

Evaluation of the effects of an Iraqi phosphate bonded investment and two commercial types on the marginal fitness of porcelain- fused- to- metal copings.

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Abstract:

The effect of different phosphate- bonded investments on the marginal fitness of porcelain- fused-to-metal copings cast by one type of noble alloy and one type of base metal alloy was studied. Three types of phosphate-bonded investments (Castorit-Super C, Norvest, and Iraqinvest) were used for investing the thirty copings of each group. The marginal fitness of each coping was determined by measuring the vertical marginal discrepancies between the gingival margin of the coping and the margin of the preparation at four reference points on the labial, mesial, palatal and distal aspects of the die by the aid of light traveling microscope.

The statistical analysis of the results showed that there were significant differences in marginal fitness among different investments for both Pd- Ag& Ni-Cr alloys. The Castorit- Super C and Norvest investments produced comparable results with both alloys, while the Iraqinvest appeared less compatible with Pd-Ag alloy than the other two investments and it had comparable compatibility to Norvest investment when used with Ni- Cr alloy. The Ni- Cr alloy (Heraenium NA) copings revealed significantly greater marginal discrepancy than the Pd-Ag alloy (QD) copings specially when using Castorit- Super C and Norvest investments.

Key Words:

Iraqi investment, Marginal fitness, PFM copings

Introduction

Fixed restorations are important part of restorative dentistry and their successful use whether they are (cast, porcelain-fused to metal (PFM) or all ceramic) should begin with proper diagnosis and thoughtful treatment planning⁽¹⁾. The ultimate value of metal casting lies in the accuracy of fit of the metal restoration and its identical duplication of tooth structure, any break in the chain of technical events occurring up to and during the casting process can produce inadequate restorations⁽²⁾. Marginal seal is one of a critical factor for a successful dental

restoration. Poor marginal seal can encourage plaque and bacterial deposition resulting in caries and periodontal disturbances with concomitant deterioration of the restoration⁽³⁾. The marginal fit of cast restorations is one of the most researched subjects in fixed prosthodontics because it is important for longevity of restorations and periodontal health maintenance⁽⁴⁾. The introduction of ceramometal technology made the use of higher melting temperature alloys necessary to withstand the firing cycles of porcelain without noticeable distortion, and lead to the development and use of

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phosphate-bonded investments that can resist higher temperatures and higher stresses during casting⁽⁵⁾. Selection of a compatible combination of alloy-investment is critical for predictable results⁽⁶⁾. An imbalance between expansion and shrinkage of the alloy and investment material is one of the causes of unsatisfactory cast margins. One of the aspects that could be affected and may necessitate evaluation in this process is the marginal fitness of the PFM copings as it has been shown previously, that metal copings could be subjected to further distortion of the margins during the firing cycles of porcelain build up^(7&8).

The aim of this study was to evaluate the effects of three different phosphate bonded investments on the marginal fitness of PFM copings.

Materials and methods:

A brass model representing an upper central incisor tooth, was embedded in a metal ring filled with plaster of Paris. The brass model was prepared for PFM crowns with heavy chamfer finishing line all around the

tooth with a depth of 1.1mm. The completed die was 7mm in length, 4mm in width and 6-8 degree of convergence.

A split mold was fabricated for standardization of the wax pattern copings with uniform thickness of 0.5mm. A split mold framework of steel was turned with two halves to facilitate wax pattern removal similar to that of Zakaria & Jassim⁽⁸⁾. A total of 60 wax patterns, 30 for each group were made.

Each ten wax patterns of each subgroup with their minor sprues were attached to a runner bar (3mm thickness in diameter and 30mm in length) to ensure that the ten wax patterns of each subgroup were invested and cast in the same ring and each group would pass through the same casting cycles.

Three available phosphate bonded investments were used for investing the 30 copings of each group that were divided into 3 subgroups, according to the type of investment used. The investments were selected and used according to the manufacturers recommendations for casting ceramic alloys (Table 1).

Table (1): Manufacturer's information for investments tested

Type product	Manufactures	L/P ratio Ml/gm	Working time (min)	Setting time (min)	Thermal expansion %	Total expansion %	Final burnout temperature °C and time
Castorit-super C	Dentaunum, (Germany)	34/150	4-5 min	40 min	1.33	3.05	950°C 30 min
Norvest	D.T.&F. S.r.L, (Italy)	15-17/100	4-6 min	45 min	0.8-1.1	1.8-2.4	900°C 30 min
Iraqinvest	Ministry of industry and minerals (Iraq)	18/100	3-5 min	45 min	1.2-1.3	1.7±0.3	900°C 30 min

Note: All investments studied were non carbon type.

After completion of spruing, investing was done immediately using investing ring size 3x, which was lined with a single layer of asbestos free ring liner (1mm thickness). A full liner was wet with water and adapted slightly to the inner surface of the ring. Surface tension reducing agent (debubblizer) was applied carefully to the pattern with more attention paid to the inner surface.

Each investment was mixed according to its manufacturer's liquid/powder ratio, with its special liquid at room temperature without dilution, except for Iraqinvest, which was mixed with distilled water at room temperature.

After vacuum mixing, the investment mix was gently brushed into the patterns with a small brush, then poured gradually down to the ring under mechanical vibration for 30 seconds to eliminate the incidence of air bubbles. After complete fullness, the rings were left to set according to the investment manufacturers' instructions (Table 1). After setting, the glaze which formed on the surface of the investment was scrapped off to allow gases to escape during the casting process. All the aforementioned steps were carried out quickly as much as possible in order to minimize the possibility of wax distortion. In addition, the investing was accomplished at the room temperature with virtually no sudden change in the temperature of the surrounding atmosphere.

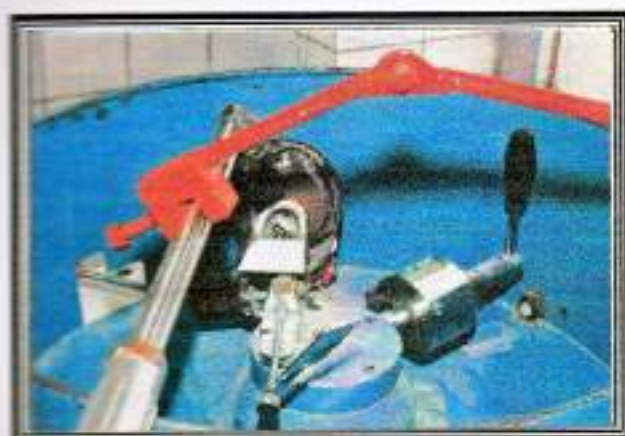
The burnout schedules were carried out according to the manufacturers' directions for the desired temperatures and timings for each type of investment that was used for casting the selected PFM alloys (Table 1). The two alloys tested were Pd-Ag ceramometal alloy (Quayle Dental, England) that was used for casting the 1st group, and Ni-Cr

(Beryllium free) ceramometal alloy (Heraenium-NA, Heraeus Kulzer, Germany) that was used for casting the 2nd group. Both alloys were handled according to the manufacturers' instructions.

Casting procedures were done by a manual driven broken arm centrifugal casting machine. All castings were made with the same casting pressure (four turns). A ceramic crucible was used in a centrifugal casting machine and it was imperative that a new crucible be used for each casting, since alloys may deposit metals or other materials along the sides of the crucible which could likely increase impurities. The crucibles were glazed according to the manufacturer's instructions before use as follows; crucible was dried out and preheated in a preheating furnace by increasing the temperature from 300 °C to 1000 °C. An oxy-acetylene torch flame was used for melting the alloy. To standardize the optimal heat application, the torch was clamped by a metal holder which was attached to the casting machine to lock the torch in a way so that the flame distance from the crucible was kept fixed at 10 cm.⁽⁹⁾, (Fig.1). During the melting process, as the temperature was not monitored, slumping of the metal and disappearance of oxide film first from the metal were employed to determine the proper moment for casting which was made at just that point.

The same previous casting steps were done for each ring which was cast with 24gm of new metal by weighing with the aid of double pan balance (Gallenkamp, England).

After casting, the rings were quenched in water as soon as the red glow of the button disappeared, then the castings were devested from the investment manually with metal instrument, rinsed and cleaned with tap water and bristle brush and then dried.



Fig(1): Casting torch clamped by the metal holder attached to the casting machine.

Then the metal copings were separated from their sprues by a cutting disc mounted on a laboratory hand piece. The internal surfaces of each coping was visually inspected by a magnifying lens for bubbles and other positive defects that prevented complete seating which were either flicked off with a sharp instrument or removed with round carbide bur at high speed. These steps were created on each coping prior to being placed to the die. The metal thickness of each coping at the site of sprue attachment was checked after finishing of the coping using a caliper device so that it became equal in thickness with the other parts of the coping (0.5mm). All copings among each subgroup were numbered 1,2,10, and each subgroup was isolated in a plastic container. The samples were divided into two groups according to the type of ceramometal alloy used, Pd-Ag group (P) and Ni-Cr group (H), each of the two groups were subdivided into three subgroups according to the type of investment used, as follows:

Group I (P) was divided into:-

P(C): invested with Costorit-Super C investment.

P(N): invested with Norvest investment.

P(I): invested with Iraqivest investment.

Group II (H) was divided in the same behavior of group I.

Measurements were made on predetermined areas that were marked on the four aspects of the die (labial, mesial, palatal and distal) below the margin of preparation. A "screw" loaded holding device similar to that used by Thiab&Zakaria⁽⁹⁾ was used during measurements to maintain a seating pressure of (13.4Newton) between the metal copings and the metal die. The marginal adaptation of each coping was determined by measuring the vertical marginal discrepancy between the margin of preparation and the gingival margin of the coping.(Fig.2). This was achieved with a measuring light travelling microscope (Carlzeiss-Jena, ermany) alibrated to 0.001 mm (1 μ m) at magnification x 200. Measurements for each aspect were done 3 times repeatedly to ensure the accuracy and to overcome any faults in the readings. The marginal discrepancy value of each coping was the arithmetic mean of these four measurements (on the four surfaces).



Fig(2): Measuring the vertical marginal discrepancy between cervical margin preparation of the brass die and that of metal coping held by screw loading device.

Results:

The mean marginal gaps and standard deviations, for

each subgroup of Pd-Ag alloy (P) and Ni-Cr alloy (H) are listed in (Table 2).

Tables (2): Descriptive and inferential statistics of the two different alloys distributed among the three different investments.

Investments	Pd-Ag alloy (P)			Ni-Cr alloy (H)			*C.S By t-test p-value
	Mean	SD	CV%	Mean	SD	CV%	
C Castorit Super C	32.475	8.424	25.940	39.450	6.556	16.619	**S P<0.05
N Norvest	37.725	8.132	21.556	44.600	6.136	13.758	S P<0.05
I Iraqinvest	48.475	8.070	16.648	46.200	8.864	19.186	***NS P>0.05

*CS (One-tailed (t-test))

**S (significant)

***NS (Non significant)

The comparison significant of marginal gap means in μm for

subgroups of Pd-Ag and Ni-Cr alloy are shown in Fig (3).



Fig (3): Bar-chart for the two different alloys distributed among

C:Castorit-Super C Investment

N:Norvest Investment

I:Iraqinvest Investment

P:QD alloy (Pd-Ag)

H:Heraenium-NA alloy (Ni-Cr)

The results for Pd-Ag alloy showing the lowest mean of marginal gap was related to P(C) which was $32.475 \mu\text{m}$ followed by P(N) which was $37.725 \mu\text{m}$, and the highest mean was related to P(I) which was $48.475 \mu\text{m}$.

The same behavior for mean values related to Ni-Cr alloy were presented as they began with $39.45 \mu\text{m}$ for H(C) followed by $44.6 \mu\text{m}$ for H(N) and ending with $46.20 \mu\text{m}$ for H(I). Among the two alloys, the lowest marginal gap was recorded for P(C) and the highest was for P(I).

Employing the Student-t test between the two alloys tested in each subgroup of investments revealed significant differences at $p < 0.05$ level

between Pd-Ag and Ni-Cr alloys in C (Castorit-Super C) and in N (Norvest) subgroups while non-significant differences were recorded in I (Iraqivest) subgroup.

The means of marginal gaps related to the 1st and 2nd subgroups of Pd-Ag alloy were less than its contrasts of Ni-Cr alloy subgroups while the mean related to the 3rd subgroup of Pd-Ag alloy was greater than that of Ni-Cr alloy.

Analysis of variance (ANOVA) among the subgroups of Pd-Ag group represented that there was highly significant difference at $P < 0.01$ as shown in (Table 3).

Table (3): ANOVA – One Way for Pd-Ag alloy group

S.O.V	SS	d.f	MS	F	P Value
Between	1330.417	2	665.208	9.869	HS $P < 0.01$
Within	1819.919	27	67.404		
Total	3150.335	29			

A least significant difference (LSD) test was applied which showed that non significant differences existed between P(C) and P(N), followed by

highly significant differences between P(C) and P(I) and finally followed by highly significant differences between P(N) and P(I), (Table 4).

Table (4): ANOVA (By – LSD) for Pd-Ag alloy group

P(C)	P(N)	P(I)
*NS	0.164	
**HS	0.000	
	HS	0.007

*NS: $P > 0.05$ (Non –significant)

**HS: $P < 0.01$ (highly –significant)

On the other hand, the ANOVA test created among the subgroups of Ni-Cr alloy group represented that there were significant differences at $P < 0.05$ for at least between two subgroups as shown in (Table5), whereas the (LSD) test showed that

non significant differences at $P > 0.05$ existed between H(C) and H(N), followed by significant differences at $P < 0.05$ between H(C) and H(I) and finally followed with non significant difference between H (N) and H (I), (Table6).

Table (5): ANOVA – One Way for Ni-Cr alloy group

S.O.V	SS	d.f	MS	F	P Value
Between	248.817	2	124.408	2.344	S $P < 0.05$
Within	1432.850	27	53.069		
Total	1681.667	29			

Table (6): ANOVA (By – LSD) for Ni –Cr alloy group

	H(C)	H(N)	H(I)
*NS	●	●	
**S	●		●
		●	●

0.126 (between H(C) and H(N))
0.048 (between H(C) and H(I))
0.627 (between H(N) and H(I))

*NS: $P > 0.05$ (Non -significant)

**S: $P < 0.05$ (significant)

Discussion:

Effect of Investment

In comparison among different investment materials, the analysis of variance showed statistically high significant differences in the marginal fit of Pd-Ag alloy copings, and significant differences in marginal fit of Ni-Cr alloy copings. These differences could be attributed to the different expansions of the

investments. There is an indication that the better fitting castings were made from molds that had more available expansion, thus allowing the casting to seat farther, and consequently reducing the vertical marginal discrepancy⁽⁵⁾. For both alloys, Castorit-Super C produced copings that had the lowest mean of marginal gap followed by Norvest, and the highest mean was related to Iraqinvest investment. The total expansions of Costorit-Super C

and Norvest investments, stated by the manufacturers to be 3.05% and 2.4% respectively, were considerably more than the total expansion of Iraqivest ($1.7 \pm 0.3\%$). These figures would seem to verify the findings of this study, and they agreed with Custer & Desalvo⁽¹⁰⁾ and Jenkins & Philips⁽¹¹⁾ who found that there were significant differences in the fit of the casting crowns between the various investments that had different expansion values and were used according to the manufacturers' directions.

Copings made from Iraqivest had significantly greater marginal discrepancies than those made with Castorit-Super C and Norvest investments and these differences were more pronounced in Pd-Ag alloy group. The possible explanation of that could be due to the use of water rather than special liquid in Iraqivest investment that might have provided insufficient expansion and high degree of surface roughness. This finding is consistent with the studies of Hutton & Marshal⁽¹²⁾ who found that mixing the phosphate-bonded investments with their special liquids, rather than distilled water, resulted in elevated setting and thermal expansion, and also agreed with Arfaei & Asgar⁽¹³⁾ who reported an increase in surface roughness when the silica solution was diluted or completely replaced with water. The solutions consisting of very fine silica particles in colloidal suspension, probably help to fill the voids between the much greater silica particles of the investment powder.

On the other hand and in contrast to the Iraqivest the other two investments, that their special liquids (silica solution) were provided by the manufacturers, exhibited no significant differences between their results in both groups. This finding agrees with Lombardas et al⁽⁵⁾ who found that

there were no significant differences of vertical marginal discrepancy of PFM copings produced with the conventional casting technique and invested with two different phosphate-bonded investments mixed with their special liquids according to their manufacturers' recommendations.

The other possible cause for the differences in the marginal fit among different investments was their effect on the castability of the alloy. In general, it has been reported that the incomplete castability results in incomplete cast crown margins and increase in marginal discrepancy⁽¹⁴⁻¹⁶⁾.

The castability of dental casting alloys can be affected by many variables, one of them being the investment material, and this was supported by the findings of Barreto et al⁽¹⁷⁾ & Cohen et al⁽¹⁸⁾ who showed that the castability varies a great deal, qualitatively and quantitatively, according to the type of investment used. Their results indicated that the alloy-investment combination is significant and could explain the controversial reports on castability of tested alloys. Authors attributed the differences in alloy castability to the variation in investment formulations. Investments may differ in terms of composition, particle size, heat transmission, wettability and so forth.

The differences in castability can reflect the compatibility of different investments with tested alloys that appeared in this study as variation in the marginal gap among different subgroups.

Under the conditions of the present study, the results achieved from Castorit-Super C and Norvest investments were comparable with both Pd-Ag and Ni-Cr alloys. The Iraqivest appeared less compatible with Pd-Ag alloy than the other two investments as their combination gave the greatest mean of marginal

discrepancy but it had comparable compatibility to Norvest when combined with Ni-Cr alloy as the results showed no significant differences between them. Such finding can be attributed to the presence of Ni and Cr oxides within the composition of the Iraqinvest investment which may contaminate the Pd-Ag alloy and result in impaired castability and the resulted castings had more surface bubbles than other subgroups. On the other hand, these oxides could have enhanced the castability of Ni-Cr alloy as they are transported by the action of the liquifier material within the investment to the alloy-investment interface at high temperatures.

Effect of Alloy

In comparing group I with group II, there were statistically significant differences between the Pd-Ag and Ni-Cr alloys using both Castorit-Super C and Norvest investments being that Pd-Ag alloy produced significantly better marginal fit copings than Ni-Cr alloy. However, the differences between them using Iraqinvest investments were not significant (Table 2).

Those differences can be attributed to alloy fusion temperature and alloy composition. These findings agreed with Duncan ⁽¹⁹⁾ who reported that the shrinkage of the alloys after casting could be related to the fusing temperature being that high fusion temperature would cause greater discrepancies of fit and the conclusion was that the expansion of the investment is not adequate to compensate for casting shrinkage of the alloy to obtain good fit.

It has been shown that differences in alloy compositions could result in different shrinkage rates and that palladium was effective in

reducing the casting shrinkage of noble alloys ⁽²⁰⁾.

The difficulty to produce sharp margins with base metal casting can be considered as another cause related to, as they tend to produce round margins. Such finding was consistent with the studies of Wight et al ⁽²¹⁾ & Byrne et al ⁽²²⁾. In the present study, the noble metal alloy (Pd-Ag) appeared to have a lower melting temperature, less casting shrinkage and better marginal fitness than base metal (Ni-Cr) alloy. This agreed with Nitkin & Asgar ⁽²³⁾ Duncan ⁽¹⁹⁾ who found that the precious alloy produce the least discrepancy of marginal fit and Ni-Cr alloy produced inferior marginal fit compared to precious or semiprecious alloys. The results also agreed with Byrne et al ⁽²²⁾ Tjan et al ⁽²⁴⁾ who found that the marginal accuracy of noble metal (high Palladium) alloy was higher than that of base metal alloy.

On the other hand, it disagreed with Strating et al ⁽²⁵⁾ who found that non-precious (Ni-Cr) alloys can be cast as accurate as semiprecious or precious ceramoalloys. The means of marginal gaps in this research were less than 50 μm for all alloy-investment combinations. A similar amount of discrepancy was achieved in other studies ^(9,11,22,26-28) who reported that a mean marginal gap less than 50 μm is considered clinically acceptable.

It has been also reported that additional marginal discrepancies during porcelain firing cycles could be minimized by using Pd-Ag noble metal alloy to construct PFM crowns on heavy chamfer or shoulder finishing line preparations to resist the thermal distortion ⁽⁸⁾.

Conclusions:

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

1. The tested investment materials had significant effects on the vertical marginal discrepancy of metal copings constructed from Pd-Ag and Ni-Cr alloys.
2. All alloy-investment combinations produced clinically acceptable marginal fit (less than 50 μ m), with the lowest mean of marginal gap resulted from the Pd-Ag / Castorit-Super C combination, while the highest mean resulted from Pd-Ag / Iraqinvest combination.
3. The Castorit-Super C and Norvest investments produced comparable results with Pd-Ag and Ni-Cr alloys. On the other hand, Iraqinvest investment was less compatible with Pd-Ag alloy than either Castorit-Super C and Norvest investments but it had comparable compatibility to Norvest investment when used with Ni-Cr alloy.
4. Pd-Ag alloy revealed significantly better marginal fit than the Ni-Cr alloy specially when using Castorit-Super C and Norvest investments.

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