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EFFECT OF REPEATED FIRING OF PORCELAIN FUSED TO METAL ON PORCELAIN COLOR CHANGE

PENGARUH PEMBAKARAN BERULANG PORCELAIN FUSED TO METAL TERHADAP PERUBAHAN WARNA PORSELEN

Original Research Article
Penelitian

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ABSTRACT

Background: *The color of the porcelain surface is the main criterion for achieving perfect aesthetics. A factor that influences the color is the amount of firing of the porcelain.* ***Purpose:*** *To determine the color change of porcelain after repeated firing four times.* ***Method:*** *The research specimens consisted of 6 metals coated with Classic porcelain and 6 metals coated with Noritake porcelain and were subjected to four firing stages, then each stage was fired four times. The color change value was measured using VITA Easyshade. Statistical analysis using ANOVA.* ***Result:*** *The Classic and Noritake groups experienced a significant increase in color change from 1st to 2nd burning and from 1st to 3rd burning with a p-value < 0.05. There is a significant difference in the color change value based on the repetition of porcelain firing with a significance value of 0.000 < 0.05. There is a significant difference in the color change value based on porcelain products with a significant value of 0.020 < 0.05. There is no significant effect between repeated firing on porcelain and porcelain products in affecting the color change value with a significance value of 0.143 > 0.05.* ***Conclusion:*** *Both product groups experienced an increase in color change from firing 1st to 2nd and from firing 1st to 3rd. There was no increase in color change from firing 2nd to firing 3rd. There are significant differences in color change values based on porcelain products and there is no significant effect between repeated firing on porcelain and porcelain products on affecting color change values.*

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ABSTRAK

Latar belakang: Warna gigi tiruan porcelain fused to metal merupakan kriteria utama untuk mencapai estetika. Pembakaran berulang pada porcelain dapat mempengaruhi warna. **Tujuan:** Untuk mengetahui jumlah pembakaran yang disarankan untuk mendapatkan estetika. **Metode:** Spesimen penelitian terdiri dari 6 logam dilapisi porcelain *Classic* dan 6 logam dilapisi porcelain *Noritake* dan dilakukan empat tahap pembakaran selanjutnya masing-masing tahap dibakar sebanyak empat kali. Nilai perubahan warna diukur dengan menggunakan *VITA Easyshade*. Analisis statistik menggunakan ANOVA. **Hasil:** Kelompok *Classic* dan *Noritake* mengalami peningkatan perubahan warna yang signifikan dari pembakaran ke-1 ke pembakaran ke-2 dan dari pembakaran ke-1 ke pembakaran ke-3 dengan nilai *p-value* < 0,05. Terdapat perbedaan nilai perubahan warna yang signifikan berdasarkan pengulangan pembakaran porcelain dengan nilai signifikan 0.000 < 0.05. Ada perbedaan yang signifikan pada nilai perubahan warna berdasarkan produk porcelain dengan nilai signifikan 0.020 < 0.05. Tidak terdapat pengaruh yang signifikan antara pengulangan pembakaran pada porcelain dan produk porcelain dalam mempengaruhi nilai perubahan warna dengan nilai signifikan 0.143 > 0.05. **Kesimpulan:** Kedua kelompok produk mengalami peningkatan perubahan warna dari pembakaran 1 ke pembakaran 2 dan dari pembakaran 1 ke pembakaran 3, tidak ada peningkatan perubahan warna dari pembakaran 2 ke pembakaran 3. Terdapat perbedaan nilai perubahan warna yang signifikan berdasarkan produk porcelain dan tidak terdapat pengaruh yang signifikan antara pengulangan pembakaran pada porcelain dan produk porcelain dalam mempengaruhi nilai perubahan warna.

Kata kunci:
Perubahan warna, *Metal porcelain*, Pembakaran berulang

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INTRODUCTION

A beautiful smile will look perfect if the teeth look neat, clean, aligned and as one of the most important aspects in communicating (Demirel and Tunçdemir, 2023). Teeth are an important organ in the body that has a chewing function that people use every day (Nuraeni and Fitriyani, 2023). Loss or damaged teeth will have an impact to the aesthetics, and it will affect the confidence aspect and social activities. Furthermore, teeth have function to masticate the food, maintain the perfect shape of the face, and also help pronunciation aspects in speaking (Afkhami *et al*., 2019; Alfarisa, 2020). Loss of teeth can also occur, this causes the chewing process to become imperfect, which has an impact on digestive health (Siagian, 2016). Fixed restorations are one of the various types of restoration that can be an alternative replacement for missing teeth (Laoh *et al*., 2016). Fixed restoration can replace part or all of the tooth surface that has a problem or is damaged, one important factor that can affect the aesthetics of artificial teeth is the color of the material used (Amir Rad *et al*., 2015; Demirel and Tunçdemir, 2023).

One of the materials to make fixed restorations is porcelain (Hidayatin *et al*., 2019). Fixed restoration made from porcelain material looks more natural and has superior biomechanics (Swapna *et al*., 2018; Mohamed *et al*., 2020). Porcelain is a material made from kaolin, feldspar, silica and various pigments (Warreth and Elkareimi, 2020). Porcelain fused to metal restorations has a higher strength and hardness compared to all other porcelain restorations and the color is easily matched to the color of natural teeth (Gunawan *et al*., 2017; Rosenstiel *et al*., 2006). The color of porcelain restoration is greatly influenced by the manufacturing process, expertise in combining porcelain core materials and firing temperature are the main factors to create aesthetic restorations (Kumar *et al*., 2017).

The process of making fixed restoration involves duplicating the morphological appearance of the natural teeth and is a complex process that requires careful control of shape, surface texture, and color (Swapna *et al*., 2018). The making of porcelain fused to metal restoration has many procedures and it can cause some errors, one of the procedures that must be carried out is building up with porcelain powder and firing (Manappallil, 2015). The firing process during the build-up process will affect the color change because repeated firing has a negative impact on the surface structure of the porcelain and causes discoloration (Yılmaz *et al*., 2014; Swapna *et al*., 2018), the occurrence of color change can be influenced by the thickness of the porcelain layer (Elbasuny *et al*., 2021). One of the successes of dental technicians in making porcelain restoration is the stability of the porcelain color because this is a guarantee for the long term. The porcelain color measurement system can be done in several ways, including visual methods or observing objects directly or by using instruments or tools to measure the color of an object. In Commission Internationale de l'Eclairage L^*, a^*, b^* (CIELab), L^* represents value or lightness (Alnassar, 2022).

Based on the results of a preliminary study, porcelain firing was carried out more than five times, 36.4% stated this was done for porcelain color correction. This research is important to determine the color changes of porcelain fused to metal restoration. They are fired repeatedly so that the manufacturing procedure is carried out correctly to prevent correction of anatomical shape and color.

MATERIAL AND METHOD

In this research, two types of porcelain were used, IPS Classic metal porcelain and Noritake metal porcelain. Each group consisted of six specimens, so total of 12 specimens were prepared. The shape of the specimen is a disk with 2 mm of thickness and the diameter is 10 mm (Yılmaz *et al*., 2014). Nickel-chrome (0.5 mm thickness), was used as a coating. The thickness of porcelain veneers was 1.5 mm then fired in an ivoclar programmat P300 furnace oven (Figure 1). Specimens were made from porcelain Classic® with A3 shade and porcelain Noritake® A3 shade are presented on Figure 2 and Figure 3. This sample was made by porcelain fused to metal restoration method. There are two groups, the first uses materials porcelain Classic® shade A3, with first firing (as a control), the second firing and, the third firing as a treatment group, and the second group used porcelain Noritake®A3 shade with first firing (as control), second firing and third firing as treatment group.

In this research, color testing used VITA Easyshade® (Figure 4) and was carried out periodically. After the first stage of firing, color testing was carried out on both groups of porcelain as a control. After the second stage of firing, a second color test was carried out, and after the third stage of firing, a third color test was carried out.

Testing was carried out by placing the specimen in a mini-studio that had been given a white base with room lighting, then the tip was attached to the center of the specimen that had been determined. After that, the L*, a*, b* values that will appear on the tool monitor screen VITA Easyshade® were recorded. The values obtained were calculated using a Formula 1.

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \qquad (1)$$

Information, ΔE^*: color change Value, ΔL^*: $L_0 - L_1$ (after firing – before firing), Δa^*: $a_0 - a_1$ (after firing – before firing), Δb^*: $b_0 - b_1$ (after firing – before firing). L^*: light color coordinates (value/lightness), a^*: red (+)

and green (-) color coordinates, b*: yellow (+) and blue (-) color coordinates. Statistical analysis of the research results was carried out using Shapiro-Wilk and ANOVA with a significance level of p-value < 0.05, to determine the value of color change and the level of difference in color change.

Figure 1. Firing process porcelaian fused to metal

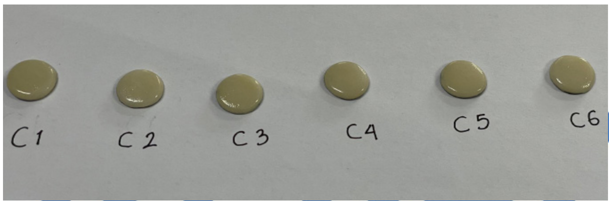

Figure 2. Specimen porcelaian fused to metal Classic® shade A3

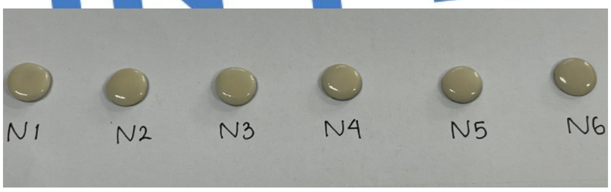

Figure 3. Specimen porcelaian fused to metal Noritake® shade A3

Figure 4. VITA Easyshade® (Source: VITA Easyshade®)

RESULT

Based on Table 1, it shows the average value of color change (ΔE) that has been tested using the VITA Easyshade - V® tool. The results of the color change assessment test (ΔE) after statistical analysis test resulted in different mean values. The Classic product group in the first shooting (as control) produced a mean value of 0.0000 ± 0.0000, the Classic product group in the second shooting produced a mean value of 4.6790 ± 2.2869, and the Classic product group in the third shooting produced a mean value of 4.8614 ± 2.457. While the Noritake product group in the first firing (as control) produced a mean value of 0.0000 ± 0.0000, the Noritake product group in the second firing produced a mean value of 1.4834 ± 1.0234, and the Noritake product group in the third firing produced a mean value of 3.3476 ± 3.1378.

The results on Classic materials show there is a significant increase in color change (ΔE) from firing 1 (initial) to firing 2, because 0.012 < 0.05, there is a significant increase in color change (ΔE) from firing 1 (initial) to firing 3, because 0.014 < 0.05, but there is no significant increase in color change (ΔE) from firing 2 to firing 3, because 0.374 > 0.05. Based on Table 2, can also be seen that for the increase in color change ΔE of Noritake product ingredients there is a significant increase in color change (ΔE) from firing 1 (initial) to firing 2 because 0.016 < 0.05, there is a significant increase in color change (ΔE) from firing 1 (initial) to firing 3 because 0.047 < 0.05, but there is no significant increase in color change (ΔE) from firing 2 to firing 3 because 0.233 > 0.05.

The results of the research obtained results showing Classic porcelain from firing 1 (initial) to firing 2, experienced a significant increase in color change (ΔE) because 0.012 < 0.05. Firing 1 to firing 3 also saw a significant increase in color change (ΔE) because 0.014 < 0.05. However, there was no significant increase in color change (ΔE) from firing 2 to firing 3, because 0.374 > 0.05. Meanwhile, Noritake porcelain from firing 1 to firing 2 experienced a significant increase in color change (ΔE) because it was 0.016 < 0.05. Next, from firing 1 to firing 3 experienced a significant increase in color change (ΔE) because 0.047 < 0.05. However, there was no significant increase in color change (ΔE) from firing 2 to firing 3 because 0.233 > 0.05.

Based on Table 3, the results show a significance value of 0.000 < 0.05, so it can be concluded that there is a significant difference in the value of color change (ΔE) based on repeated firing of porcelain. A significance value of 0.020 < 0.05 was obtained, so it can be concluded that there is a significant difference in the value of color change (ΔE) based on the porcelain product used. A significance value of 0.143 > 0.05 was obtained, so it can be concluded that there is no significant effect between repeated firing of porcelain and porcelain products used in affecting the value of color change (ΔE).

Table 1. Mean value of the color change (ΔE) porcelain fused to metal samples in the Classic porcelain and Noritake porcelain firing groups 1, 2, 3

Specimen number	Classic firing			Noritake firing		
	1	2	3	1	2	3
1	.0000	2.6038*	2.8054	.0000	0.5385*	9.1263**
2	.0000	7.3192	7.9051**	.0000	3.3196**	4.4844
3	.0000	7.5703**	7.7343	.0000	1.1705	2.4228
4	.0000	2.7532	2.6344*	.0000	1.0488	1.7944
5	.0000	4.8177	5.0794	.0000	1.9925	1.7948
6	.0000	3.0100	3.0100	.0000	0.8307	0.2828*
Mean value ± SD	0.0000 ± 0.0000	4.6790 ± 2.2869	4.8614 ± 2.457	0.0000 ± 0.0000	1.4834 ± 1.0234	3.3476 ± 3.1378

Table 2. Repeated measures ANOVA test, increase in color change (δe) of Classic and Noritake porcelain firing group 1, 2 and 3

Classic group		**Firing**	
Firing	**1**	**2**	**3**
1		0.012*	0.014*
2			0.374
3			
Noritake group		**Firing**	
Firing	**1**	**2**	**3**
1		0.016*	0.047*
2			0.233
3			

* p-value < 0.05

Table 3. Two-way ANOVA test (p-value < 0.05), differences in discoloration value based on firing, product and firing-product interaction on porcelain discoloration value

Group	df	Mean square	Sig.
Based on firing	2	54.776	0.000
Based on product	1	22.179	0.020
Based on firing–based on product	1	7.666	0.143

DISCUSSION

The repeated firing process can increase the color change in porcelain fused to metal with Classic materials, influenced by factors such as material composition and firing temperature. This is in line with research by Ueda *et al*. (2021) which shows that repeated heating of porcelain materials for artificial teeth produces significant color changes. Their research also confirmed that increasing the temperature and firing time can cause significant color changes in porcelain, due to the chemical reactions that occur during the process. Firing porcelain up to six times can produce significant color changes (Barnard, 2021).

Fused to metal porcelain with Noritake material shows a similar pattern, although the color change is smaller than that of fused to metal with Classic material. This suggests that although there is a significant color change after heating, the level of color stability seems to be better than that of the Classic product. Research by Katada *et al*. (2024) showed that the material used in porcelain can affect the color change after heating, which could explain this difference. Vichi *et al*. (2023) showed that variations in the thickness of the opaque layer can result in significant differences in light absorption and reflection, leading to different color changes for each product group. This emphasizes that the heating process affects color and factors such as material design and application can play an important role in the final result. Both porcelain materials showed significant mean differences, implying that each product type has unique characteristics that affect the response to repeated firing. Research by Tabatabaian *et al*. (2016) emphasized the importance of statistical analysis in identifying significant differences in porcelain color studies. The significant increase in color change values from the second to the third firing for both types of porcelain suggests that there are certain limits to the effects of repeated firing. This may be due to the color stability already achieved after the second burn (Tabatabaian *et al*., 2016). It was also noted that, after a certain point, additional firing did not result in significant color changes, which emphasizes the importance of understanding the saturation point in the heating process.

Repeated firing has a clear impact on the discoloration of porcelain materials, where the firing temperature and time can trigger chemical reactions that contribute to visual changes. According to Ueda *et al*. (2021), increased firing temperature and duration can alter the glass structure of porcelain, which has a direct impact on the resulting color. Meanwhile, according to Özdemir and Duymus (2019), factors such as the thickness of the ceramic layer, firing parameters and temperature, and the amount of firing affect the aesthetics.

Repeated firing does not affect the type of porcelain material in affecting the color change value. Although there are significant differences in color change in both types of porcelain, the combined effect of the two factors does not produce significant changes. This is in line with research by Tabatabaian *et al*. (2016) which shows that the interaction between various factors in ceramic color studies only sometimes produces a significant cumulative effect.

CONCLUSION

Repeated firing of fused to metal porcelain with Classic and Noritake can affect the color change of porcelain. Increased firing temperature and duration contributed to significant color changes. Color changes in both porcelain materials occurred after the first firing to the second firing and the first firing to the third firing. Repeated firing has no effect on the type of porcelain material in affecting the color change value, although there is a significant difference in color change in both types of porcelain. Factors such as opaque layer thickness and material composition also play an important role in determining the final color characteristics. Each type of porcelain material has a variety of responses and unique characteristics after repeated firing. It is recommended that porcelain fused to metal firing be done in one firing to achieve pleasing aesthetics.

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