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To evaluate the variation in shade by a spectrophotometer of porcelain fused to metal samples with respect to repeated firing and variation in lot of ceramic – An in-vitro study



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ABSTRACT

Shade matching is an integral part of esthetic dentistry. Thus, this study was done to compare the variation in shade of standardized porcelain fused to metal samples after 5th, 7th and 9th firing with no repeated firing (control group) using a spectrophotometer. It also compared the variation in shade by changing the lot of ceramic of same dentinal shade. For the study 120 samples were made in the form of discs and subdivided into four groups for the required grouping. All the samples were gauged by Vernier caliper. Layering was done of the samples for wash opaque, shade opaque and lastly ceramic layer of dentine. 1st firing was wash opaque firing, 2nd firing – shade opaque, 3rd firing – 1st dentine build up, 4th firing – 2nd dentine build up and 5th firing – autoglaze. Any firing after this was considered as repeated firing. The results were calculated by using ANOVA test and 'F test.' Thus, within the limitations of this study it was concluded that repeated firing did not significantly affect the shade of porcelain fused to metal samples and secondly variation in batch showed a statistical significant change but within the acceptable limits of an individual's color perception.

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1. Introduction

Since decades ceramo-metal restorations are commonly used as they provide both esthetics and strength. Shade matching is an important aspect for ceramo-metal or all ceramic restorations. Errors in shade matching can be attributed to various reasons, they include individual shade selection, communication of shade to the laboratory and the ability of the ceramist to reproduce the communicated shade. Color variation may be due to some inherent limitations of the ceramic materials like its physical properties and optical phenomenon. Varied literature of studies is available on laboratory procedures on repeated firing,[1–3] surface texture,[4,5] thickness of porcelain,[6] batch variation,[7] condensation techniques,[8] type of metal substructure[9] and firing temperatures[10] which cause perceptible difference in shade. Though all laboratory and clinical procedures are followed meticulously even then the shade in final restoration may vary. Trying to neutralize a shade with a stain never really works, so the question arises where the error is? Hence, this

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in-vitro study was planned to know if there exists any significant shade change by repeated firing and on the variation in batch of the shade for ceramo-metal samples and whether it will affect the final results in shade perceived, selected and obtained.

2. Methodology

120 Porcelain fused to metal samples in disc shape were made to:

1. To evaluate the effect of repeated firing on the samples of the shade (3M2) and its effect on shade variation.
2. To evaluate the shade variation of ceramic material of (3M2) taken from three different batches of the same material.

As per the requirement of the spectrophotometer and to simulate the width of enamel and dentine of central incisor which is done for tooth preparation each porcelain fused to metal sample was made in the form of discs of dimensions 1.5 mm thickness by 8 mm diameter. Hard pattern wax shaped into discs with the help of silicone mold and was used for casting to get the substructure. The substructure was made by bonded Nickel Chromium Ceramic Alloy. Silicone duplicating material was used to fabricate a mold. In this mold hard pattern wax was flowed and required patterns were obtained (Figs. 1–3).

Each of the patterns were attached to the feeder sprues of diameter 4 mm which were further attached to primary sprues of 6 mm diameter. After debubblizing investment was done using rapid heating phosphate bonded carbon free investment material type I. Casting was done with the bonded Nickel Chromium Ceramic Alloy as per the manufacturer's instructions. After the castings of the samples are obtained sprues were severed and nodules were removed by means of carborundum separating discs (Fig. 4). All the samples were gauged with the help of Vernier caliper and necessary modifications were done if required to get the uniform thickness of 0.5 mm. It was measured at three different points for uniformity. Modifications required were done by tungsten carbide trimmers (Fig. 5). The specimens were numbered for ease of identification. They were steam cleaned by steam jet and ultrasonic vibrator.

After achieving the samples first layer of wash opaque ceramic was applied and firing was done according to manufacturer's instructions. Second firing was done of shade opaque. Once the samples were cooled they were gauged with electronic digital caliper to ensure a uniform thickness of opaque porcelain of 0.2 mm and a total thickness of 0.8 mm. Division of the samples was done after the shade opaque firing as follows:

Batch number	Sample size	Lot number of ceramic material (dentine)
1	80	7295
2	20	7893
3	20	31,400

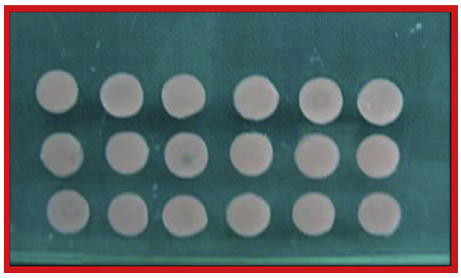


Fig. 1 – Acrylic discs.



Fig. 2 – Silicone mold.

Condensation of ceramic was done with dentine shade 3M2. The depth of the metal mold was such that the dentin thickness could be controlled to 1.5 mm with an overbuilt of 0.1 mm (to compensate for shrinkage). The vertical sides of the samples were trimmed to flush with the sides of the metal base by light grinding with a sintered diamond at slow speed. The thickness of each sample was then rechecked with an electronic digital caliper and corrected as necessary until the desired thickness of sample was achieved (1.5 mm). For uniformity in dimension and thickness of metal samples a metal mold was made and for shade analysis spectrophotometer was used (Fig. 6).

The firing sequence to which the samples were subjected was:

- 1st firing – wash opaque firing.
- 2nd firing – shade opaque firing.
- 3rd firing – 1st dentine build up.
- 4th firing – 2nd dentine build up.
- 5th firing – autoglaze.

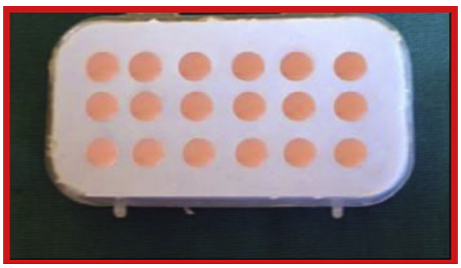


Fig. 3 – Wax flown in silicone mold.

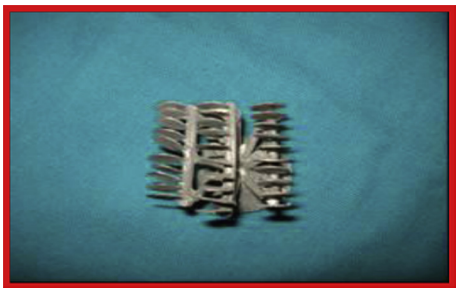


Fig. 4 – Casting of samples.

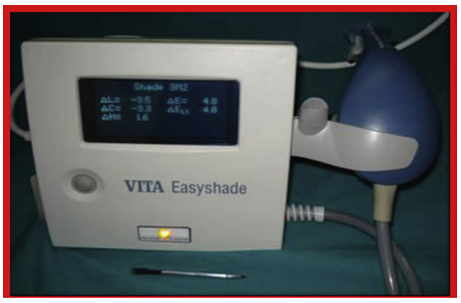


Fig. 6 – Spectrophotometer.

After that every firing was considered repeated firing. Batch 1 samples were divided into four subgroups:

Sub group	Number of repeated firings	Sample size	
A	0	20	Also used for batch variation control
B	5	20	
C	7	20	
D	9	20	

The samples were individually analyzed with a Spectrophotometer. It measured reflectance of the sample and a standard (white opal) every 10 nm over the visible spectrum (380–720 nm) so that absolute reflectance of the sample could be recorded. Standard illuminant D65 was used for all measurements and were recorded and expressed in CIE notation (L^*, a^*, b^*).

The color difference (ΔE) of the samples on repeated firing was calculated using the following formula. The control group batch 1 subgroup A was taken as baseline and color after repeated firing was compared to this.

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

Where,

- ΔL, difference in the lightness (L^*) of the sample between two firings.
- Δa, difference in the value (a^*) (chroma on red-green axis) of the sample between two firings.
- Δb, difference in the value (b^*) (chroma on yellow-blue axis) of the sample between two firings.

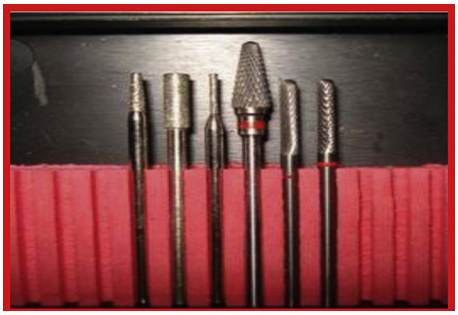


Fig. 5 – Carbide trimmers.

3. Statistical analysis, observations and result

The statistical analysis was done using formulas of mean, variance, standard deviation, standard error and null hypothesis. The results were plotted accordingly to the graphs and tabular form.

4. Null hypothesis

$Y_{ij} = m + x_i + e_{ij}$ here, m is the overall mean, x_i is the effect due to the treatment and e_{ij} is the random error independently and normally distributed with mean zero and variance σ^2.

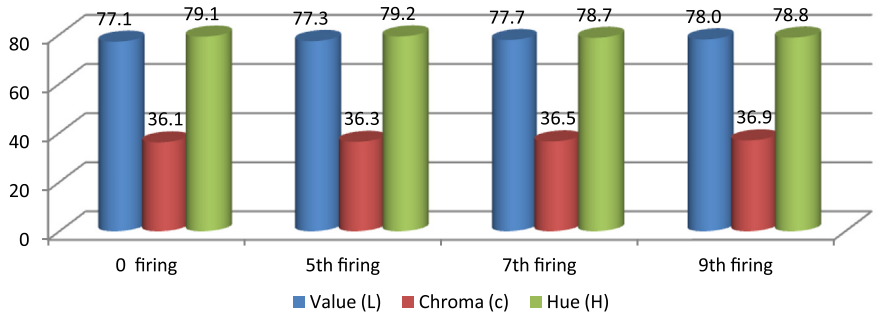
This color of each sample is expressed as following variables:

L^* = Value, C^* = Chroma ($a^* + b^*$), H^*= Hue, ΔC = Difference in chroma, ΔH = Difference in hue, ΔL = Difference in value, ΔE = Difference in color sensation for hue, ΔE_{lc} = Difference in color sensation for value and chroma (Tables 1–4).

5. Discussion

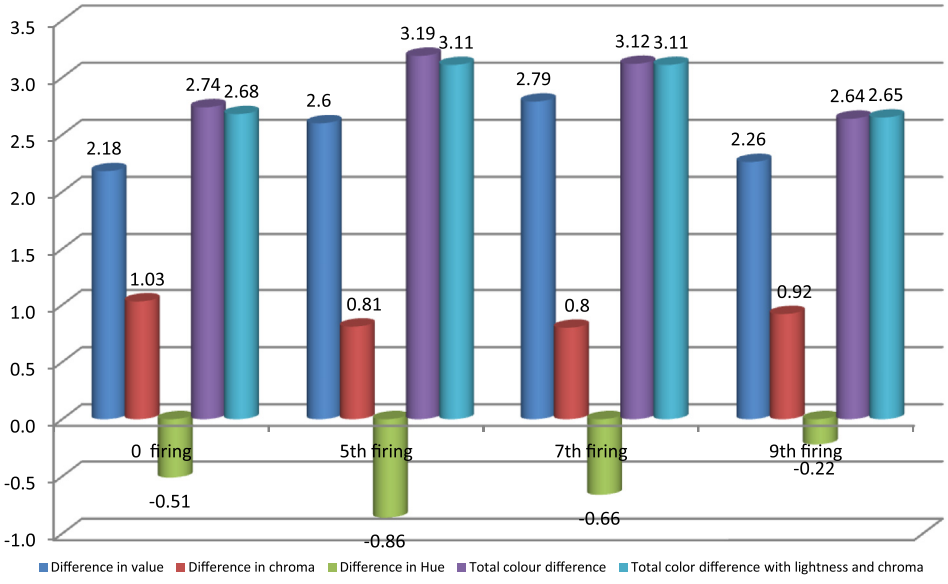
The selection or modification of shade for a ceramic restoration is complex and requires careful consideration.[9] Shade replication in porcelain fused to metal restorations comprise of two distinct phases. One is shade selection (matching) phase and the other is shade duplication phase. Shade selection can be done either visually by means of shade matching tools called dental color standards or shade guides or it can be done instrumentally by using colorimeter or spectrophotometer. Visual shade assessments are the result of physiological and psychological responses to radiant energy stimulation.[11] It is also affected by ageing, previous eye exposure, fatigue, environmental and lighting conditions. Study by Douglas RD, Brewer JD[11] revealed that color perception of one individual varies from other and within persons over time. Tools used for the instrumental interpretation mainly include spectrophotometers, colorimeters, film-based photography and digital photography.[12] They also

Table 1 – Mean minimum, maximum & standard error, *F* value and probability values for repeated firings.



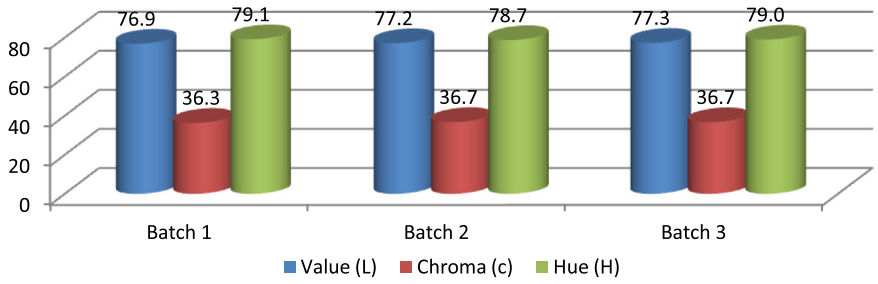
Parameter	0 Firing		5th Firing		7th Firing		9th Firing		*F* value	Probability & significance
	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE		
L	77.1	0.31	77.3	0.43	77.7	0.33	78.0	0.12	1.74	$P > 0.05$ NS
C	36.1	0.26	36.3	0.34	36.5	0.23	36.9	0.20	1.76	$P > 0.05$ NS
H	79.1	0.20	79.2	0.15	78.7	0.19	78.7	0.22	2.14	$P > 0.05$ NS
ΔL	2.2	0.24	2.6	0.16	2.8	0.21	2.3	0.14	2.32	$P > 0.05$ NS
ΔC	1.0	0.23	0.8	0.15	0.8	0.19	0.9	0.24	0.26	$P > 0.05$ NS
ΔH	−0.5	0.27	−0.9	0.20	−0.7	0.20	−0.2	0.24	1.40	$P > 0.05$ NS
ΔE	2.7	0.18	3.2	0.17	3.1	0.21	2.6	0.14	2.30	$P > 0.05$ NS
ΔE_{lc}	2.7	0.18	3.1	0.13	3.1	0.22	2.6	0.14	2.21	$P > 0.05$ NS

Table 2 – Difference in value, chroma and hue at 0, 5th, 7th and 9th firing.



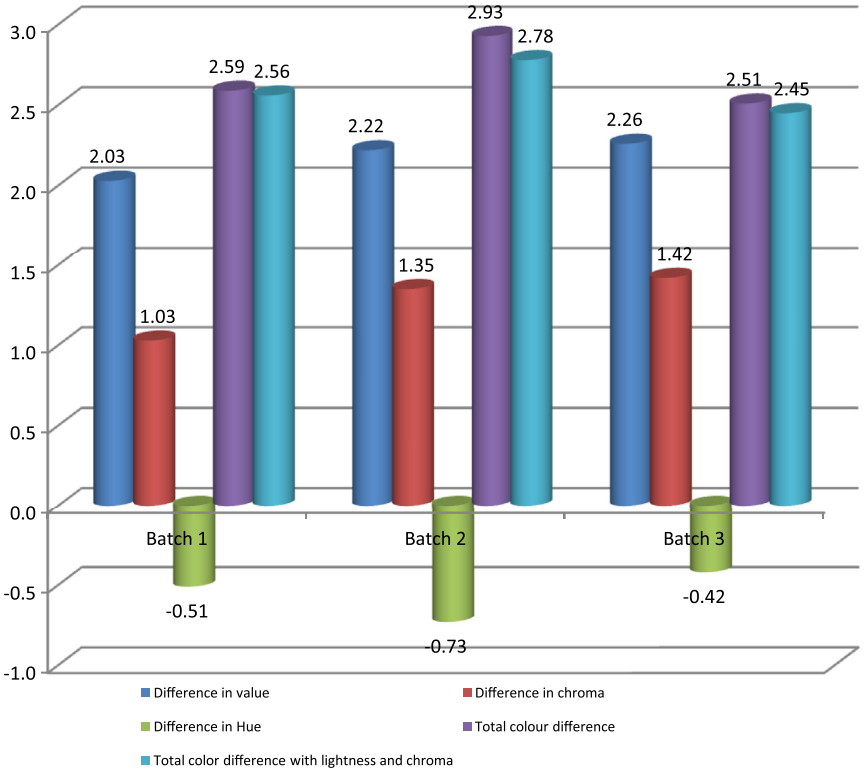
	0 Firing	5th Firing	7th Firing	9th Firing
Value (*L*)	77.1	77.3	77.7	78.0
Chroma (*C*)	36.1	36.3	36.5	36.9
Hue (*H*)	79.1	79.2	78.7	78.8
Difference in value	2.18	2.6	2.79	2.26
Difference in chroma	1.03	0.81	0.8	0.92
Difference in hue	−0.51	−0.86	−0.66	−0.22
Total color difference	2.74	3.19	3.12	2.64
Total color difference with lightness and chroma	2.68	3.11	3.11	2.65

Table 3 – Mean minimum and maximum values for batch 1, batch 2 & batch 3 at 0 firing stage.



Parameter	Batch 1		Batch 2		Batch 3		*F* value	Probability & significance
	Mean	±SE	Mean	±SE	Mean	±SE		
L	76.87	0.47	77.15	0.24	77.33	0.17	0.51	$P > 0.05$ NS
C	36.32	0.34	36.72	0.15	36.66	0.11	0.96	$P > 0.05$ NS
H	79.14	0.20	78.67	0.14	78.99	0.18	1.82	$P > 0.05$ NS
ΔL	2.03	0.25	2.22	0.10	2.26	0.07	0.58	$P > 0.05$ NS
ΔC	1.03	0.23	1.35	0.11	1.42	0.06	1.85	$P > 0.05$ NS
ΔH	−0.51	0.27	−0.73	0.13	−0.42	0.30	0.44	$P > 0.05$ NS
ΔE	2.59	0.21	2.93	0.10	2.51	0.06	2.43	0.096 Sig
ΔE_{lc}	2.56	0.21	2.78	0.07	2.45	0.06	1.59	0.211 Sig

Table 4 – Difference in value, chroma and hue for batch one, two and three.



	Batch 1	Batch 2	Batch 3
Value (*L*)	76.9	77.2	77.3
Chroma (*C*)	36.3	36.7	36.7
Hue (*H*)	79.1	78.7	79.0
Difference in value	2.03	2.22	2.26
Difference in chroma	1.03	1.35	1.42
Difference in hue	−0.51	−0.73	−0.42
Total color difference	2.59	2.93	2.51
Total color difference with lightness and chroma	2.56	2.78	2.45

solves the complex problem of metamerism. Metamerism is a phenomenon observed when two samples appear to have similar color under one set of viewing conditions, but different with other.

In the literature, many factors have been shown to affect the final shade of metal ceramic restorations such as porcelain brand,[13] porcelain batch,[5,14] underlying metal,[9,15,16] firing temperature,[9] condensation technique,[17] repeated firing,[9,14,18,19] porcelain thickness,[1,18,20] and surface texture.[7] The spectrophotometer used in this study for shade guide was a digital spectrophotometer with standard luminance of D65 and ranged from the spectrum of 380–720 nm with a tip which could sensor the shade and gave the values. This spectrophotometer could give the readings very precisely in the terms of hue, value and chroma digitally. It was found that there was slight variation in the value on repeated firing which increased though the results were insignificant. There was no variation in the values of hue and chroma. Various reasons for error in the study can be attributed to different particle size, air incorporation at the time of ceramic condensation, but to avoid errors samples were gauged with Vernier caliper and vacuum firing was used for condensation. The material was used of the same company to obtain averagely uniform size and ceramic furnace with settings of the same company material.

In the present study results have shown that there is slight amount of variation in shade on repeated firing which is stable after fifth firing as in studies by authors like Barghi N and Goldberg J.[1]

With the samples of batch variation slight variation was observed in total color difference which was within the clinically acceptable limit as seen with the earlier studies as done by authors Barghi N, Pedrero JAF, Bosch RR[7] that determined the effect of various batches of porcelain on the shade of three porcelain-bonded to metal systems. They used three different batches of three commercially available porcelains for their study. The shades were visually compared by nine observers. The results showed no significant color difference among specimens of individual batches discerning color changes were observed among three batches of one brand of porcelain. Among the three porcelain systems studied, none produced a shade to match the manufacturer's standard shade guide which was confirmed by all the observers. It was recommended that batch to batch variation of porcelain necessitates the fabrication of customized shade tabs with fresh batches of porcelain. The results in the present study were nearly similar with the previous studies showing slight variation in shade in terms of total color difference on batch variation .The variation was within the acceptable limits which may be due to difference in the particle size and contamination of long stored material. In the present study, the results of repeated firing were not found to be statistically significant. Whereas, the results of batch variation were statistically significant but could not be differentiated by an individual's visual perception.

6. Conclusion

Problems related to color matching arise from structural differences that exist between metal ceramic crowns and natural teeth. The contributing factors to the final color of metal ceramic restorations include the type of porcelain, the thickness of the dentin porcelain, surface texture of opaque porcelain, the number of firings, the firing temperatures, type of underlying metal, batch of porcelain and many others. Thus, this study was planned to obtain results in relation to variation in lot (batch) of ceramic and effect of repeated firing. The results showed no statistical significant change in the value, chroma and hue of the samples after repeated firing. On variation in lot of dentine slight variation in values in total color difference was observed which was under acceptable situations of an individual's visual perception. Thus, within the limitations of this study, it was concluded that:

1. Repeated firing did not significantly affect the shade of porcelain fused to metal samples.
2. Variation in batch showed a statistical significant change but it was within the acceptable limits of an individual's color perception.

Conflicts of interest

All authors have none to declare.

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