Original Article

Evaluation and Comparison of the Vertical Marginal Discrepancy of Ni-Cr and Co-Cr Alloys Before and After Porcelain Firing: An in Vitro Study

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Abstract

Introduction: Marginal seal is the critical factor for the success of any restoration. Accuracy of marginal seal of copings depends on alloy systems & manufacturing techniques. In every technique like laser sintered, conventional casting etcetera, significant marginal discrepancy takes place after porcelain firing. The aim of this study is to evaluate and compare the vertical marginal discrepancy of Ni-Cr and Co-Cr alloys before and after porcelain firing. **Methods:** Custom made stainless steel die model was prepared to simulate the dimensions of the mandibular molar with a round shoulder margin. Cast copings of two base metal alloys Ni-Cr alloy & Co-Cr alloy were prepared. Total 40 copings were made and divided into two groups, G1 (Ni-Cr alloy) & G2 (Co-Cr alloy). According to alloy type, 20 specimens were used for each group of the study. The vertical discrepancy was measured with an optical LASER microscope (Nikon, Japan) before and after application of porcelain on the copings. Wilcoxon signed ranked test and Mann Whitney U test were used for Statistical analysis. **Results:** The median vertical marginal discrepancy before and after porcelain firing for Ni-Cr alloy was 48.13 and 52.87 um respectively and for Co-Cr alloy was 95.33 and 100.04 um respectively. There is a highly significant difference ($P < 0.001$) in the median vertical marginal discrepancy between Co-Cr alloy copings & Ni-Cr alloy copings before & after porcelain firing.

Conclusions: Co-Cr alloy PFM restorations have double vertical marginal discrepancy compared to Ni-Cr alloy restorations but both the values can be considered within clinical acceptability range of the marginal discrepancy.

Keywords: Base Metal Alloy Copings, Firing Cycles, Marginal Seal.

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Introduction

Competency of the casting to the basic tooth structure decides the favourable outcomes of any cast restoration (1). For Aesthetics, persistency, good mechanical properties, and least plaque retention at marginal area precision is required in the restoration. An inadequate margin opens the way to plaque retention which results in gingival inflammation, marginal leakage which is the causative factor of secondary caries, sensitivity, gingival recession, cement dissolution, and debonding of the restoration (1).

Regardless of scrupulous observation to waxing, investing, and casting procedures the marginal discrepancies of cast restorations are inescapable. Even though published data on clinically acceptable marginal discrepancy varies from 30µm to 200 µm, a marginal

discrepancy of up to 74µm as clinically acceptable (2). It is one of the tasks of luting cements to close these discrepancies. However, cement will dissolve rapidly under the margins if the gap is too large as the rate of luting cement dissolution has been related empirically to the degree of marginal discrepancy. Keeping this in mind, many materials and methods have been suggested by various authors to improve the fit and marginal accuracy of the casting. Buchanan et al. (3) reported a greater marginal discrepancy in base metal alloys than precious alloys and suggested the thicker oxide layer formed on the inner surfaces of the base metal alloys castings as the probable cause. As there is a scarcity of research work in the literature on the comparison of the marginal discrepancy between Ni-Cr and Co- Cr alloys before & after porcelain firing. Hence, the purpose of this study is to measure the marginal discrepancy of porcelain fused to metal restorations, with different base metal alloys; Ni-Cr and Co-Cr alloys.

The first null hypothesis was that no significant differences would be found in the vertical marginal discrepancy of Ni-Cr alloy & Co-Cr alloy copings before porcelain firing fabricated by conventional casting technique. The second hypothesis was that the application of veneering ceramic would not affect the vertical marginal adaptation of the restorations.

Materials and Methods

This study was carried out in the Department of Prosthodontics, Government College of Dentistry, Indore and the marginal discrepancy measured at Indian Institute of Technology (IIT), Indore. The most commonly used materials and procedures were used in the study to simulate the actual clinical and laboratory conditions.

Custom made stainless steel die model was prepared to simulate the dimensions of the mandibular molar with a round shoulder margin. 40 cast copings were prepared with the two base metal alloys & divided into two groups of 20 copings in each group.

G1- Ni-Cr alloy group (Wirocer Plus, Bego, Germany)

Nickel- 65.2% chromium- 22.5% molybdenum- 9% Beryllium free

G2- Co-Cr alloy group (Wirobond C, Bego, Germany)

Cobalt- 63.3% chromium- 24.8%, molybdenum- 5% Beryllium free

The vertical discrepancy was measured with optical LASER microscope (Nikon, Japan) before and after application of porcelain on the copings.

Methodology used in the study

The stainless steel master die and stainless steel former assembly (Figure 1) employed in this study is custom made, based on the model employed by Adriana F Quintas et al. (4) for their studies.

A standard stainless steel die was prepared, with a rounded shoulder margin, & a 10-degree total axial wall taper all around. The height of the die was 5mm and its occlusal diameter was 7mm. The base diameter was 11.6mm including a 1.3mm margin all around. A lateral notch is placed cervical to the finish line for exact repositioning of the copings in consecutive measurements.

A custom-made stainless steel former was fabricated (Figure 1) such that it could be accurately positioned over the stainless steel die. The stainless steel former was larger than the die in all dimensions by 0.5mm uniformly. This was done to maintain a uniform space of 0.5mm between the die and the former.

This space helped to obtain the patterns with a uniform thickness of 0.5mm. Each metal model was duplicated with the additionional silicone elastomeric impression material (Aquasil soft putty and Aquasil LV, Dentsply, Germany) (Figure 2) and poured in type IV stone (Kalrock, KalabhaiKarsonPvt. Ltd, Mumbai, India) (Figure 3) for the fabrication of working dies.

The die models obtained from duplicating custom-made stainless steel die assembly, as described above, was used to fabricate standardized wax patterns. A uniform thickness of 0.5mm was obtained throughout the wax patterns. In this manner total of 40 patterns were made and divided into two groups, G1and G2, according to alloy type, and twenty specimens were used for each group of the study. All wax patterns were invested individually using graphite free, phosphate bonded investment material (Deguvest^{R} Impact, Degudent, Germany) and all 40 copings were obtained with the lost wax technique and divided into two groups, G1 (Ni-Cr alloy) & G2 (Co-Cr alloy), and 20 specimens were used for each group of the study (Figure 4a-4d).

Measurements of the marginal gap:

Each coping was seated on the die before & after the application of the porcelain. Microscopic measurements were recorded at 10x magnification, perpendicular to the axial wall of die and coping, with an optical LASER microscope (Figure 5a) at IIT, Indore, India. Measurements were taken from the coping margin to the die margin for recordings vertical marginal discrepancy (Figure 5b). Marginal discrepancies were measured to the

nearest micron on each casting at the 3 predetermined sites -90^0, 180^0, and 270^0 on the base of the die from an anti-rotational notch.

The same procedure was followed to record the vertical marginal discrepancy for each of the twenty test samples belonging to each test group (Figure 6a-b, 7, 8). The measurements thus obtained were statistically analyzed.

Porcelain application over cast copings

Each metal coping was finished by firstly grinding all the surfaces with a carbide bur in order to obtain a clean smooth surface with an even thickness of 0.5mm, then copings were cleaned, sandblasted according to manufacturers' recommendations.Ceramco3, Dentsply, USA porcelain was used to apply over the copings with opaque, body, and enamel ceramics at recommended firing cycles. The obtained samples again tested for vertical marginal discrepancy by optical LASER microscope in same manner at predetermined sites (Figure 6b).

The data collected was entered into Microsoft Excel sheet and crosschecked for any errors. The data were then subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS, IBM version 20.0). The level of significance was set at 5% and a P-value of 0.05 was considered statistically significant.

Descriptive statistics were used to find the frequency and median vertical marginal discrepancy before and after porcelain firing. Normal distribution of data was checked using the Shapiro-Wilk test. As the data was not under normal distribution, non-parametric test like Mann-Whitney U and Wilcoxon signed-rank tests were employed to compare the vertical marginal discrepancies between the groups.

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Figure 1: Stainless steel metal die and former

Figure 2: Polyvinyl siloxane impression of the metal die

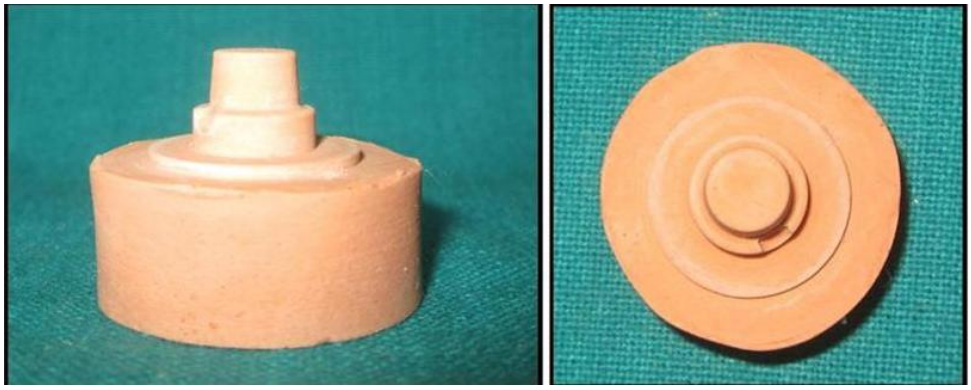


Figure 3: Die stone model with shoulder margin

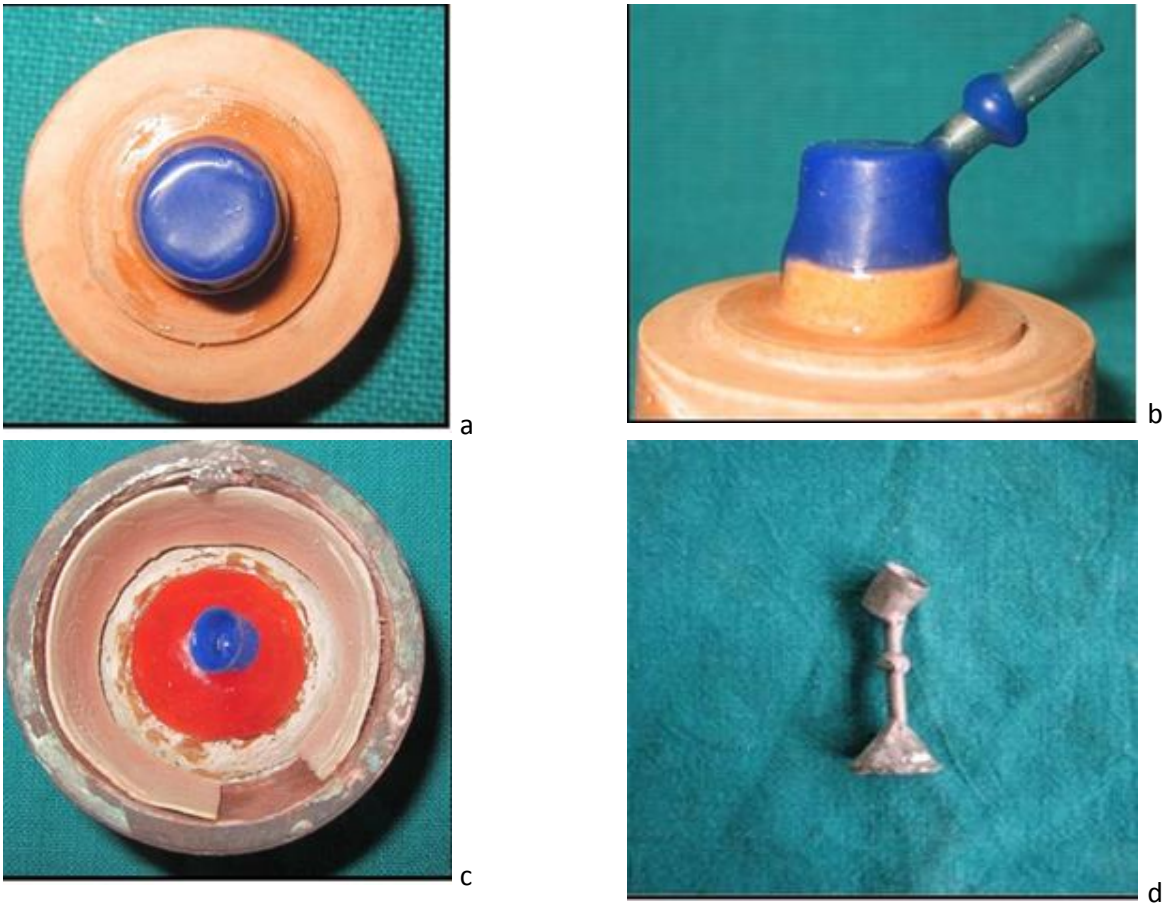
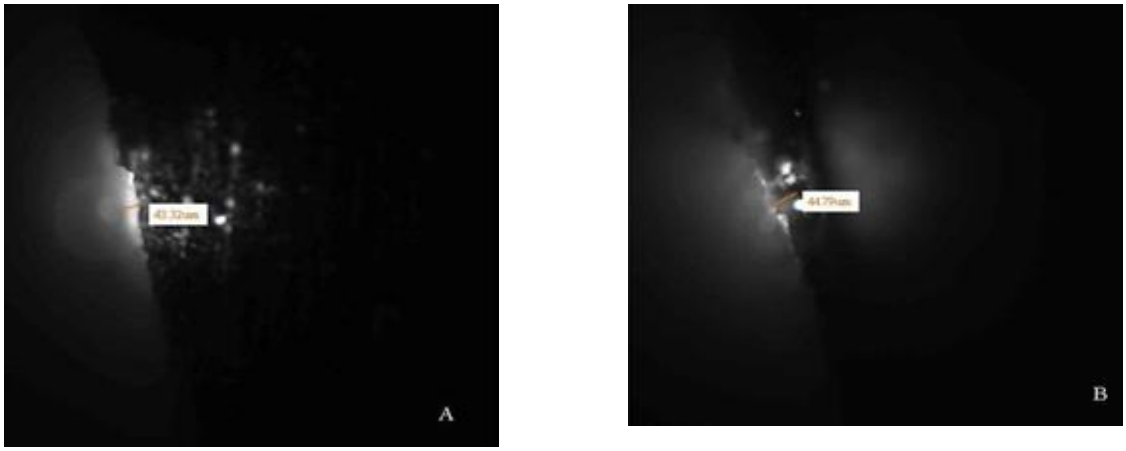
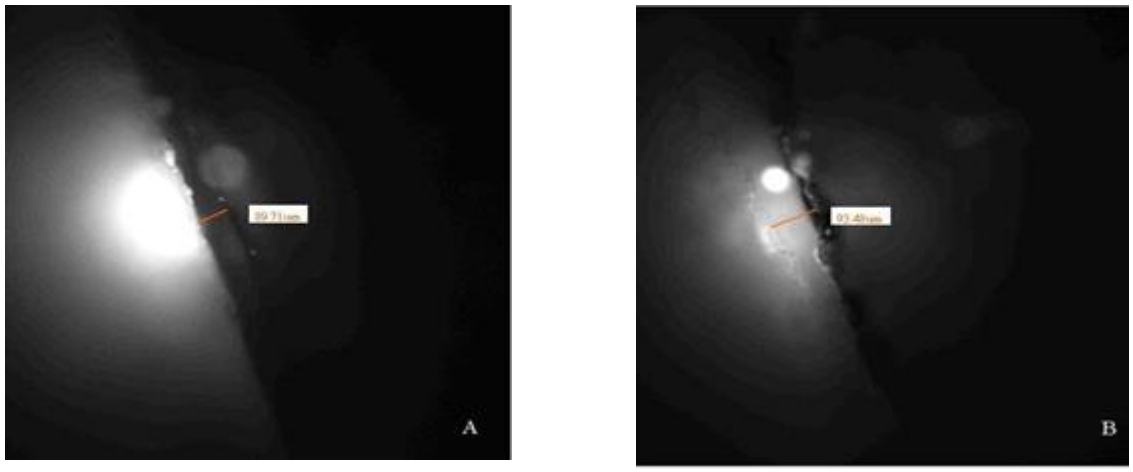


Figure 4:(a-d) Fabrication of wax pattern and coping. a-Wax Pattern. b-Wax Pattern With Attached Sprue. c-Wax Pattern ready for investing. d- Divested casting



Before



After

Figure6(a-b): Microscopic images of vertical marginal discrepancy of Ni-Cr and Co-Cr alloy copings before and after application of porcelain. 6a-Microscopic image of vertical marginal discrepancy of Ni-Cr alloy copings (A) and Co-Cr Alloy copings(B) before porcelain application. 6b-Microscopic image of vertical marginal discrepancy of Ni-Cr alloy copings (A) and Co-Cr Alloy copings(B) after porcelain application

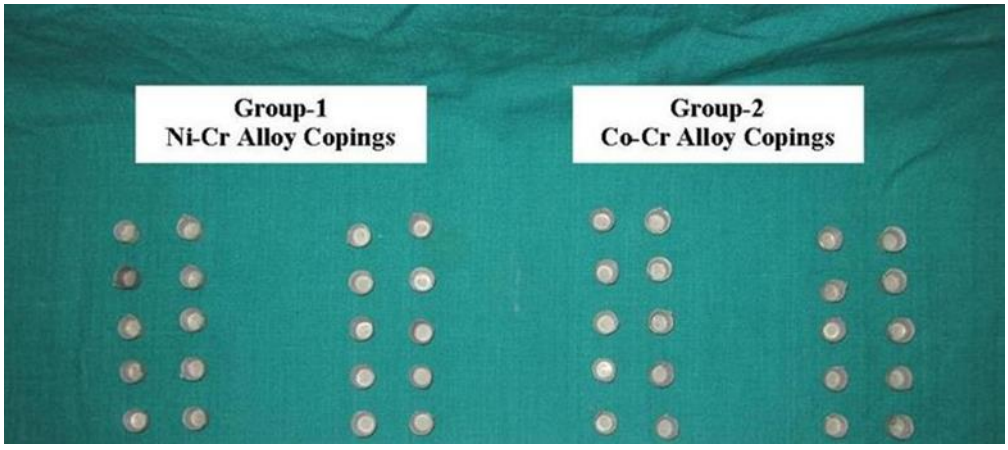


Figure7: Final copings

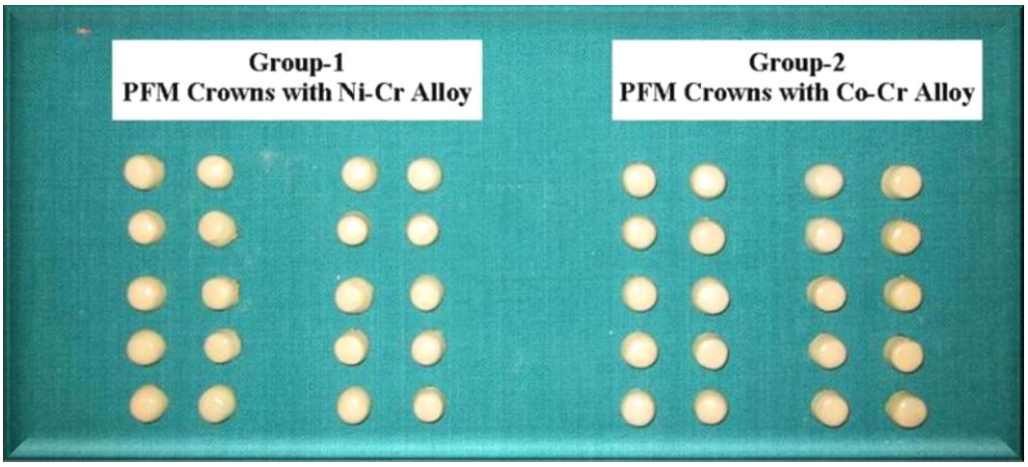


Figure 8: Final PFM crowns

Results

After statistical analysis of the data median, minimum, & maximum values for each group were calculated.

The median value for Ni-Cr copings before porcelain firing was 48.13 um while the minimum and maximum values were 31.19 um and 70.59 um.

The median value for Co-Cr copings before porcelain firing was 95.33 um while the minimum and maximum values were 74.32um and 145.76 um.

The median value for Ni-Cr copings after porcelain firing was 52.87 um while the minimum and maximum values were 35.70um and 72.78um.

The median value for Co-Cr copings after porcelain firing was 100.04 um while the minimum and maximum values were 78.98um and 148.64um.

Wilcoxon signed-rank test showed a median difference of 4.74 um and 4.71 um in a vertical marginal discrepancy of Ni-Cr and Co-Cr copings before and after porcelain firing

Statistically significant difference (P<0.001) was found in a mean vertical marginal discrepancy of Ni-Cr& Co-Cr alloy copings before and after porcelain firing.

On comparison of the vertical marginal discrepancy between Ni-Cr & Co-Cr copings before and after porcelain firing Mann Whitney test showed a difference of 47.20 um and 47.17 um before and after porcelain firing (Table 1).

Table 1. Intragroup (Wilcoxon Sign rank test) and intergroup (Mann Whitney Test) comparison of vertical marginal discrepancy before and after porcelain firing.

Group	Time				p-value
	Before		After		
	Median (IQR)	Range (Min Max)	Median (IQR)	Range (Min Max)	
Ni-Cr Alloy	48.13 (18.67)	31.19-70.59	52.87 (17.91)	35.7-72.78	<0.001
Co-Cr Alloy	95.33 (37.44)	74.32-145.76	100.04 (34.82)	78.98-148.64	<0.001
p-value	<0.001		<0.001		

IQR:Interquartilerange

Discussion

The accuracy of fit of casting is essential for longevity and clinical success of the cast restoration in the oral cavity. The castings considered clinically and radiographically acceptable with marginal discrepancies ranging from 10 to 160um (5).

Many research studies in past have been done on evaluation of the marginal fit of crowns made from different alloys i.e. high noble metal alloys, noble metal alloys, base metal alloys. The Ni-Cr alloy has enjoyed the

popularity of base metal alloy for porcelain fused to metal restorations for many years, because of its properties like, higher modulus of elasticity which decreases the minimum thickness of the copings of 0.5 to 0.3 compared with that of noble metal alloys, comparable coefficient of thermal expansion with that of porcelain which causes decreases crack propagation in the ceramics after multiple firing cycles. But around 28.5% of U.S.A. population is allergic to Nickel (6) and no Indian data is available for the same. On the contrary, Cobalt-Chromium alloy which is widely used for the cast partial dentures has many promising properties. Cobalt increases the elastic modulus and strength to higher levels than nickel (7,8). Molybdenum is added to lower the thermal expansion coefficient and adds to the corrosion resistance. In vitro electrochemical and dissolution studies have shown Co-Cr alloys to be more corrosion-resistant than the Ni-Cr family of alloys (9,10). From these data, it can be concluded that Co-Cr alloys are a suitable substitute for fixed prosthetics, and should no longer be limited to partial dentures (11).

The purpose of the present study is to evaluate and compare the vertical marginal discrepancy of Ni-Cr and Co-Cr alloys before and after porcelain firing.

Many authors have studied marginal discrepancy of various base metal alloys with different techniques such as casting, laser sintering, cad cam and found consistent results within the range of this study (12-19).

After final coping fabrication, it is subjected to repeated firing cycles for porcelain application. This study shows the median vertical marginal discrepancy before and after porcelain firing for Ni-Cr alloy was 48.13 and 52.87um respectively, and that for Co-Cr alloy was 95.33 and 100.04um respectively.

Another theory contends that during the cooling phase of the firing cycle, any differential in the rate of contraction between the metal substructure and the adhering porcelain produces interfacial stress. This stress then acts to deform the restoration which produces marginal discrepancy (6). Disha Saraswathi D et al. (20) had compared the vertical marginal discrepancies of full zirconia crowns, layered zirconia crowns, & metal ceramic crowns & found that marginal discrepancy of full zirconia crown was less than the layered zirconia crown & metal-ceramic crown. Dederich (21) has done a similar study but found a much lesser degree of marginal opening after porcelain firing compared to the study of Buchanan. In Kocaagaoglu et al. (22) study after application of veneering ceramic, statistically significant differences were found in the increase of marginal discrepancy in the laser sintered group in comparison to conventional casting, hard metal milling, & soft metal milling groups of Co-Cr alloy.

In the present study, the median vertical marginal discrepancy of Co-Cr alloy copings after porcelain firing was 100.04 um while that before porcelain firing was 95.33 um. This rather larger increase in marginal discrepancy compared to that of before and after the change in the marginal discrepancy of Ni-Cr alloy coping may be attributed to the strength of the alloy. These results are the same as that of the Buchanan study in which the marginal opening was more in the specimen made from the higher strength metal than it did in those made from the lower strength metal. This large change in the marginal opening of the higher strength alloy may be explained by the thicker metal-oxide layer which could have formed on the inside of the non- precious metal castings during the various thermal cyclings.

The Co-Cr alloy has higher melting range than that of Ni-Cr alloy and hence it has higher solidification shrinkage than the latter which is responsible for more marginal discrepancy than Ni-Cr alloy (23).

The results of this study showed that Co-Cr alloy PFM restorations have double vertical marginal discrepancy compared to Ni-Cr alloy restorations but both the values can be considered within the clinical acceptability range of (100-120 um) the marginal discrepancy. Both Ni-Cr and Co-Cr alloy have advantages and disadvantages of their own with respect to physical and biological properties. A major concern regarding Ni-Cr alloys is its lesser corrosion resistance. The degree of corrosion, which results when one or more components of the alloys are oxidized, is critical to the long-term success of a fixed prosthesis for several reasons. As a restorative dentist, we should know merits and demerits of each type of dental material and should select the one which is more physiologically compatible with a particular patient or particular clinical situation. Hence, Co-Cr alloy can be selected in restorations with supragingival or equi-gingival margins, in patients having higher caries susceptibility, and in long-span fixed partial dentures where higher strength properties of the material are desired. It can also be used if the patient has an allergic history with Nickel alloys. Ni-Cr alloy can be used more prevalently and also in subgingival restorations. In every technique, whether it is laser sintered, conventional casting, soft metal milling, hard metal milling, & accelerated casting marginal discrepancy takes place after porcelain firing (24,25,26). Integrity in all casting steps results in precise fit of casting (27). Further longitudinal studies are required to evaluate the longevity and marginal deterioration of these two materials to conclude the better choice between these two.

Conclusion

After statistical analysis and thorough discussion, within the limitations of the present study, following conclusions were drawn:

Statistically significant difference ($p<0.001$) was found in the median vertical marginal discrepancy of Ni-Cr alloy (48.13 um) copings & Co-Cr alloy (95.33 um) copings before porcelain firing.

Statistically significant difference ($p<0.001$) was found in the median vertical marginal discrepancy of Ni-Cr alloy (52.87 um) copings & Co-Cr alloy (100.04 um) copings after porcelain firing.

The median vertical marginal discrepancy of Ni-Cr & Co-Cr alloy copings after porcelain firing (52.87 um & 100.04 um) was significantly ($p<0.001$) higher than vertical marginal discrepancy before porcelain firing (48.13 um & 95.33 um).

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Conflict of Interest

The authors of this manuscript certify that they have no conflict of interest

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