An evaluation of an Iraqi phosphate-bonded investment and a commercial type on the marginal fit of ceramometalcopings using three different investing and burnout techniques

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ABSTRACT

Background: The accuracy of fitness of any dental casting is imperative for the success of any prosthodontic treatment. From the time that dental casting was first introduced, efforts have been made to produce more accurate and better fitted castings with minimal marginal discrepancy. The aim of this in vitro study was to evaluate the effects of three different investing and burnout techniques on the vertical marginal discrepancies ofceramometalcopings invested with two types of phosphate- bonded investments.

Materials and methods: Sixty wax patterns were fabricated on a standardized prepared brass die representing an upper central incisor by the aid of a custom-made split mold. Three different investing and burnout techniques were applied for an Iraqi investment and a commercial type; Group I:Ring investing with conventional burnout technique (RC);Group II: Ringless investing with conventional burnout technique (RLC);Group III: Ring investing with accelerated burnout technique (RA).Twenty wax patterns of each group were divided into two subgroups according to the type of investment material used (10 for each subgroup) represented as (B) for the BellaStar XL and (W) for the WYMvest investments. Complete castings were finished and seated on the metal die. The accuracy of fit of each coping was determined by measuring the vertical marginal discrepancies between the finish line on the metal die and the margins of each coping at four specific reference points on the labial, mesial, palatal, and distal aspects of the die by the aid of a light microscope supplied with a digital camera.The arithmetic mean of each three records was computed and regarded as the amount of the marginal discrepancy of each coping and was used as a unit for the statistical analysis.

Results: Mean marginal accuracy for W(RLC)was found to be the least (13.839$\pm$4.5724 um) while the highest mean value related to B(RLC) (29.033$\pm$2.102 um). In general, ANOVA test showed significant results among the mean values of the Binvestment subgroups while LSD test showed non-significance between the (RA) and both the (RC) and (RLC) subgroups. On the other hand, significance was present between the (RLC) and (RA)of the Winvestment subgroups while non-significance was located between the (RC) and both the (RLC) and (RA) subgroups. Comparing similar subgroups of the two tested investments, the Student's t-test showed non-significance between the (RC) subgroups while high significance was located between the (RLC) and (RA) subgroups respectively.Concerning the vertical marginal discrepancy of the copings, applying the (RC) technique for both investments caused non-statistical significance between the labial, mesial, palatal, and distal aspects.The (RLC) technique caused high significance between the four aspects, while the (RA) technique caused non-significance between the labial aspect only and the others.

Conclusion: The Iraqi investment generally produced less vertical marginal discrepancies (using the three different investing and burn-out techniques) than the commercial investment.In order to achieve a better marginal fit, it seems that ceramometalcopings invested with the commercial investment tested are better be cast using the conventional ring investing and burnout technique.

Key words: Phosphate-bonded investments, marginal fit, ceramometalcopings. (J Bagh Coll Dentistry 2014; 26(3):18-26).

INTRODUCTION

The accuracy of fitness of any dental casting is imperative for the success of any prosthodontic treatment. From the time that dental castingswere first introduced, efforts have been made to produce more accurate and better fitted castings with minimal marginal discrepancies [(1)].

Fixed restoration margins must fit as precisely as possible to the prepared tooth which is essential for its longevity because it allows less plaque accumulation at the marginal area, provides better mechanical properties (stability, resistance), less cement space (less possibility for leakage) and improves the esthetic result; therefore, the fabrication of metal castings that fit tooth preparation has been considered as one of the prime objectives of fixed prosthodontics [(2)].

One of the critical factors associated with crown construction is the dimensional accuracy of casting. The fitness of crown is influenced by the quality of the investment material and the metal, casting conditions, metal finishing, and firing of porcelain [(3,4)].

The production of accurate dental casting by the lost wax process involves casting molten alloy into a refractory mold which is sufficiently and precisely oversized to accommodate the shrinkage

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of the alloy during cooling.Expansion of dental investment plays an equally important role in the fit of dental casting, the phosphate- bonded investments expand rapidly at the temperature used for casting alloys thus their size can be conveniently controlled [5].

The final fit of the casting is the result of controlled distortion of the mold, which is the cumulative result of variables such as the water/ powder ratio, mixing speed, temperature of the room and liquid, type of lining material and it is also influenced by the restrictive confines of the casting ring and the variation in dimension of the mold cavity [5].

It has been stated that "the slight modification of recommended investing procedures is required to produce consistently well fitting castings with base metal casting alloys" [6].

The conventional investing and casting techniques have been reported to be as time consuming and that the accelerated investing and casting technique can be a vital alternative to the conventional type [7].

Crowns were found to be successfully cast using acceleratedmold preparation techniques in spite of littlefinesse observed [8].

It has been demonstrated that it was possible to eliminate metal casting ring technique when using phosphate bonded investments to provide greater expansion of the investment mold, thus providing a more precise fit for base metal alloy castings. Ringless casting technique has simplified the casting of Ni-Cr and Pd alloys by eliminating not only the metal rings but also the use of ring liners and water bath [9].

Results had shown that the castings produced by the ringless investing and burn-out technique had provided significant less vertical marginal discrepancies than those produced by the conventional metal ring technique. Ringless investing technique allows for more expansion of the investment mold and therefore produces castings which bind less on the die [2, 10].

Ringless system of casting has been recommended for use in fabricating implant supported fixed dental restorations since it produced significantly less vertical marginal discrepancy compared to the metal ring casting technique [11].

In addition, since testing different phosphate-bonded investments proved to cause significant effects on the vertical marginal discrepancies of metal copings cast by Pd-Ag and Ni-Cr alloys utilizing the conventional investing technique [12], and since the Iraqi-made phosphate-bonded investment (WYMvest) was efficiently able to cast Ni-Cr alloys for PFM copings [13].The necessity to evaluate the effects of such investments utilizing ringless investing and accelerated methods on the vertical marginal discrepancies of cast crowns becomes a priority.

MATERIALS AND METHODS

A milling machine (Bego, Germany) was used to prepare the axial walls ofa brass model representing a maxillary central incisor to ensure proper degree of taper. A heavy chamfer finishing line all around the tooth of 1.1mm depth was prepared and measured with a digital vernier caliper of $\pm$0.1mm accuracy. Final preparation measurements were 7mm in height, and 6-8 degrees of convergence.

In order to produce standardization of the wax patterns to have a uniform thickness of 0.5mm, a brass split mold was fabricated consisting of two halves secured with two metal bolts to facilitate wax pattern removal (Fig.1).

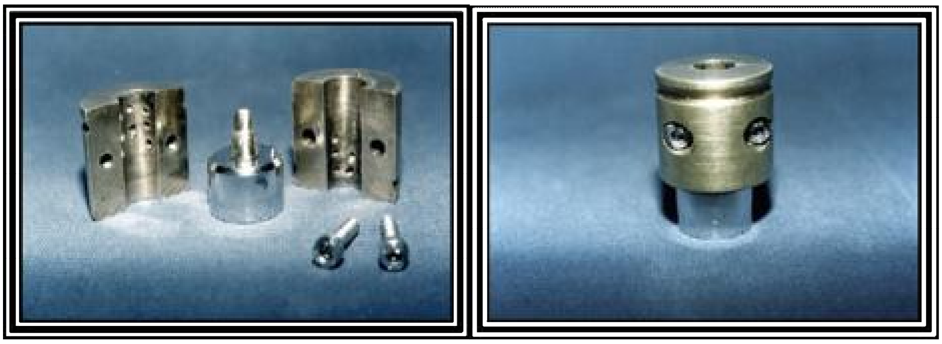

Figure 1: The split mold framework with the prepared brass die fixed into the mold.

A total of sixty wax patterns (Type II blue inlay wax, DT&T, Italy) were obtained.Two phosphate-bonded investments (Bella StarXL, Bego, Germany, and WYMvest, Iraq) were used for investing 20 copings for each group which were divided according to the type of investing and burnout techniques used; Group I: Ring investing with conventional burnout technique(RC), Group II: Ringless investing with conventional burnout technique(RLC), and Group

III: Ring investing with accelerated burnout technique (RA).

Ring investing with conventional burnout technique (RC) was carried out using a metal ring (size 3X) which harvested each sprued10 wax patterns. The ring was lined with a single layer of asbestos-free liner wetted with water. The wax patterns were painted with a surface tension reducing agent (WaxitSpray, Dentaurum, Germany), and invested with each of the tested investmentsmixed at room temperature according to the manufacturer's L/P ratio with its special liquid without dilution, (Table1).

Table 1: Manufacturer's information for investment tested.

Invest-Ment	Manuf.	L/P Ratio ml/gm	Working Time (min.)	Setting Time (min.)	Thermal Expan. %	Total Expan. %	Final burnout temp.&time
BellaStar XL	**Bego Germany**	40/160	3	For conventional: at least 30 For accelerated: 20-30	1.1	2.1	900ºC 30 min.
WYM vest	**Iraq**	21/100	5	For conventional: 35 For accelerated: 15	1.1-1.2	1.9-2.0	950ºC 30 min.

After completeinvesting, the rings were left to bench set according to the burnout technique used later. Ringless investing with conventional burnout technique (RLC) included a rapid ringless system which consisted of a plastic ring (size 3X) (Rapid Ringless System, Bego, Germany) instead of a metal ring. Similar procedures used with the ring investing technique were adopted except that the plastic ring was removed after 15 min. of initial setting of the investment following the manufacturer's instructions, (Fig.2).

Figure 2: The muffle of investment disassembled from the plastic ring

Burnout techniques consisted mainly of two procedures; a. Conventional burnout technique: in which, after the final setting was completed, the ring assembly was kept in the electrical furnace (GC auto furnace, GC Dental Industrial Corp., Japan) at room temperature with the crucible side downward to facilitate evacuation of the molten wax after heating. Then the ring was heated gradually to 250°C at a rate of 5°C/min., and was kept at this temperature for 60 min. for complete wax elimination. The temperature was elevated gradually to the final burnout temperature (900°C-950°C) and kept for 30 min. At the last 10 min., the ring position was reversed with the crucible side positioned up to allow oxygen to contact the surface of the mold to ensure complete wax residue elimination; b. Accelerated burnout technique: in which, after a bench set of 20 min. for the Bella Star XL investment and 15 min. for the WYMvest investment, the ring was placed directly in the preheated furnace at a final temperature of (900°C-950°C), and was maintained at the final temperature for 30 min., then the ring was ready for casting procedure [7].

The alloy used for casting all specimens was Ni-Cr (Beryllium free) ceramometal alloy (Heraenium-NA, HeraeusKulzer, Germany). Each ring was cast with 24gm of new metal by weighing it with the aid of a double pan sensitive electronic balance (Sartorius, Germany). The casting procedure was done using an induction casting machine (Manfredi, Italy) to eliminate casting variables resulting from torch casting. After casting, the rings were left to bench cool to room temperature and the castings were devested from the investment manually, rinsed and cleaned with tap water and bristle brush followed by drying with oil-free air [8].The metal copings were separated from their spruesby cutting discs mounted on a laboratory hand piece attached to a micro-motor dental laboratory machine (W&H, Austria).

The internal surface of each casting was visually inspected by a magnifying lens (10X) for the presence of minute internal nodules that prevented complete seating on the die, which were removed using round tungsten carbide bur mounted on a straight hand piece.

The copings external surfaces were finished sequentially with stone burs to a standardized thickness of 0.5 mm verified with a metal caliper device (Aesculap, Germany). All copings among each subgroup were numbered from 1 to 10 and each numbered coping was isolated in a plastic container.

Each major group was subdivided into 2 subgroups (10 copings each) according to the type of investment tested as follows;B (RC): Invested with BellaStar XL investment, W (RC): Invested with WYMvest investment, B(RLC):Invested with BellaStar XL investment, W (RLC): Invested with WYMvest investment, B (RA): Invested with BellaStar XL investment, and W (RA): Invested with WYMvest investment.

Each coping was seated on the metal die that was affixed to a clear acrylic block in order to ensure that each margin on the four aspects of the coping would be examined and measured from the same angle at each time.The measurements were made on predetermined areas that were marked on the four aspects of the metal die (labial, mesial, palatal and distal) as a dented point below the margin of the preparation, to be easily found under the microscope in order that the measurements could be made at the same point on each aspect at each time[(2)].

A screw-loaded holding device was used during measurements to maintain the seating between the metal copings and the metal die [(14)] (Fig.3).

Figure 3: Close view of preparation margin of the brass die and the gingival margin of the coping

The marginal adaptation of each coping was determined by measuring the vertical marginal discrepancy between its gingival margin and the margin of the die preparation at four specific reference points which was achieved by using a light microscope (Nikon-Eclipse ME 600, Japan) provided with a digital camera (Nikon DXM 1200F, Japan) connected with a computer. The microscope was calibrated to 0.001mm (1µm) at 100X magnification.

The measurements were done by placing the sample on the micrometer stage, which was driven until the imaging picture of the marginal area was displayed clearly on the computer monitor.This imaging picture was treated with two programs; the first program (ATC1) was used to measure the value in (µm) of vertical marginal discrepancy between the coping and the metal die at the predetermined mark by drawing a line between the preparation area and the margin of coping. This line gave a digital reading which was recorded. The other program (LUCIA) was used to record the imaging picture of the measured area.

This method was carried out first on the labial aspect followed by mesial, palatal and distal aspects. Measurements for each aspect were done 3 times repeatedly to ensure the accuracy and to overcome any fault in reading [(15)]. Measurements were continued for all the samples of the series of each subgroup in the same manner. The marginal discrepancy value of each coping was the arithmetic mean of those three measurements on the four surfaces.

RESULTS

The mean marginal gaps, standard deviation and standard errors for the subgroups of Bellastar XL (B) and WYMvest (W) investments are listed in Table2. Among the two types of investments, the highest mean marginal gap for the Bellastar XL investment was scored using the (RLC)technique (29.033±2.102µm), while its lowest mean was scored by the (RC) technique (15.476±4.3926 µm). For the WYMvest investment, the highest mean was scored by the (RC) technique (14.240±3.2509 um) while the lowest mean related to the (RLC) technique (13.839±4.5724 um),(Table 2).

Table 2: Descriptive statistics of BellaStar XL(B) &WYMvest (W)investment groups distributed among their different subgroups.

Subgroup	No.	Mean (µm)	SD	SE
B(RC)	10	15.476	± 4.3926	1.3890
B(RLC)	10	29.033	±2.1020	0.6647
B(RA)	10	19.719	±1.0701	0.3384
W(RC)	10	14.420	±3.2509	1.0280
W(RLC)	10	13.839	±4.5724	1.4459
W(RA)	10	14.224	±2.6968	0.8528

RC: Ring investing with conventional burnout technique, RLC: Ringless investing with conventional burnout technique, RA: Ring investing with accelerated burnout technique

Analysis of variance (ANOVA) test among the BellaStar XL subgroups showed significant differences at p<0.05 between two subgroups (Table 3) which was clarified by the LSD test showing significant difference between (RC) and (RLC) techniques. On the other hand, non-significant differences at p >0.05 existed between the (RA), and both (RC) and (RLC)techniques (Fig. 4).

Table 3: ANOVA – One Way for BellaStar XL investment subgroups.

S.O.V	SS	Df	MS	F	P-value
Between	6.372	2	3.186	27.947	(S) P<0.05
Within	0.800	7	0.114		
Total	7.172	9			

RC	**RLC**	**RA**

S ●------0.014------●
NS●--------------0.168--------------●
NS ●-----0.536-----●

S: P<0.05, sig., NS: P>0.05 (Non – sign.)

Figure 4: ANOVA (By – LSD) for BellaStarXL investment subgroups.

ANOVA test among subgroups of WYMvest investment showed non-significant differences at p>0.05 between two subgroups at least, (Table 4) clarified by LSD test showing non-significant differences at p> 0.05 between (RC) and both (RLC) and (RA) subgroups while significant differences existed between (RLC) and (RA) subgroups (p<0.05), (Fig. 5).

Table 4: ANOVA – One way for WYMvest investment subgroups.

S.O.V	SS	df	MS	F	P-value
Between	0.100	2	0.050	0.125	(NS) P>0.05
Within	2.800	7	0.400		
Total	2.900	9			

RC	**RLC**	**RA**

NS ●-----0.884------●
NS●------------0.335------------●
S●------0.043------●

S: P<0.05 (sign.), NS: P>0.05 (Non – sign.)

Figure 5: ANOVA (By – LSD) for WYMvest investment subgroups

Applying the Student's t-test to compare similar groups of the two tested investments, non-significant differences were located between (RC) subgroups of both types while highly significant differences existed between (RLC) and (RA) subgroups as shown in Table 5.

Table 5: t-test of mean marginal gap between BellaStar XL and MYMvest investment subgroups

Subgroup	T	df	P-Value	C.S.
B(RC) –W(RC)	0.652	9	P>0.05	NS
B(RLC) –W(RLC)	7.830	9	P<0.01	HS
B(RA) – W(RA)	6.014	9	P<0.01	HS

Marginal gap mean values for the labial, mesial, palatal, and distal aspects of the tested copings using the three investing techniques for the BellaStar XL and WYMvest investments are presented in Figs.6 and 7.

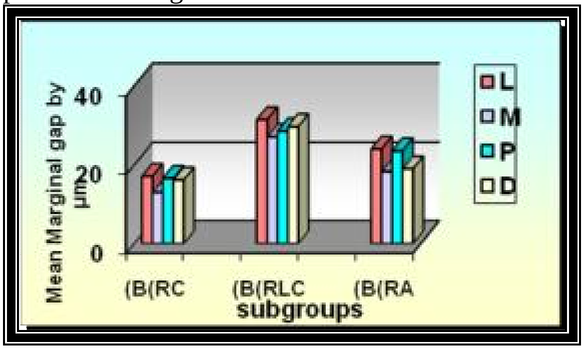

Figure 6: Bar-chart according to the mean values of themarginal gap by (µm) for each subgroup related the BellaStar XL investment for all coping aspects.

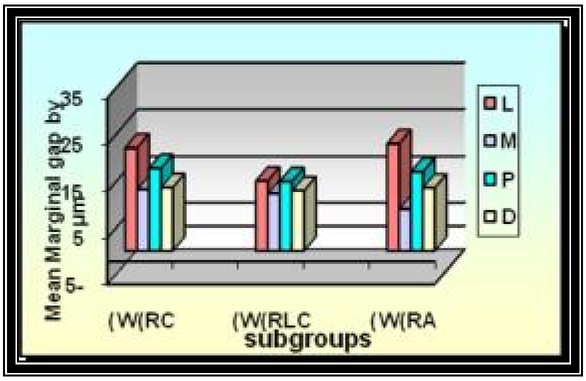

Figure 7: Bar-chart according to the mean values of the marginal gap by (µm) for each subgroup related to the WYMvest investment for all coping aspects.

Applying the Student's t-test to verify the statistical significance between similar pairs of subgroups in the two investments tested, non-significant differences were present between the four aspects using the conventional ring investing technique (RC), (Table 6).

Table 6: t- test of marginal gap for all aspects of copings in µm invested by BellaStar XL (B) and WYMvest (W) using (RC) technique.

Aspects	Subgroup	t	df	C.S
Labial	B(RC) –W(RC)	1.322	9	NS*
Mesial	B(RC) –W(RC)	0.772	9	NS
Palatal	B(RC) –W(RC)	0.115	9	NS
Distal	B(RC) –W(RC)	1.797	9	NS

***P> 0.05**

On the other hand, the ringless conventional investing technique (RLC) caused high significant differences in the four aspects of the tested copings for both investments, (Table 7).

Table 7: t- test of marginal gap for all aspects of copings in µm invested by BellaStar XL (B) and WYM vest (W) using (RLC) technique.

Aspects	Subgroup	T	df	C.S
Labial	B(RLC) –W(RLC)	8.894	9	HS
Mesial	B(RLC) –W(RLC)	9.640	9	HS
Palatal	B(RLC) –W(RLC)	4.645	9	HS
Distal	B(RLC) –W(RLC)	7.519	9	HS

Ring investing with accelerated burnout technique (RA) caused non-significant differences (p> 0.05) in the labial aspects of the copings using both investments while highly significant differences (p <0.01) were scored in the mesial, palatal, and distal aspects for both investments, (Table 8).

Table 8: t- test of marginal gap for all aspects of copings in µm invested by BellaStar XL (B) and WYMvest (W) using (RA) technique.

Aspects	Subgroup	T	df	P-value C.S.
abial	B(RA) W(RA)	0.339	9	P>0.05 NS
esial	B(RA)–W(RA)	4.901	9	P<0.01 HS
alatal	B(RA)–W(RA)	3.598	9	P<0.01 HS
Distal	B(RA)–W(RA)	2.882	9	P<0.01 HS

Marginal gaps of metal-ceramic copings cast with the BellaStar XL investment using the (RC, RLC, and RA) techniques are shown in Figs.8-10.

Figures (11-13) show labial marginal gaps of the copings cast with WYMvest investment using the RC, RLC, and RA techniques respectively.

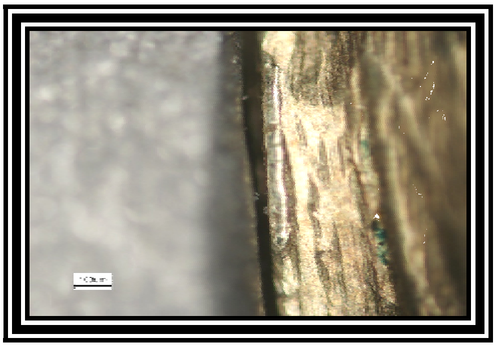

Figure 8: Labial marginal gap of coping using the (RC) technique for BellaStar, XL investment. Yellow= brass die. Black= marginal gap, Gray= coping

Figure 11: Labial marginal gap of coping usingthe (RC) techniquefor WYMvest investment

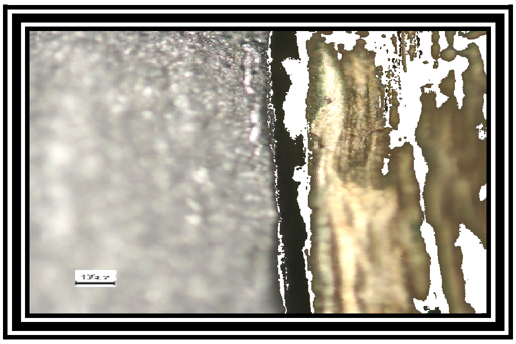

Figure 9: Labial marginal gap ofcoping using the (RLC) technique for BellaStar XL investment.

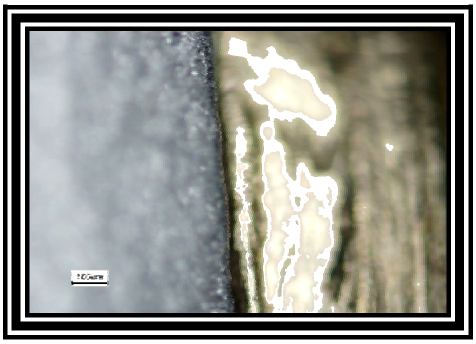

Figure 12: Labial marginal gap of coping using the (RLC) technique for WYMvest investment

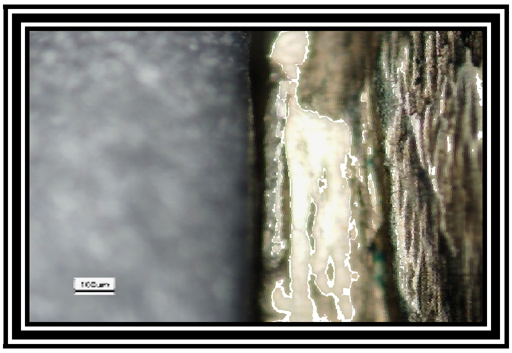

Figure 10: Labial marginal gap of coping using the (RA) technique for BellaStarXL investment.

Figure 13: Labial marginal gap of coping usingthe (RA) technique for WYMvest investment

DISCUSSION

Effect of Investing and Burnout Techniques

The high mean of marginal gap caused by the BellaStar XL investment when utilizing the ringless investing with conventional burnout technique (RLC), could be attributed to that when there was no ring liner employed , no expansion of the mold occurred during setting of the investment , a result which was in agreement with the findings of Lombardas et al. [2] and Ding et al.[10] since the expansion of the investment was found to be influenced by water absorption by the investment from the ring liners providingadditional hygroscopic expansion of the investment during its setting [16].

The other cause of marginal discrepancy could be attributed to different degrees of surface roughness produced in the castings which were invested by phosphate-bonded investments since surface roughness was reported to be increased when using high mold temperatures [17].

On the other hand, the ANOVA test showed statistically non significant differences in the vertical marginal discrepancy of the copings invested by the WYMvest investment regarding each tested investing and burnout technique, a finding which agreed with Konstantoulakis et al.[7]and Schilling et al. [18] who reported that marginal gaps for castings made with an accelerated technique showed no statistical differences when compared with a conventional casting group. It was also supported by the findings of Lombardas et al.[2] and Ding et al.[10]that showed that the castings produced by the ringless technique can improve marginal seating of castings better than the conventional metal ring technique. On the other hand, it did not coincide with Li et al. [19] findings where significant differences between the groups invested with metal rings (RC) and paper rings (RLC) were located.

The WYMvest investment with (RLC) technique resulted in less marginal discrepancies than using it with both (RC) and (RA) techniques, which demonstrated that it is possible to eliminate metal casting rings in order to provide greater expansion of the investment mold thus producing more precise fit for Ni-Cr alloy castings, a finding that coincided with Engelman et al. [9] and Lombardas et al. [2].

The fluctuation of the observation of marginal discrepancy in the coping aspects (labial, mesial, lingual , distal) invested with BellaStarXL and WYMvest investments using the three different investing and burnout techniques lies in that, if the distortion had occurred during the investment setting expansion, spreading of the mesial and distal sides of the wax pattern would have happened thus causing the bending of the occlusal portion and resulting in poor fit of castings at the gingival floor and axial line angle margins of the die [20].

Effect of Investments

In regard for the investment materials, the statistical analysis showed highly significant differences between BellaStar XL and WYM vest investments using the (RLC) and (RA) techniques. In both investing and burnout techniques, WYMvest investment produced copings that had the lowest mean of marginal gap while the highest mean related to BellaStar XL investment.

These differences could be attributed to the compositional differences of the investments' formulations. Investments may differ in terms of composition, particle size, heat transmission, wettability and so forth, and as a consequence, the castability of the dental casting alloys could be affected, which agreed with Cohen et al. [21] findings.

The other possible cause for the differences in the marginal fit among the two tested investment materials could be attributed to the effect of investments on the alloy castability. In general, it has been reported that incomplete castability results in an incomplete cast crown margins and therefore an increase in marginal discrepancy [14, 22]. Also those differences could be related to the alloy fusion temperature and alloy composition. These study findings agreed with Duncan [22] who reported that the shrinkage of the alloys after casting related to the high fusing temperature that causedgreater fit discrepancies, and that the expansion of the investment wasn't adequate to compensate for the casting shrinkage of the alloy to obtain a good fit.

On the other hand, copings made from BellaStar XL and WYM vest investments using the (RC) technique exhibited no significant differences between their results. Such finding agreed with Lombardas et al. [2] who found that there were no significant differences in the vertical marginal discrepancy of PFM copings produced with ringless and conventional casting technique and invested with two different phosphate-bonded investments mixed with their special liquids according to their manufacturer's recommendations.

The marginal gap mean values in the present study were less than 50µm for all tested investment–technique combinations. A similar amount of discrepancy was achieved in other studies [12-14,18,24,25] in which it was reported that the mean of marginal gap less than 50µm is considered clinically acceptable.

This research also revealed that the WYMvest investment generally produced less vertical marginal discrepancies (applying all three different investing and burnout techniques) than the BellaStar XL investment. In order to achieve a better marginal fit, it seems that PFM copings invested by using the BellaStar XL investment are better be cast using the conventional ring investing and burnout technique.

Under the conditions of this study, the following conclusions were drawn:

1. The WYMvest investment generally produced less vertical marginal discrepancies (using the three different investing and burn-out techniques) than the BellaStar XL investment.
2. Regarding the WYMvest investment, both ringless investing with conventional burnout and ring investing with accelerated burnout techniques produced highly significant lower vertical marginal discrepancies for PFM copings than the BellaStar XL investment.

3. The highest mean of marginal discrepancy among all tested groups was scored by the BellaStar XL investment in the ringless investing with conventional burnout technique, while the lowest mean was scored by the WYMvest using the same technique.
4. In order to achieve a better marginal fit, it seems that PFM copings invested with the BellaStar XL investment are better be cast using the conventional ring investing and burnout technique while the three investing and burnout techniques are acceptable for the WYMvest investment.
5. Marginal gap means presented by both tested investments (using the three different investing and burn-out techniques) can be considered clinically acceptable (less than 50µm).

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