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## **The role of coping material type and collarless margin design toward fracture resistance of metal porcelain restoration**

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**Abstract**---Aims: Metal-porcelain restoration is currently the most popular restoration that can be used for the anterior teeth. However the collar coping design on facial margin gingiva causes dark and shadowed zone in gingival, which is called "Umbrella Effect". This situation can be overcome by using collarless coping design. But this coping design has weaknesses such as decrease the fracture resistance of restoration. In some previous studies, the type of coping material can also affect fracture resistance. This study aimed to determine the effect of the coping material type and collarless margin design on the fracture resistance of restoration. **Material and Method:** A total of 24 samples of metal-porcelain restorations from two material types and designs were fabricated and cemented on 24 metal dies. The study was divided into four groups; Group A with Ni-Cr and Full Metal Collarless, Group B with Ni-Cr and Modified Metal Collarless, Group C with Co-Cr and Full Metal Collarless, and Group D with Co-Cr and Modified Metal Collarless. The measurement of fracture resistance

was carried out using universal testing machine (Torse UTM AMU-10, Tokyo, Japan) at a crosshead speed of 0.05 mm/minute. Loading point was applied at an angle of 45° until the porcelain layer fractured. Result: The mean value and standard deviation of fracture resistance are 867,68 ± 187.68 N in Group A, 753,62±125.97 N in Group B, 1775,89±470.67 N in Group C, and 1152,62±218.14 N in Group D. Independent T-Test show there is a significant effect between groups A and C, groups B and D, Groups C and D (P<0,05) while there is a nonsignificant effect between groups A and B (P>0,05). Conclusion: the Co-Cr coping material with the modified metal collarless coping design has good fracture resistance and is still above the maximum value of human incisor strength and is clinically acceptable.

**Keywords**---coping material, coping design, fracture resistance, metal porcelain restoration.

## Introduction

Many dentists still prefer porcelain fused to metal for anterior restoration although various types of all-ceramic crown system has been introduced to dentistry. Porcelain fused to metal crown is a restoration that combines the strength of the alloy, the aesthetics of porcelain and the affordable price.<sup>1,2</sup> For years clinicians have used high noble alloys in the manufacture of coping porcelain metal crowns. This alloy has good biocompatibility properties and corrosion resistance. However, the use of these alloys in dentistry was limited due to the rising cost of gold during the 1980s and after the global financial crisis in 2008. Therefore, predominant alloys were used instead of high noble alloys. Predominant alloys have high rigidity properties with a high modulus of elasticity so that they can be made thin but still have good strength. The alloys used in the manufacture of porcelain metal crowns are Nickel Chromium (Ni-Cr) and Cobalt Chromium (Co-Cr).<sup>3,4</sup>

The use of Ni-Cr alloys as metal coping materials in the manufacture of porcelain metal crowns is the most commonly used. However, there are doubts about the biocompatibility of Ni-Cr alloys due to the release of Ni ions during the corrosion process. Nickel is the most allergenic metal of all metallic elements and nickel sensitivity is considered as a potential clinical effect of the alloy.<sup>4</sup> Therefore, Co-Cr alloys are used as substitutes where it have heat resistance, non-magnetic properties, modulus of elasticity. high and has good resistance to wear, corrosion and is more biocompatible than Ni-Cr.<sup>3,5,6</sup>

Another problem that arises in porcelain metal crown restorations on anterior teeth is the appearance of black shadows in the cervical area (umbrella effect)<sup>4</sup>. The researchers modified the metal collar design by shortening the metal collar from the labial edge so that the dark color of the metal could be masked by the thickness of the porcelain. However, the weakness of this design is that fracture resistance decreases due to reduced metal support, from several studies it was found that the best metal collar designs to overcome the umbrella effect are full

metal collarless and modified metal collarless. Several studies have shown varying fracture resistance results against these two designs.<sup>4,7</sup> This study evaluates the influence of the type of coping material and collarless margin design on the fracture resistance of porcelain metal crowns.

### Material and Methods

In this study, two types of coping materials were used, Co-Cr and Ni-Cr alloys with two collarless margin designs, *Full Metal Collarless* and *Modified Metal Collarless*. The sample consists of four groups, Group A; Ni-Cr alloy with *Full Metal Collarless* design, Group B; Ni-Cr alloy with *Modified Metal Collarless* design, Group C; Co-Cr alloy with *Full Metal Collarless* and Group D design; Co-Cr alloy with *Modified Metal Collarless* design. Metal die manufacture obtained by preparation the tooth structure of the typodont according to the procedure and the thickness of the tooth preparation recommended by Shillingburg et al. (2012) and Rosenstiel et al. (2006), a 2 mm reduction in the incisal area; making depth guides as a guide for preparation in the 1.5 mm labial area; reduction of the proximal and palatal areas of 1 mm, and resulted in a 1.5 mm shoulder margin in the labio-marginal to mesio-distal region and fused to the palatal region (Fig. 1A).

Afterward, typodont tooth was mounted into a square metal block (3 cm × 3 cm × 3 cm) containing putty polyvinyl siloxane (PVS) impression material and light body PVS (I-SiL, Spident, Korea). The mold was filled self-cured acrylic resin (Hilton, Japan). Twenty-four resin teeth were obtained from the mold and then sprued with soft wax inlay (Violet, Tokyo Japan). Thereafter, they were mounted into phosphate-bonded investment material (Deyuan, China), and casting procedures were done by using nickel-chromium/Ni-Cr alloy (Ker-N, Eisenbacher Dental, Germany) in order to get 24 analog teeth. In addition, the metal analog teeth were coated with wax and planted vertically into a square block (3 cm × 3 cm × 3 cm) containing self-cured acrylic resin up to 1 mm apical from the cemento-enamel junction. After the resin block had been set, the wax layer on the tooth root was melted by boiling water. The distance between the root of the tooth and the resin block was filled with silicone paste (Clear RTV Silicone, Permatex, USA). The procedure was carried out on 24 metal analog teeth, resulting in 24 metal dies (Fig. 1B)

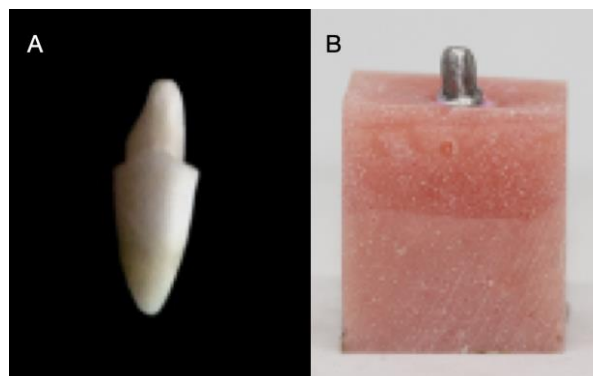


Fig.1 A. Typodont tooth preparation , B. Metal die planted on resin block

In the coping procedure, two layers of spacers are applied to the entire surface of the metal except 1mm in the marginal area. Green inlay covered limitedly on the cavosurface angle with the thickness of 0.3 mm for Group A and C, While on Group B and D, green inlay wax was trimmed 1.5 mm above the cavosurface angle. The measurements above were carried out using a wax caliper (Caliper Iwanson, Medesy, Italy). Then, the wax sprues were placed on the incisor surface of the wax pattern and invested in a phosphate-bonded investment material which had been mixed in a vacuum mixer (Mixyvac, Manfredi, Italy). The casting procedure was carried out with Ni-Cr alloy. Afterward, the finishing of metal coping was carried out using rotary instruments and sprayed with 50  $\mu\text{m}$  alumina sand on a sandblasting machine (Blasty, Manfredi, Italy). The thickness and expansion of metal coping on the labiomarginal surface was measured with digital vernier calipers (Mitutoyo Co, Kawasaki, Japan). (Fig 2A dan 2B)

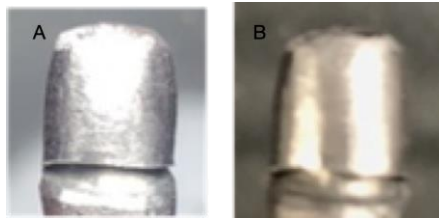


Fig. 2A. Full Metal Collarless Design

### **Modified Metal Collarless Design**

In the Build Up procedure using porcelain (VITA VMK Master, VITA Zahnfabrik, Germany). In each group, opaque and dentin were applied. Then in groups A and C the enamel layer was only applied to the coronal 2/3 area, while in groups B and D the enamel was applied with a thickness of 0.3 mm. The Combutions using a Vacuum Furnace (VITA Vacumat 40, VITA Zahnfabrik, Germany) which was set at 950<sup>o</sup> C and the temperature was lowered according to the combustion scheme of the manufacturer's instructions. In groups B and D, porcelain was applied using the direct lift technique. All samples were contoured with abrasive wheels. Measurements were made using a digital caliper to ensure the total thickness of the metal and porcelain was 1.5 mm. Then all samples were glazed.

The intaglio surface of the restorations and the surface of metal die were sprayed with 50  $\mu\text{m}$  alumina sand and immersed in ultrasonic cleaner (Fulgor, Med. Pro 3.5 lt, Italy) with distilled water for 10 min and dried in room temperature. Afterward, the restorations were cemented on each metal dies with glass ionomer cement (Fuji 1, GC, Japan) which was mixed in accordance to the manufacturer's instructions. (Fig 3)



Fig 3. Porcelain metal restoration cemented in metal die

All samples were tested using universal testing machine (Torsee UTM AMU-10, Tokyo, Japan). The sample was placed at an angle of 45° from the long axis of the tooth, and the pressure was applied at 2 mm below the incisal end of the palatal surface to simulate contact from the mandibular incisor (Figure 5). This was based on the normal occlusion of Class I angle of the average adult.<sup>8</sup> A metal rod with a diameter of 3 mm with crosshead speed of 0.05 mm/min was used during the test until the porcelain was fracture.

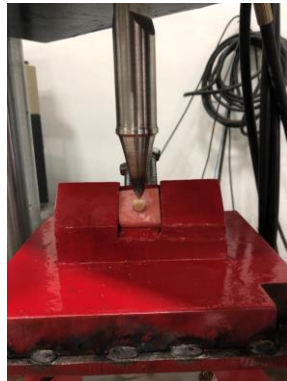


Fig 4. The position of sample testing on universal testing machine

Statistical analysis (IBM SPSS, version 21 × 86, Indonesia) was carried out using Independent T-Test.

### Result

The values of fracture resistance recorded in computerized by the form of Kilogram-Force were converted into Newton (N), Table 1 shows the mean and standard deviation values of the fracture resistance of porcelain metal crown restorations.

Table 1. Fracture resistance test results for metal-porcelain restorations

NO.	Fracture Resistance (Newton)			
	<i>Full Metal Collarless</i>		<i>Modified Metal Collarless</i>	
	Ni-Cr	Co-Cr	Ni-Cr	Co-Cr
1	924,24	1688,11	859,17	1197,22**

2	629,96*	2417,84**	916,78**	1191,34
3	782,31	1229,18*	715,52	924,80
4	1146,2**	1545,58	620,112	1355,29
5	736,22	2281,71	798,875	859,17*
6	987,15	1492,92	611,273*	1387,9
$\bar{x} \pm SD$	867,68±187,68	1775,89±470,67	753,62±125,97	1152,62±218,14

Description: \* smallest value \*\* greatest value

Table 2 shows the effect of Ni-Cr and Co-Cr coping materials with full metal collarless coping design on fracture resistance of porcelain metal crowns. From the results of the Independent T-test obtained a significance of  $p = 0.004$  ( $p < 0.05$ ), this indicates that there is a significant effect of Ni-Cr and Co-Cr coping materials with full metal collarless coping design on the fracture resistance of porcelain metal crowns.

Table 2. Effect of Ni-Cr and Co-Cr Coping Materials with Full Metal Collarless Coping Design on Fracture Resistance of Porcelain Metal Crowns

Coping Material	Fracture Resistance of Porcelain Metal Retoration <i>Full Metal Collarless Design (N)</i>		
	n	$\pm SDX$	p
Ni-Cr	6	867,68 ± 187.68	0,004*
Co-Cr	6	1775,89 ± 470.67	

Table 3 shows the effect of Ni-Cr and Co-Cr coping materials with modified metal collarless coping design on fracture resistance of porcelain metal crowns. From the results of the Independent T-test obtained a significance of  $p = 0.003$  ( $p < 0.05$ ), this indicates that there is a significant effect of Ni-Cr and Co-Cr coping materials with modified metal collarless coping design on the fracture resistance of porcelain metal crowns.

Table 3. Effect of Ni-Cr and Co-Cr Coping Materials with Modified Metal Collarless Coping Design on Fracture Resistance on Porcelain Metal Crowns

Coping Material	Fracture Resistance of Porcelain Metal Retoration <i>Modified Metal Collarless Design (N)</i>		
	n	$\pm SDX$	p
Ni-Cr	6	753,62 ± 125,97	0,003*
Co-Cr	6	1152,62 ± 218,14	

Table 4 show the effect of full metal collarless and modified metal collarless coping designs with Ni-Cr coping materials on fracture resistance of porcelain metal crowns. From the results of the Independent T-test, the significance of  $p = 0.245$  ( $p > 0.05$ ), this shows that there is no effect of the full metal collarless and modified metal collarless coping design with the type of Ni-Cr coping material.

Table 4 The Effect of Full Metal Collarless and Modified Metal Collarless Coping Designs with Ni-Cr Coping Materials on Fracture Resistance on Porcelain Metal Crowns

Coping Design	Fracture Resistance of Porcelain Metal Retoration Coping Material (Ni-Cr) (N)		
	n	± SD $\bar{X}$	p
<i>Full Metal Collarless</i>	6	867,68 ± 187,68	0,245
<i>Modified Metal Collarless</i>	6	753,62 ± 125,97	

Table 5 show the effect of the Full metal collarless and Modified metal collarless coping design with the Co-Cr type of coping material on the fracture resistance of porcelain metal crowns. From the results of the Independent T-test obtained a significance of  $p = 0.015$  ( $p < 0.05$ ), this indicates that there is a significant effect of the full metal collarless and modified metal collarless coping design with the type of Co-Cr coping material.

Table 5. Effect of Full Metal Collarless and Modified Metal Collarless Coping Design with Co-Cr Coupling Materials on Fracture Resistance of Porcelain Metal Crowns

Coping Design	Fracture Resistance of Porcelain Metal Retoration Coping Material (Co-Cr) (N)		
	n	± SD $\bar{X}$	p
<i>Full Metal Collarless</i>	6	1775,89 ± 470,67	0,015*
<i>Modified Metal Collarless</i>	6	1152,62 ± 218,14	

## Discussion

In this study, two types of collarless margin coping designs were compared, full metal collarless and modified metal collarless. The purpose of this collarless design is to overcome the umbrella effect caused by metal shadows on the coping collar design, causing aesthetic problems in the anterior teeth. Several studies have found that the best metal collar designs to overcome the umbrella effect are full metal collarless and modified metal collarless.<sup>7,8,10,11</sup> In this study, two types of Co-Cr and Ni-Cr coping materials were compared. The use of Ni-Cr as a metal coping material in the manufacture of porcelain metal crowns is the most commonly used. However, there are doubts about the biocompatibility of Ni-Cr alloys due to the release of Ni ions during the corrosion process. Nickel is the most allergenic of all metallic elements and nickel sensitivity is considered a potential clinical effect of this alloy.<sup>4</sup> Therefore, clinicians are now using other predominant base alloys such as Co-Cr for the manufacture of porcelain metal crowns. several studies stated that Co-Cr has heat resistance, non-magnetic properties, high modulus of elasticity and has good resistance to wear, corrosion and is more biocompatible than Ni-Cr.<sup>3,5,6</sup>

Table 2 shows the results of the analysis using an independent T-test which stated that there was a significant effect of Ni-Cr and Co-Cr coping materials with a full metal collarless coping design on the fracture resistance of porcelain metal crowns  $p=0.004$  ( $p<0.05$ ). This is because the Co-Cr alloy has a higher modulus of elasticity than Ni-Cr. The modulus of elasticity determines the resistance to stress, also contributes to maintaining the integrity of the porcelain; the higher the modulus of elasticity, the less bending of the metal structure under load and the lower the chance of cracking porcelain, which is very sensitive to bending forces.<sup>13</sup> Fracture resistance is also affected by the thickness of the oxide layer. The oxide layer plays an important role in the bonding between metal and porcelain. From previous research, it was found that Co-Cr produces an oxide layer that binds strongly to porcelain compared to Ni-Cr. The metal composition also affects the fracture resistance of a restoration. Where Co, Mo and Cr function to increase the strength of Co-Cr and make this metal lighter. New metal components are also added in Co-Cr, such as Ce, Ga, and Nb, to provide fluidity, control thermal expansion, and modify the oxidation characteristics of these alloys to form better porcelain metal bonds.<sup>4</sup>

Table 3 shows the results of the analysis using an independent T-test which stated that there was a significant effect of Ni-Cr and Co-Cr coping materials with modified metal collarless coping designs on the fracture resistance of porcelain metal crowns  $p= 0.003$  ( $p<0.05$ ). This happens because Co-Cr has better Yield strength than Ni-Cr. Yield strength is the strength value most commonly used to compare alloys. Yield strength is the force per unit area (stress) required to permanently distort an alloy. The unit of yield strength is megapascals (MPa) which is accompanied by a total distortion of <sup>12</sup>. Yield strength is very important from a clinical perspective, because a higher yield strength value will protect the metal-porcelain system from the initiation of plastic deformation and the occurrence of porcelain debonding, especially in the cervical region where the thin. Where the Yield strength value for Co-Cr is 870 mpa while Ni-Cr is 710 mpa. Due to the higher yield strength of Co-Cr than Ni-Cr alloys, it can support porcelain elongation in cervical areas that are not supported by metal.<sup>4</sup>

Table 4 shows the results of the analysis using an independent T-test which stated that there was no effect of the full metal collarless and modified metal collarless coping design with Ni-Cr coping material on the fracture resistance of porcelain metal crowns  $p=0.245$  ( $p>0.05$ ). Several previous studies showed that the design of full metal collarless and modified metal collarless with Ni-Cr coping materials showed insignificant results because the thickness of the porcelain layer in the marginal area had exceeded the minimum thickness of porcelain and did not exceed the minimum thickness limit of metal-porcelain restorations, ranges from 1.2 – 1.5 mm, so that full metal collarless and modified metal collarless restorations also have high fracture resistance.<sup>7,8</sup>

Table 5 shows the results of the analysis using an independent T-test which states that there is a significant effect of the Full metal collarless and modified metal collarless coping design with Co-Cr coping material on the fracture resistance of the porcelain metal crown  $p=0.015$  ( $p<0.05$ ). In this study, the full metal collarless design showed a higher fracture resistance value than the modified metal collarless design because the metal still supports the entire

porcelain to the labial portion of the tooth preparation structure so that fracture resistance increases as well as material properties and good oxide layer formation on Co-Cr thereby increasing bonding. alloy and porcelain.<sup>1,4,13</sup>

### Conclusion

Metal-porcelain restoration with Co-Cr coping material and modified metal collarless coping design has good aesthetic value, high fracture resistance, good marginal adaptation and Co-Cr alloy has better biocompatible properties than Ni-Cr so it can be an alternative substitute for Ni-Cr alloys. Therefore, metal-porcelain restorations with a collarless metal modified coping design with metal-coupling reduction in the labio-marginal area by 1.5 mm can be recommended for patients who are indicated to wear metal-porcelain restorations on anterior teeth as the final restoration of a prosthodontic treatment. , so that satisfactory results are obtained in terms of mechanics and aesthetics for both dentists and patients.

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