion, shrinkage of wax and alloy. All these abovementioned factors influence both group I and group II castings, as the same procedure has been followed for both.<sup>15-17</sup> Various authors have confirmed elevated thermal expansion with the use of special liquid for mixing investment. The expansion can be varied by the proportions of silica solution and water. Phosphate-bonded investment mixed with 100% special liquid resulted in higher heat and higher setting expansion.<sup>15,18</sup> Various authors have noted the restrictive effect of rigid metal casting rings on investment setting and thermal expansion; their findings all confirm the need for a liner in casting ring.<sup>14,15,18-20</sup> The importance of introducing the mold into the preheated oven when the investment has reached its peak temperature was first emphasized by Marzouk and Kerby.<sup>7,21</sup> When the investment reaches its maximum exothermic setting reaction temperature, most of the chemical reactions and most of the setting expansion

are considered to have been completed, and the investment has sufficient strength to withstand the thermal shock.

### Limitations of the Study

- The study was done with phosphate-bonded investment materials only. The study does not tell about the marginal fit of the castings produced with other investment materials.
- The study showed the result of single unit castings only. It did not tell us about the fit of large castings such as cast partial denture frameworks.

### SUMMARY AND CONCLUSION

From the results obtained, and within the limitations of the study, the following conclusion were drawn:

- The marginal discrepancy for castings made with ringless casting system was less when compared to metal ring casting system.
- There was no difference in marginal discrepancy when compared to all metal alloy (WIRONIUM®) and PFM alloy (WIRON®99) within the same group.
- The ringless technique was clinically acceptable and can be used for the fabrication of fixed prosthodontic restorations.

### CLINICAL IMPLICATION OF THE STUDY

- The ringless casting technique offers a cost-effective and time-saving method by which single-unit castings for metal ceramic crowns can be fabricated.
- The ringless casting method used for casting is technique sensitive, but repeated use of this technique can help the dental laboratory technician to fabricate casting which will be clinically acceptable for metal/ceramic crowns.

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