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IP Annals of Prosthodontics and Restorative Dentistry

Journal homepage: https://www.aprd.in/

Original Research Article

An in vitro study to evaluate the shade variation observed in ceramic restorations as affected by the different substructure materials using spectrophotometer

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ARTICLE INFO

Article history:
Received 20-11-2024
Accepted 30-01-2025
Available online 19-02-2025

Keywords:
Shade selection
Shade tab
Substructure
Metal
Zirconia
Lithium disilicate

ABSTRACT

Introduction: Shade selection is one of the most important aspect of achieving optimum esthetics. Shade selection is done manually in most of the dental clinics with the help of commonly available shade guides. However, appropriate shade reproduction is still a challenge in cosmetic dentistry. Porcelain fused to metal restorations have been considered as the gold standard, however with increasing demands in esthetic and with advent of newer materials , crowns can now be fabricated free of metal ie, all ceram or porcelain fused to zirconia restorations. These restorations besides being highly esthetic have strength comparable to metal.
Aim & Objectives: This study evaluated the effect of different substructure i.e. metal, zirconia and lithium disilicate on resulting shade in comparison with the commercially available shade guide and to determine whether single shade tab is suitable for different substructure.
Materials and Methods: 45 disc samples were fabricated with respect to metal, zirconia and lithium disilicate (15 each) and commercially available shade tab used as control.
Result: Compared with control group, Porcelain fused to metal was closest to shade tab as compared to Porcelain fused to zirconia and Lithium disilicate showed significant shade deviation.
Conclusion: Different shade tabs should be made available for different substructures.
Need of the study: Inspite of development of newer materials and newer technologies, shade selection is still carried out with the help of commercially available shade guides which donot consider the change of material or the advances in materials that have taken place over the years. Hence, the dental profession is still plagued with the problem of accurate reproduction of tooth color.

1. Introduction

Cosmetic dentistry has turned out to be a keystone for most dental practices. Significance of shade selection and its accurate reproduction in the laboratory cannot be overemphasized. However, accurate shade reproduction remains a challenging task for both the clinicians and the laboratory technicians. Resk, Shapiro and Seghi et al.[1] have found the shade selection process to pose a challenge to the artistic skills of the clinician and laboratory technician through each physiological and psychological factors. It was found that more than 80% of the patients with anterior metal-ceramic restoration are aware of the color differences relative to their adjacent natural teeth.[2] Commonly used visual shade selection is a highly subjective method, technologies have developed to standardize shade selection like spectrophotometers, colorimeters, digital color analyzers, or a mixture of these have evolved for ease of shade selection, however the most commonly used method still remains manually

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https://doi.org/10.18231/j.aprd.2025.012

using the commercially available shade guides. Besides, the advancements in the field of dental materials have led to the development of newer materials that mimic the tooth, Hence the need for an accurate reproduction of the shade cannot be overemphasized. Differences have been reported in the shade of readymade shade guides available and the final porcelain restoration. Moreover, there is a single shade guide that is used irrespective of the substructure. This study attempted to evaluate and compare the shade selected and the shade obtained in porcelain fired on different substructures (i.e, metal, zirconia or lithium disilicate etc) under laboratory conditions with the help of a spectrophotometer and also to determine whether a single shade guide can suffice for porcelain fused to different substructures.

2. Materials and Methods

This in-vitro study was conducted in the Department of Prosthodontics, Crown and Bridge and Oral Implantology, Faculty of Dental Sciences, SGT University, Gurugram.

Disc type samples were fabricated that were divided into three groups:

1. Group I : Veneered metal discs (PFM) (n=15)
2. Group II : Veneered zirconia discs (PFZ) (n=15)
3. Group III : Lithium disilicate discs (e-max) (n=15)

Commercially available Shade Guide was the Control Group.

2.1. Fabrication of metallic jig

Two metallic jigs made up of stainless steel were fabricated for standardization with 15 circular housings each measuring 7 mm diameter and 3 mm thickness.

One metallic jig (Figure 1a) used was having 3 sets of plates (Figure 1b) arranged one over the other with 1mm dimension each to achieve uniform thickness of each layer during layering of porcelain (1 mm substructure thickness + 2 mm ceramic layering for metal and zirconia substructure).

Second jig (Figure 2) was one single plate for fabrication of lithium disilicate.

2.2. Sample Fabrication: Porcelain fused to metal

Fifteen wax patterns were made by flowing inlay wax (Kronenwachs blau-BEGO) into each circular housing of metal jig (Figure 3) which were invested (Cuymxx, Germany) using phosphate bonded investment material. The wax patterns were then casted in the conventional manner according to the lost wax technique to obtain the metal disc samples (Figure 4).

Application of ceramic/porcelain on metal discs:

VITA VMK (A2) ceramic was applied to achieve thickness of 2 mm over metal discs (0.2 mm opaque, 0.8 mm dentine and 1 mm enamel). The ceramic layering was done with the help of plates of custom made metallic jig. Finally, samples were finished and glazed to achieve a uniform thickness of 3 mm (1mm disc thickness + 2mm ceramic thickness).

2.3. Sample Fabrication: Porcelain fused to zirconia

Optical impressions of metallic jig circular housing were made using Optical Scanner (Identico). A 3D image of the scanned data was formed (Figure 5) and the disc samples were designed accordingly using the CAD software (Exocad). The data of the designed images was stored as STL data. This data was transferred to the CAM machine. Zirconia block (Cercon® Dentsply Sirona) was clamped in milling chamber of Ceramill Mikro 4X) machine and the milling burs (2mm and 1mm drills) were used for the milling of the Zirconia samples. Following milling (CAM), samples were transferred to Ceramill Therm 3 for sintering after which the samples were examined for any cracks or defects. The samples were finished and polished with a silicone polisher. Fifteen such zirconia discs were obtained.

2.4. Application of ceramic/porcelain on zirconia discs

Zirconia discs were veneered with VITAVM®9 Zahnfabrik Bad Sackingen, Germany (A2 shade). For the application of dentin, powder and modelling liquid was mixed according to standard procedure and a custom made metallic jig was used to achieve a uniform thickness of 1mm and was fired at 910^0C and then enamel was applied of 1mm thickness and fired at 900^0C. Finally samples are finished with a diamond bur to achieve a uniform thickness of 3mm.

2.5. Sample Fabrication: Lithium disilicate

2.5.1. Optical scanning of metallic jig

Metallic jig measuring 7 mm diameter and 3 mm thickness was sprayed with scan spray to decrease its glancing so as to make an accurate optical impression using Identico optical scanner. The software design of the wax pattern was made by CAD/CAM software (Exocad).

2.6. Fabrication of the 3D printed wax pattern

The software design was transferred to a CAD/CAM milling machine (Ceramill Mikro 4X) to make the wax patterns using CAD/CAM milling wax. Wax patterns were invested using investment material (IPS PressVEST, Ivoclar Vivadent, Liechtenstein) After which the invested mold was transferred to a burnout furnace (Tempcon Muffle furnace) and heated to 850°C (5°C min^{-1}rate) to melt down wax (holding for 60 min). Then the invested mold was immediately transferred into commercially available automated dental heat-pressing equipment (Ivoclar Vivadent Programat EP 3010) which had been already preheated up to 700°C. After inserting the ingot and an alumina plunger,different heat pressing procedures under a pressure of 0.5 MPa were applied. After this, the specimens were carefully divested and polished with a series of silicon carbide papers sequentially (#320, 400, 600, 800, and 1000). The samples were seated on the master die to check for any irregularities and finally stained and glazed.

2.7. *Spectrophotometer analysis*

To evaluate shade, each samples were placed over the aperture of Spectrophotometer (CHN Spec Spectrophotometer, CS-600, China). Samples were subjected to monochromatic light through aperture and electric signals generated were converted by galvanometer and these signals were presented as CIELAB values using a computer attached with the spectrophotometer.

2.8. *Statistical analysis*

The CIELAB values obtained were tabulated and statistically analyzed using independent t-test. A p-value of less than 0.05 was considered as statistically significant.

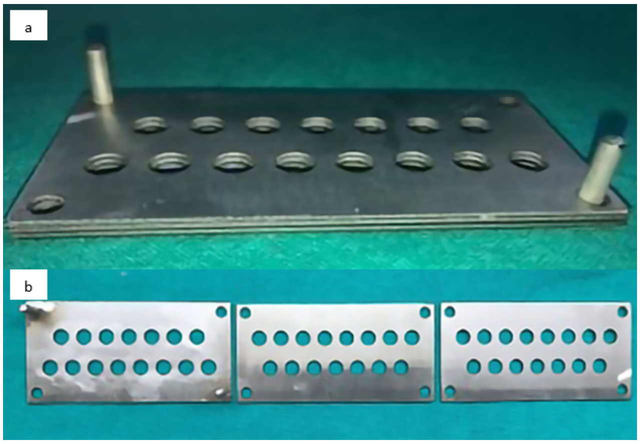

Figure 1: a: Metallic Jig; **b:** Metallic Jig, for even layering of PFM samples

3. Results

Comparison of control group with Group I, Group II & Group III with L*, a*, b* and ΔE values was done by independent t test.

Group I: Comparatively, the mean L* and b* value were higher in Control and mean a* and ΔE were higher in Group I. P-value is less than 0.05 which shows significant difference between two groups. (Table 1)

Group II: Comparatively, the mean L* and ΔE values were higher in Group II and mean a* and b* were higher in Control. P-value is less than 0.05 which shows significant difference between two groups. (Table 2)

Figure 2: Metallic Jig

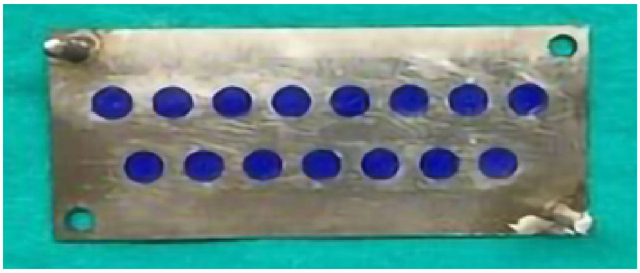

Figure 3: Metallic Jig with wax patterns for fabrication of metal substrate

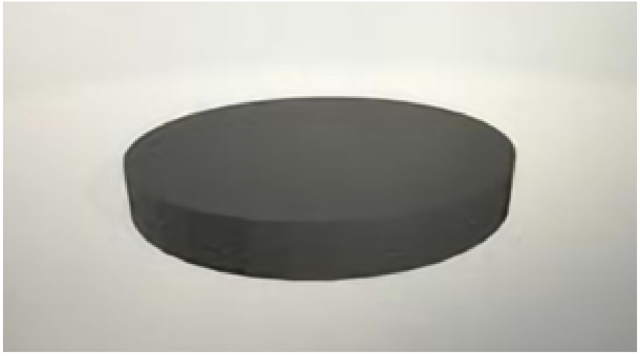

Figure 4: Designing of zirconia substrates

Figure 5: Finished samples

Group III: Comparatively, the mean L*, b* and ΔE values were higher in Group III and mean a* was higher in Control. P-value is less than 0.05 which shows significant difference between two groups. (Table 3)

4. Discussion

Color is the most imperative determining factor for providing satisfactory esthetics. As color is based on perception and is highly subjective, so, even if observers are looking at the same object, they can express the same color in different words. Due to this expression difference, describing a particular color to another person is extremely difficult. In dentistry, color determination is mainly done by two systems namely Munsell and CIELAB system. Commonly, it is done manually and visually by shade guides which are based on Munsell system for color determination such as Vita Classical (Vita Zahnfabrik), Chromascop (Ivoclar Vivodent) etc. Vita classic shade guide is probably the most commonly used, it was developed in 1956 but has not changed much in the last 70 years except for the addition of more tab colors. To overcome these limitations, VITA 3D Master shade guide was introduced which includes systematic arrangement of shade tabs based on value.

Common problem encountered is difference in shade of shade tab and final prosthesis i.e., failure to receive shade of prosthesis based on shade selection utilizing shade tab. Li et al (2009) conducted a study and concluded that the final color could hardly match the commercially available shade guide.[3] According to ADA guidelines, difference can exist between shade tabs of the same numeric shade of upto 2ΔE*ab.[4] This difference may be attributed to the fact that shade tabs are thicker and prosthesis are usually layered as compared to single piece shade tab. Moreover, shade tabs represent only 30 percent range of natural dentition, this range is increased with the advent of newer technologies of shade matching that comprises of instrumental shade selection such as colorimeters, spectrophotometers and digital imaging method.

Although search in literature has shown influence of substrate on final restoration shade, it is still obscure as to which substrate produces shade in range comparable to that of commercially available shade guide. Hence, this present study was designed to evaluate the shade variance in ceramic with different substructures i.e., metal, zirconia and lithium disilicate in comparison with the shade of the commercially available shade guide and to determine which substructure matches maximum to the shade guide.

Porcelain fused to metal crowns were considered as gold standard, but shade difference is known to occur in comparison with commercially available shade guide. Prabhu et al (2012) concluded that porcelain fused to metal samples do not match the shade guides to which they are compared and the mean color difference exceeds the accepted limit for dental shade guides.[5] This present study evaluated the effect of metal substructure on resulting shade of ceramic as compared with commercially available shade guide. Results revealed that mean L* values of shade tab and Group I i.e. porcelain fused to metal were 65.56 and 65.45 respectively, mean a* values were 0.96 and 1.61 respectively, mean b* values were 8.61 and 7.92 respectively and ΔE values were 1.15 and 1.65 respectively. The average color difference between shade guide and Group I was 0.5 that indicates significant results ($p<0.05$). A significant difference was observed between the shade guide tab and shade obtained in PFM samples.

To overcome esthetic problems related to metal based restorations, high strength metal free zirconia restorations were introduced in 1990s. Habib RS (2015) stated that various factors affect matching ability of zirconia which comprises of veneering ceramic, coping material, luting cement, abutment etc.[6] Accordingly, this present study evaluated and compared the shade of ceramic with zirconia substructure using shade guide as control group. Results revealed that mean L* values of shade tab and Group II i.e. porcelain fused to Zirconia were 65.56 and 68.15 respectively, mean a* values were 0.96 and 0.82 respectively, mean b* values were 8.61 and 5.91 respectively and ΔE values were 1.15 and 3.66 respectively. The average color difference between shade guide and Group II was 2.51 that indicates significant results ($p<0.05$).

Soram Oh (2018) stated that crystalline based ceramics i.e. zirconia have better mechanical properties but poor esthetics as compared to glass based ceramics i.e., lithium disilicate which were introduced in late 1990s.[7] Czigola A (2019) in their study showed that color difference i.e., ΔE values of CAD/CAM lithium disilicate full crowns were influenced by ceramic thickness and translucency, substrate and cement color. So, influence of lithium disilicate substructure on final shade and comparative analysis with that of shade guide was done in the present study. Results revealed that mean L* values of shade tab and Group III i.e. lithium disilicate were 65.56 and 73.62 respectively, mean a* values were 0.96 and -0.31 respectively, mean b* values were 8.61 and 10.07 respectively and ΔE values were 1.15 and 7.97 respectively. The average color difference between shade guide and Group III was 6.82 that indicates highly significant results ($p<0.05$).

Hence, results and statistical analysis revealed that substructure does influence shade of final prosthesis. Comparing with a commercially available shade tab, Group I revealed slight difference in ΔE (0.5) followed by Group II (2.51) and Group III has maximum deviation (6.82) i.e., Porcelain fused to metal samples were in comparable range to that of the shade guide. This result was in contrary with the result of a study done by Fazi G (2009), he concluded that the color difference recorded between porcelain metal discs and corresponding VITA Classical Shade tab was ΔE 2.5.[8]

Table 1: Comparison of control group with Group I with L*, a*, b* and ΔE values by independent t test.

Variable	Groups	N	Mean	SD	SE	t-value	P-value
L*	Control	15	65.56	0.72	0.18	0.2718	0.0078
	Group I	15	65.45	1.39	0.36		
a*	Control	15	0.96	0.16	0.04	-8.8454	0.0001*
	Group I	15	1.61	0.24	0.06		
b*	Control	15	8.61	0.60	0.15	2.4799	0.0194*
	Group I	15	7.92	0.90	0.23		
ΔE	Control	15	1.15	0.44	0.11	-1.8638	0.0729
	Group I	15	1.65	0.94	0.24		

*p<0.05 indicates significant

Table 2: Comparison of control group with Group II with L*, a*, b* and ΔE values by independent t test.

Variable	Groups	n	Mean	SD	SE	t-value	P-value
L*	Control	15	65.56	0.72	0.18	-8.6411	0.0001*
	Group II	15	68.15	0.91	0.24		
a*	Control	15	0.96	0.16	0.04	3.0289	0.0052*
	Group II	15	0.82	0.09	0.02		
b*	Control	15	8.61	0.60	0.15	12.4473	0.0001*
	Group II	15	5.91	0.59	0.15		
ΔE	Control	15	1.15	0.44	0.11	-15.4834	0.0001*
	Group II	15	3.66	0.45	0.12		

*p<0.05 indicates significant

Table 3: Comparison of control group with Group III with L*, a*, b* and ΔE values by independent t test.

Variable	Groups	n	Mean	SD	SE	t-value	P-value
L*	Control	15	65.56	0.72	0.18	-32.9606	0.0001*
	Group III	15	73.62	0.62	0.16		
a*	Control	15	0.96	0.16	0.04	11.0416	0.0001*
	Group III	15	-0.31	0.41	0.11		
b*	Control	15	8.61	0.60	0.15	-5.0989	0.0001*
	Group III	15	10.07	0.94	0.24		
ΔE	Control	15	1.15	0.44	0.11	-35.2404	0.0001*
	Group III	15	7.97	0.61	0.16		

*p<0.05 indicates significant

Study comparing color difference between zirconia and commercially available shade guide was done by Vichi A (2012)[9] in which spectrophotometric evaluation of VITA VM9 zirconia based restorations to that of VITA Classical shade tab was done and their results revealed that mean color difference was 2.7 which is in agreement with the present study.

Study comparing IPS e-max i.e., lithium disilicate and VITA classical shade tab was done by Della bona (2015)[10] in which he evaluated and compared color difference between IPS e-max and corresponding shade of VITA Classical shade tab and concluded that ΔE ranged from 6.32 to 13.42 which are in accordance to ΔE in present study which was 6.82.

Although, It has been suggested that there is no significant difference between visual, digital and shade selection done with electronic shade selection.[11] However, the Vita 3D Master shows more consistent results in repetitive shade selection.[12] Besides, before evaluating and selecting the precise color shade for restoration of teeth, it is important to understand the fundamentals of color and light, the electromagnetic spectrum and visual characteristics of the item.[13]

Therefore, it is suggested that a single shade tab cannot be used for porcelain fired on different substructures. There should be different shade tabs for different substructure for better esthetic outcome as each substructure is affected by variables that influence final shade of restoration.

5. Conclusion

The present study was undertaken to evaluate and compare the effect of three different substructures i.e., metal, zirconia and lithium disilicate on the resulting shade of ceramic when compared with shade tab of a commercially available shade guide using spectrophotometer.

Within the limitations of the study, it can be safely concluded that:

1. Different substructures i.e., metal, zirconia and lithium disilicate influence the final shade obtained and is significantly different from the actual shade selected from commercially available shade guide.
2. Porcelain fused to metal samples are the closest with that of commercially available shade guide.
3. Compared with control group, Porcelain fused to metal showed significant color difference in CIELAB system, however, it was closest to shade tab as compared to Porcelain fused to zirconia and Lithium disilicate showed maximum deviation.
4. Different shade guides should be available for different substructures rather than using single shade tab.

Colored zirconia frameworks have been introduced to enhance color reproduction,[14] hence a need to study the colored zirconia cores as substrate material also need to be addressed in future studies. The samples were not exposed to saliva or thermal fluctuations, thus this invitro study could not fully replicate the clinical conditions.[15] Therefore, Further in vitro and in vivo studies are required that can assess the effect of various variables that influence shade selection such as different substructures, material and brand used, ambient lightening, timing of shade selection etc.

6. Source of Funding

None.

7. Conflict of Interest

None.

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Cite this article: Rao S, Malhotra P, Sanan R, Phukela S, Singh D, Nischal K. An in vitro study to evaluate the shade variation observed in ceramic restorations as affected by the different substructure materials using spectrophotometer. *IP Ann Prosthodont Restor Dent* 2025;11(1):60-65.