

The evaluation of vertical marginal discrepancy induced by using as cast and as received base metal alloys with different mixing ratios for the construction of porcelain fused to metal copings

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ABSTRACT

In this study the effect of mixing as received and as cast metals by different ratios on the marginal fitness of metal copings casted by two types of base-metal alloys (Wiron 99 and Heraenium-NA) which are used by dental technicians in Iraq was evaluated.

The general procedure consisted of first, fabrication of wax pattern on a standardized prepared brass die that represented an upper central incisor with a heavy chamfer cervical margin. The wax patterns were standardized by the aid of a split mold constructed specially for this purpose; the total number of wax patterns was 100. Each fifty copings were casted with one of these two alloy types, and each type was divided into five sub-groups according to the amount of as received (new) and as cast (recasted) metals mixed. Completed castings were finished and seated on the die. The marginal fitness of each copying was determined by measuring the vertical discrepancies between the gingival margin of the copying and the margin of the preparation at four reference points on the labial, mesial, palatal, and distal aspects of the die with the aid of light traveling microscope.

The statistical analysis of the results related to Wiron 99 alloy group showed that there were highly significant differences between its related five sub-groups indicating that the marginal fit changes increased with the increase of the recasted metal ratios of

الخلاصة

إن الغرض من هذا البحث هو تقييم اختلال ضبط حافات الأغلفة المعدنية الخاصة بالتيجان الخزفية و ذلك باستخدام المعدن المعاد عند مزجه بالمعدن الجديد و بنسب مختلفة من السبائك غير الثمينة و المستخدمة في مختبرات صناعة الأسنان داخل العراق و هي الوايرون ٩٩ و الهيرانيوم ن أ.

إما طريقة العمل فقد تكونت من عمل القوالب الشمعية على نموذج مصنع من مادة البراص ثم تحضيره ليمثل القاطع العلوي الأمامي و بحافة عنقية مشطوفة بعمق ثم استخدام قالب حديدي مجوف ذو فلتتين لتوحيد سمك و أبعاد القوالب الشمعية و التي صبت بالمعدنين غير الثمينين ليصبح العدد الكلي مائة غلاف. لقد تم تصنيع كل خمسين غلafa معدنيا مصبوب من إحدى المعادن كمجموعة واحدة تكونت من خمسة طوائف حسب نسب المعدن الجديد والمعدن المعاد لكل منها. و بعد إتمام عملية الصب و فصل الأغلفة المعدنية ثم تنظيفها وإضفاء اللمسات الأخيرة عليها قبل إجلاسها علىنموذج البراص لغرض إجراء الفحص بواسطة المجهر الضوئي المتنقل.

كانت نتيجة التحليل الإحصائي للقراءات المستحصلة هي كما يلي: إن مادة وايرون ٩٩ أبدت حساسية اكثر لزيادة تركيز المعدن المعاد و انعكس ذلك على حدوث اختلال اكبر في ضبط الحافات بين طوائف المجموعة الخمسة و خاصة الطائفتين الرابعة و الخامسة

Wiron 99. On the other hand, Heraenium-

NA alloy did not show significant differences among its sub-groups indicating that recasting it, in different ratios reaching up to 100% as cast alloy, did not cause adverse changes on marginal fitness.

Based on this, conclusions drawn indicated that recasting of Heraenium-NA (Ni-Cr) can be utilized as a good substitute for the new alloy from an economical point of view.

Key Words: Marginal discrepancy, as cast, as received, alloys.

والتي استخدم فيها ٧٥% و ١٠٠% معدن معاد عند مقارنتها بطوائف مجموعة مادة معدن هيرانيوم ن أ. إن إمكانية استخدام معدن هيرانيوم ن أ المعاد بنسب مختلفة تصل إلى ١٠٠% بدون حدوث تأثير معاكس على ضبط حافات الأغلفة المعدنية الخاصة بتيجان الخزف مما يعزز جانب تطوير استخدام البدائل لتقليل نفقات استيراد المواد الضرورية لهذا الغرض من الأقطار الأجنبية و بالعملة الصعبة.

INTRODUCTION

Fixed prosthodontics is primarily a form of dental treatment for young and middle-aged adults, as most patients seeking this aid of treatment are between 18 and 60 years of age, to re-establish a well functioning oral relationship with pleasing esthetic. Ideally every missed tooth should be replaced soon to prevent drifting of the adjacent teeth and overeruption of the opposing.⁽¹⁾

The successful application of any dental restoration as a single unit or as a retainer for fixed partial denture depends on diagnosis and treatment planing, with adequate design, which is based on preservation of tooth structure, integrity of margin, resistance and retention.⁽²⁾

Although plastics in fixed partial denture prosthesis have satisfied to some degree the esthetic problem, but unfortunately, their color and form are not stable, in addition to ease of abrasion and inadequacy of union between veneer material and metal, as they are connected only mechanically. For that, porcelain has been the material of choice whenever esthetic appearance was in consideration.

Since the early fifties, dental researchers have renewed their interest in porcelain baked directly to gold as a veneering material.⁽³⁾

As porcelain gained popularity, more and more variation, of basic materials, as well as concept, were offered to the profession.⁽⁴⁾

With significantly increased gold price during the late 1970s, the development of

alternative alloys to gold containing increased dramatically to reduce the cost of fixed restoration. This development included alloy with reduced gold content and alloys that contained no gold or noble metal.⁽⁵⁻⁷⁾

Base metal alloys were introduced into dentistry 35 to 40 years ago. When using the inexpensive non-precious alloys, technicians used all new metal for each casting instead of mixing new metal with previously melted ingots as it was done with gold alloys, so with the increase in the cost of non-precious metals it has been suggested from economic point of view to reuse such metals in combination with new metals by different ratios instead of using all new metals.⁽⁸⁾

Since Iraq was passing through a difficult period because of the economic sanctions imposed on, this has led some dental technicians to use non-precious metal alloys in repeated castings or without new metal. One of the aspects that could be effected and may necessitate evaluation in this process is the marginal fitness of the porcelain-fused-to-metal (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.^(9, 10)

According to our knowledge, there were no studies that had been conducted to evaluate the effects of recasting base metal alloys on the marginal fitness of PFM copings especially in Iraq.

Marginal seal is a critical factor of dental restorations. Poor marginal seal can encourage plaque and bacterial depositions re-

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sulting in caries and periodontal disturbances with concomitant deterioration of the restoration.⁽¹¹⁻¹³⁾

The aim of this study was to evaluate the vertical marginal discrepancies induced by using two base-metal alloys as new (as-received) and recasted metal (as-cast) with different ratios for the fabrication of PFM copings.

MATERIALS AND METHODS

A brass model representing an upper central incisor tooth, was aligned vertically with the aid of a surveyor part of the milling machine (Bego, Germany) and was prepared for PFM crown with heavy chamfer finishing line all around the tooth with a depth of 1.1 mm.⁽¹⁴⁾

Preparation was done by straight hand-piece attached to the surveyor part of the milling machine to keep the bur vertical and parallel to the longitudinal axis of the die to eliminate the undercuts and ensure proper degree of axial tapering. The completed die was 8 mm in length, 4 mm in width and 6-8 degrees of convergence.⁽²⁾

It was important, for standardization of the copings with uniform thickness of 0.5 mm, that a split mold be fabricated of steel which was turned with two halves to facilitate wax pattern removal.⁽¹⁰⁾ The two metal halves of the split mold could be fixed to each other by two pins in one half and two corresponding pinholes in the other half. The two halves were then secured to each other with a U-clamp.

The master die was fixed to cylindrical metal base, designed to fit the split mold framework by pin in the metal base and pinhole in the framework which was used to consistently position the die-metal base assembly to the split mold. Separating medium (QD, England) was applied to the die, then a wax pattern was fabricated, using type II inlay wax (Dentaurum, Germany) and wax wire (gauge 2.5 mm) was attached to the mid area of the incisal edge of the pattern.

Each finished wax pattern was kept in a water container, which was stored at room temperature to eliminate distortion and dimensional changes. The previous steps were repeated in the same manner until we had

the total number, which were ten patterns for each sub-group.

Then the copings and their sprues assembly were attached carefully to the crucible former so the copings of each sub-group were invested with phosphate bonded investment (Castroit, Dentaurum, Germany) which was mixed according to the manufacturer's instructions, and casted in the same ring to ensure that each group would pass through the same investing and casting cycles.

The ring was notched with the top end and the facial surfaces of the patterns being lined up with this notch so that when the metal was casted the notch was faced up ensure that the molten metal enter the mold by same way for each casting.⁽¹⁵⁾

After complete fullness, the ring was kept aside for setting after one hour. The glaze layer, which formed on the surface of investment, was scrapped to allow gas escape due to enforcement of the molten metal during casting process. The gas evacuation was further facilitated by allowing only 6 mm thickness of investment over the wax pattern at the upper end of the casting ring.⁽¹⁶⁾ All 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.⁽¹⁷⁾

The burn out was carried out according to manufacturer's recommendations for temperature and timings. At the last 10 minutes, the ring position was reserved with the crucible side positioned up to allow oxygen to contact the internal surfaces of the mold to ensure complete wax residue elimination.⁽¹⁸⁾

Manual driven broken arm centrifugal casting machine (Degussa, Germany) was prepared to be ready for casting. All castings were made with the same casting pressure and to achieve that the machine was wound for four turns.⁽¹⁶⁾ It was imperative that a new crucible be used for each casting, since alloys may deposit metals or other alien materials along the sides of the crucible as these materials are likely to increase impurities. Crucibles, before use, were treated acc-

ording to the manufacturer's instructions as follows: Crucibles were dried out and preheated in a preheating furnace by increasing the temperature from about 300 °C to 1000 °C (leaflet of the manufacturing company).

To standardize the optimal heat application, the torch was clamped to a metal stand (locally constructed) to be locked in position at a required distance so the flame distance from crucible was fixed through the melts which was about 10 cm.

Three rings were casted, at the first time, each with 24 gm as received metal. The further two castings were used in addition to sprue of the first to give us a sufficient amount of as cast metal to be remelted in the following sub-groups. After casting, the rings were left for bench cooling at room temperature, then devested and cleaned from the investment, sandblasted with 50 µm particles except the copings, so that the sandblast could not affect the inner surfaces and margins which could adversely compromise the results later. The copings and other metal sprues were rinsed and cleaned with tap water and bristle dental brush.⁽¹⁹⁾

The remaining buttons and sprues related to the first casting period were sectioned by a cutting disc mounted on a laboratory handpiece to facilitate weighing of the as cast metal to be mixed with certain amounts of as received metal, as each sub-group was identified with the mixing ratio of as cast and as received metals while the buttons and sprues related to the 2nd, 3rd, 4th and 5th casting periods were neglected.

The sub-groups II, III and IV were casted by mixing the two metals (as cast + as received) by weight with aid of the sensitive electronic balance (Sortorius, Germany) calibrated to 0.0001 gm.

The same previous casting steps were done for the two tested alloys Wiron 99 (Bego, Germany, Batch No. 9868) and Heraenium-NA (Heraeus Kulzer, Germany, Batch No. 993033).

The internal surface of each coping was visually inspected by a magnifying lens (×10) for bubbles and other positive defects which were either flicked off with a sharp instrument and hard ones were removed by round tungsten carbide bur mounted on a straight handpiece. If a large defect was

present, the casting was discarded. These steps were created on each coping prior to being placed on the die. All copings among each sub-group were numbered, 1, 2....9 and isolated in a plastic container. One coping from each sub-group was neglected.

The samples were divided into two groups according to the type of commercial alloy used, Wiron 99 group (W) and Heraenium-NA group (H): Each of the two groups were sub-divided into five subgroups according to the mixing ratios of the as cast and as received metal as follows:

Group I (W) divided into:

Sub-group I (W1): 100% as received metal (new metal).

Sub-group II (W2): 25% as cast metal + 75% as received metal.

Sub-group III (W3): 50% as cast metal + 50% as received metal.

Sub-group IV (W4): 75% as cast metal + 25% as received metal.

Sub-group V (W5): 100% as cast metal (recasted metal).

Group II (H) divided into:

Sub-group I (H1): 100% as received metal (new metal)

Sub-group II (H2): 25% as cast metal + 75% as received metal.

Sub-group III (H3): 50% as cast metal + 50% as received metal.

Sub-group IV (H4): 75% as cast metal + 25% as received metal.

Sub-group V (H5): 100% as cast metal (recasted metal).

Each coping was seated on the metal die that was affixed to a clear acrylic block with parallel surfaces (gained by turning) to ensure that each margin on the four aspects would be examined and measured from the same angle at each time, as the uniform appearance of this block permitted it to be fitted and placed into the micrometer stage of the measuring microscope.⁽²⁰⁾ A reference point was shaped like Brinell indentation, as a mark to be easily found under the microscope in order that the measurements could be made at the same point on each aspect and at each time. A "screw" loaded holding device (locally constructed) similar to that used by Tjan *et al.*⁽²¹⁾ was modified with changing the spring by a screw and was used during measurements to secure the metal

coping on the die with a uniform load during the measurements.

Specimens were examined under a measuring light traveling microscope (Carlzeiss Jena, Germany) calibrated to 0.001 μm (1mm) at magnification ×200. The marginal adaptation of each copying was determined by measuring the vertical marginal discrepancy between the margin of preparation and the gingival margin of the coping. All the measurements were recorded to ensure consistency.⁽²¹⁾ The marginal discrepancy value of each coping was the arithmetic mean of these four measurements.

The analysis of variance (ANOVA) test was carried out to see if there were any differences among the means of groups with least significant difference (LSD) test that was carried out to examine the source of differences.

Z-test was applied to compare the significance among different response changes in concentration percentage of as cast metal for each sub-group with its relative sub-group related to the other material.

RESULTS

The mean marginal gaps and standard deviation, standard error, ranges, minimum and maximum values for each sub-group are listed in Table (1) for Wiron 99 and Table (2) for Heraenium-NA.

The results for Wiron 99 (showing the lowest mean of marginal gap) was related to W1 which was 27.88 μm and it increased gradually with successive sub-groups ending with 42.25 μm for W5. The same behavior for mean values related to Heraenium-NA were presented as they began with 31.3 μm for H1 and ending with 37.416 μm for H5. Among the two materials, the lowest marginal gap mean was recorded for W1 and the highest was for W5.

Inferential statistic methods employed such as ANOVA among the sub-groups of Wiron 99 represented that there were highly significant differences at $p < 0.01$ level among the sub-groups at the percentages of reused metal by weight 0%, 50%, 75%, 100% (Table 3).

Table (1): Descriptive and inferential statistics of Wiron99 group distributed among its different sub-groups

Sub-group	No.	Range	Min	Max	Mean*	SD
W1	9	10.5	21.75	32.25	27.88	2.817
W2	9	19.75	22.25	42.00	32.25	7.279
W3	9	26.75	24.00	50.75	34.30	9.205
W4	9	26.75	21.00	50.25	37.27	7.419
W5	9	24.25	30.75	55.00	42.20	8.594

*Mean in μm; Min: Minimum; Max: Maximum; SD: Standard deviation.

W1: 100% as received metal (new metal); W2: 25% as cast metal + 75% as received metal; W3: 50% as cast metal + 50% as received metal; W4: 75% as cast metal + 25% as received metal; W5: 100% as cast metal (recasted metal).

Table (2): Descriptive and inferential statistics of Heraenium-NA group distributed among its different sub-groups

Sub-group	No.	Range	Min	Max	Mean*	SD
H1	9	18.75	21.00	39.75	31.30	6.962
H2	9	14.00	28.25	42.25	33.41	4.916
H3	9	24.50	22.25	46.75	34.58	9.331
H4	9	21.75	26.25	48.00	35.50	8.600
H5	9	23.25	27.00	50.25	37.41	7.664

*Mean in μm; Min: Minimum; Max: Maximum; SD: Standard deviation.

H1: 100% as received metal (new metal); H2: 25% as cast metal + 75% as received metal; H3: 50% as cast metal + 50% as received metal; H4: 75% as cast metal + 25% as received metal; H5: 100% as cast metal (recasted metal).

Table(3): Analysis of variance-one way test among sub-groups of Wiron 99

SOV	SS	df	MS	F-value	P value
Between Sub-groups	1041.813	4	260.4531		
Within Sub-groups	2471.045	40	54.91211	4.743091	HS $p < 0.01$
Total	3512.858	44			

SOV: Source of variance; SS: Sum of squares. df: Degree of freedom; MS: Mean square. HS: Highly significant difference.

No significant differences at $p < 0.05$ level were recorded among the sub-groups of Heraenium-NA at the percentages of as

cast metal by weight 0%, 50%, 75%, 100% (Table 4).

Table (4): Analysis of variance-one way test among sub-groups of Heraenium-NA

SOV	SS	df	MS	F-value	P value
Between Sub-groups	186.324	4	46.58106		
Within Sub-groups	2642.184	40	58.71621	0.793325	NS $p > 0.05$
Total	2828.508	44			

SOV: Source of variance; SS: Sum of squares. df: Degree of freedom; MS: Mean square. NS: No significant difference.

The source of difference was investigated by least significant difference (LSD) test to examine the differences between the different pairs of the sub-groups as shown in Tables (5) and (6). There were significant differences between W1 vs. W3 and highly significant for W1 vs. W4 and W5. Also

there was highly significant difference between W2 vs. W5 and significant for W3 vs. W5, while the rest represented no significant differences (Table 5). No significant differences were obtained among Heraenium-NA sub-groups (Table 6).

Table (5): Least significant difference (LSD) test for Wiron 99 sub-groups

	W1	W2	W3	W4	W5
S	-----				
HS	-----				
HS	-----				
		HS	-----		
			S	-----	

S = significant $p < 0.05$; HS= highly significant $p < 0.01$
Dotted lines between the sub-groups show significant level comparison.
W1: 100% as received metal (new metal).
W2: 25% as cast metal + 75% as received metal.
W3: 50% as cast metal + 50% as received metal.
W4: 75% as cast metal + 25% as received metal.
W5: 100% as cast metal (recasted metal).

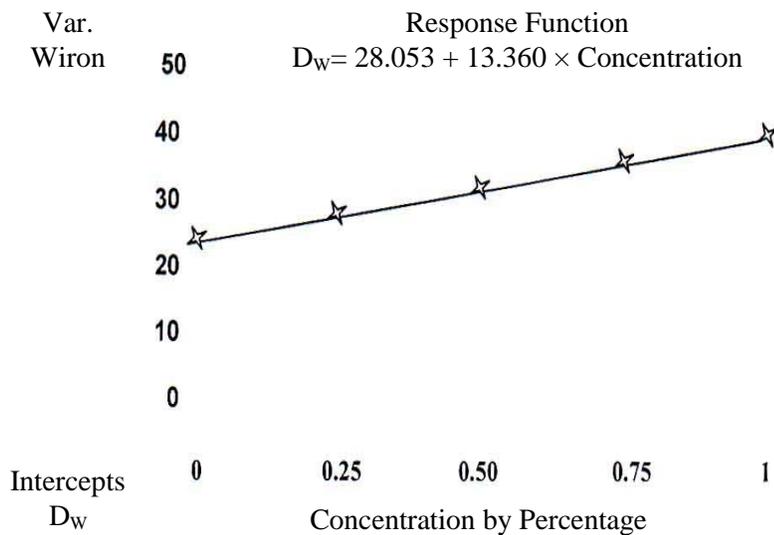
Table (6): Least significant difference (LSD) test for Heraenium-NA sub-groups

H1	H2	H3	H4	H5
All multiple comparisons obtained non significant differences at $p > 0.05$				
H1: 100% as received metal (new metal)				
H2: 25% as cast metal + 75% as received metal.				
H3: 50% as cast metal + 50% as received metal.				
H4: 75% as cast metal + 25% as received metal.				
H5: 100% as cast metal (recasted metal).				

Comparison of the significance among different responses of change in the percentage by weight of the as cast metal was estimated by Probit (probability unit) analysis which showed that increasing concentrations by percentages of recasted Wiron 99 had led to, for each increase at each 1% recasted metal, the marginal discrepancy obtained was 0.1336 μm . The initial marginal

gap related to W1, which was present with 100% as received metal and 0% cast metal was 28.053 μm . Each increase was then calculated as “intercept D_w + slope \times concentration per unit” which was 28.053+13.360 concentration where at each 1% degree of increase in recasted metal the increase was 0.0163278 μm (Table 7).

Table (7): Probit analysis for different concentrations of as cast Wiron 99



Increasing the concentrations with percentages of as cast Heraenium Na metal had led to, for each increase at each 1% recasted metal, the marginal discrepancy obtained was 0.05726 μm , and the same for the first material, the initial marginal gap related to H1 presented with 100% as received metal and 0% as cast metal was 31.580 μm . Each increase was calculated as “intercept D_H + slope \times concentration per unit” which was 31.580 + 5.726 μm , where at each 1% degree of increase in recasted metal the increase was 0.05762 μm (Table 8).

Table (9) shows the changes in percent-

ages according to the deviation registered in case of increasing concentrations of recasted metal for Wiron 99 and Heraenuim-NA. In relation to the initial point which is 0% recasted metal for W1 and H1, the discrepancy obtained was 15.64% for W2 and 6.76% for H2 and so on for the successive sub-groups ending with 51.32% increase in the discrepancy for W5 and 19.54% for H5. Also the Table shows that the comparison of significance for W2 vs. H2 was significant while the rest contrasts of concentrations obtained a high significant difference at $p < 0.01$.

Table (8): Probit analysis for different concentrations of as cast Heraenium-NA

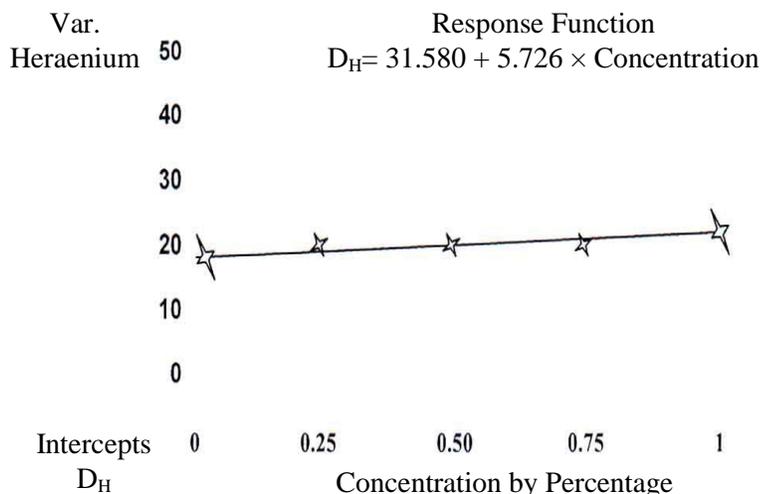


Table (9): Comparison of significance among different responses of changes in percentages of recasted metal (Z-test)

Heraenium-NA (H%)	Wiron 99 (W%)	Comparison of Significance
H1 0.00	W1 0.00	-
H2 6.76	W2 15.64	S
H3 10.49	W3 22.99	HS
H4 13.42	W4 33.64	HS
H5 19.54	W5 51.32	HS

S: Significant $p < 0.01$; HS: Highly significant $p < 0.01$.

H1: 100% as received metal (new metal).

H2: 25% as cast metal + 75% as received metal.

H3: 50% as cast metal + 50% as received metal.

H4: 75% as cast metal + 25% as received metal.

H5: 100% as cast metal (recasted metal).

W1: 100% as received metal (new metal).

W2: 25% as cast metal + 75% as received metal.

W3: 50% as cast metal + 50% as received metal.

W4: 75% as cast metal + 25% as received metal.

W5: 100% as cast metal (recasted metal).

DISCUSSION

The quality of restorations can be assessed by the marginal discrepancy measurements, present in this study as the existing vertical space between the cervical metal margin of the coping and the gingival floor of the heavy chamfer preparation.⁽²²⁾

In this study, Wiron 99 alloy showed slightly better adaptation than Heraenium-NA alloy with percentages of as cast metal at 0%, 25% and 50% while for 75% and 100%, more deterioration happened with Wiron 99 than Heraenium-NA alloy.

In general, the increase in the marginal discrepancy may be related to the impaired castability of the molten alloy. It is one of the properties of dental casting alloys which can be affected by many variables, one of them being the composition of the alloy, so in this study the recasting led to loss of some alloy additives which could have enhanced the fluidity of the melt leading to improvement of castability, and that could be due to the presence of Mn and Si in Wiron 99. Their loss could have happened in two ways: Either by evaporation or, the more

important, by oxidation. By this information, the gradual increase in the marginal gap associated with increase in percentages of recasted metal as castability decreased gradually can be explained. It was also noticed that the Heraenum-NA alloy had more stable components than Wiron 99 alloy.

Although statistically insignificant differences were recorded for Heraenum-NA alloy sub-groups, highly significant results for Wiron 99 alloy were recorded. The comparison between the sub-groups of the two materials was significant for W2 vs. H2, while the remaining sub-groups related to the two materials showed significance of high level.

It is worthy to be mentioned that despite these deteriorations which happened with Heraenum-NA and the larger deteriorations for Wiron 99 metal alloy which was statistically significant for the second material in the present study, these levels of marginal discrepancies could be clinically acceptable if the other sources of further distortion recorded for PFM restorations were regarded which are the porcelain firing cycles and finally elevation induced by final cementation, which are mentioned in literature. For example, Shillingburg *et al.*⁽²⁰⁾ found that the amount of the opening exhibited with porcelain firing cycles by chamfer margin was equal to 47.1 μm and heavy chamfer with bevel margin was equal to 29.3 μm . Also, Richter-Snapp *et al.*⁽²³⁾ reported that the total average changes during the firing cycles did not exceed 30 μm in any case and may not be clinically significant.

Gemalmaz and Alkumru⁽⁹⁾ found that the marginal discrepancies for Pd-Cu alloy (Begopal) and Ni-Cr alloy (Wiron 99) induced by porcelain firing cycles, did not exceed 30 μm . On the other hand, Zakaria and Jassim⁽¹⁰⁾ recorded that the marginal fit change induced by firing cycles at the highest value of 39 μm occurred when Ni-Cr alloy (Heraenum-NA) was used to construct copings for PFM crowns on heavy chamfer labial finishing line after running through different porcelain firing cycles. Finally, the effect of these deteriorations on the marginal gap of PFM crowns could be minimized by controlling the additional dis-

crepancy during firing cycles by using proper substrate material for porcelain with optimum thickness to resist thermal distortion. Also, the final marginal gap could be minimized by reducing the distortion induced by cement elevation if a suitable pre-cementation space was created in order to produce restorations with acceptable marginal gap.

CONCLUSIONS

Recasting in general increased the vertical marginal discrepancy of the metal copings constructed from Wiron 99 and Heraenum-NA alloys.

Vertical marginal discrepancies were more pronounced when using more than 50% as cast metal of Wiron 99 alloy.

Recasting Heraenum-NA alloy in average of 25% up to 100% as cast metal did not statistically affect the marginal fitness of PFM copings.

Marginal discrepancy increased with each 1% increase in as cast metal by weight for both tested alloys which was equal to 0.1336 μm for Wiron 99 and 0.05726 μm for Heraenum-NA alloys.

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Received: 30/11/2002

Accepted for Publication: 20/11/2003