



## *In-vitro* efficacy of two spectrophotometer-based shade matching systems for color matching of ceramics after artificial accelerated aging

Eficácia *in vitro* de dois espectrofotômetros baseados em escalas de cor para avaliação de cor de cerâmicas após envelhecimento artificial acelerado

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### ABSTRACT

**Objective:** The objective of the present *in-vitro* study was to verify the efficacy of two spectrophotometer-based shade matching systems for color matching of ceramics after artificial accelerated aging (AAA). **Material and Methods:** The ceramics used were porcelain laminated veneers. Seventy standard-shaped discs (thickness x diameter: 0.5 mm x 10 mm) of B1 shades were used. Based upon the type of resin cement used, the specimens were divided into seven groups (10/group). The following light-cured cements were used: RelyX-Veneer (L-RV), Variolink-Veneer (L-VV), and Variolink-Esthetic (L-VE). The dual-cured cements were: RelyX Ultimate (D-RU), RelyX-Unicem (D-RC), and Variolink-Esthetics DC (D-VE). The control group consisted of ceramic only. All specimens were thermocycled in water for 3,500 cycles between 5 °C -55 °C, with dwell times of 30 s in each bath and a transfer time of 10 s between baths. All specimens were thermocycled in water for 3,500 cycles between 5 °C and 55 °C, and color measurement was done using the VITA Easyshade and ColorEye spectrophotometers. Baseline color reading was performed 24-hours after cementation. Differences in color (DE) of EasyShade and ColorEye before and after AAA were determined and compared statistically. Group comparisons were done using the paired t-tests. Level of significance was set at  $P < 0.05$ . **Results:** The mean differences in color ( $\Delta E$ ) values obtained from EasyShade

### RESUMO

**Objetivos:** O objetivo do presente estudo *in vitro* foi verificar a eficácia de dois espectrofotômetros baseados em escalas de cor para avaliação de cor de cerâmicas após envelhecimento artificial acelerado (EAA). **Material e Métodos:** As cerâmicas utilizadas foram laminados cerâmicos. Foram usados setenta discos de formato padrão (0,5mm de espessura x 10 mm de diâmetro) de tonalidades B1. Com base no tipo de cimento resinoso utilizado, os corpos-de-prova foram divididos em sete grupos (10 / grupo). Foram utilizados os seguintes cimentos fotopolimerizáveis: RelyX-Veneer (L-RV), Variolink-Veneer (L-VV) e Variolink-Esthetic (L-VE). Os cimentos de cura dual foram: RelyX Ultimate (D-RU), RelyX-Unicem (D-RC) e Variolink-Esthetics DC (D-VE). O grupo controle consistia apenas de cerâmica. Todos os corpos-de-prova foram termociclados em água por 3.500 ciclos entre 5°C-55°C, com tempos de permanência de 30s em cada banho e um tempo de transferência de 10s entre os banhos. A medição da cor foi feita usando os espectrofotômetros VITA Easyshade e ColorEye. A leitura da cor inicial foi realizada 24 horas após a cimentação. As diferenças na cor ( $\Delta E$ ) do EasyShade e ColorEye antes e depois do EAA foram determinadas e comparadas estatisticamente. As comparações dos grupos foram feitas usando o teste t pareados. O nível de significância foi estabelecido em  $p < 0,05$ . **Resultados:** os valores médios de diferenças na cor ( $\Delta E$ ) obtidos

spectrophotometer for light- and dual-cured cements, were  $0.843 \pm 0.89$  (L-RV),  $4.11 \pm 0.69$  (L-VV) and  $0.833 \pm 0.47$  (L-VE); and  $2.22 \pm 0.64$  (D-RU),  $3.37 \pm 0.83$  (D-RC) and  $0.38 \pm 0.92$  (D-VE), respectively. The mean differences in color ( $\Delta E$ ) values obtained from ColorEye spectrophotometer for light- and dual-cured cements, were  $0.68 \pm 0.86$  (L-RV),  $4.55 \pm 0.83$  (L-VV) and  $2.68 \pm 0.26$  (L-VE); and  $2.06 \pm 0.84$  (D-RU),  $1.8 \pm 1.08$  (D-RC) and  $0.96 \pm 0.71$  (D-VE), respectively. There was no significant difference in the mean DE values among the groups. **Conclusion:** The VITA Easyshade and ColorEye shade matching systems are comparable in terms of their efficacy for color matching of ceramics after AAA.

## KEYWORDS

Artificial accelerated aging; Color matching; In vitro; Porcelain veneer; Spectrophotometer.

no espectrofotômetro EasyShade para cimentos fotopolimerizáveis e duais foram de  $0,843 \pm 0,89$  (L-RV),  $4,11 \pm 0,69$  (L-VV) e  $0,833 \pm 0,47$  (L-VE); e  $2,22 \pm 0,64$  (D-RU),  $3,37 \pm 0,83$  (D-RC) e  $0,38 \pm 0,92$  (D-VE), respectivamente. os valores médios de diferenças na cor ( $\Delta E$ ) obtidos no espectrofotômetro ColorEye para cimentos fotopolimerizáveis e duais foram de  $0,68 \pm 0,86$  (L-RV),  $4,55 \pm 0,83$  (L-VV) e  $2,68 \pm 0,26$  (L-VE); e  $2,06 \pm 0,84$  (D-RU),  $1,8 \pm 1,08$  (D-RC) e  $0,96 \pm 0,71$  (D-VE), respectivamente. Não houve diferença significativa nos valores médios de  $\Delta E$  entre os grupos. **Conclusão:** Os sistemas de combinação de cores VITA Easyshade e ColorEye são comparáveis em termos de eficácia para avaliação de cores de cerâmicas após EAA.

## PALAVRAS-CHAVE

Envelhecimento artificial acelerado; Avaliação de cores; In vitro; Laminado cerâmico; Espectrofotômetro.

## INTRODUCTION

A cautious recreation of prosthetic restorations in relation to their texture, translucency, shape, and shade is essential to replicate the natural appearance of dentition [1]. It has been reported that most of the complications in restorative dental sciences are associated with discrepancies in color-matching procedures [2]. With the escalating mandate for esthetic dental restorations, the importance of consistent color imitation has intensified. In this context, appropriate selection and replication of that shade is considered a critical step towards the achievement of a color of the restoration that matches with the natural dentition. Accomplishment of such an outcome is dependent on the ability to determine the precise tooth shade in a precise yet consistent manner [1].

The VITA Easyshade V digital spectrophotometer (Vita Zahnfabrik GmbH & Co. KG, Bad Säckingen, Germany) is often

used for the determination of shade veneers that closely matches with that of the natural dentition [3]. However, prosthesis that are color-matched using conventional visual shade-guides are more often rejected than those matched using spectrophotometers [4]. In this context, spectrophotometric system are more efficient in accurately determining the shade compared with the traditional visual assessment. Furthermore, measurements obtained from the VITA Easyshade spectrophotometers are repeatable and accurate up to nearly 2.5 years [5,6]. Nevertheless, there is a dearth of studies that have assessed the efficacy of this form of digital shade matching system. Based upon the currently available evidence, the ColorEye spectrophotometer also seems to be a useful digital resource for color matching of restorations with natural teeth [7]. However, there are no studies that have compared the efficacy of the VITA Easyshade and ColorEye spectrophotometers for color matching of ceramics before and after artificial accelerated aging (AAA).

The objective of the present *in-vitro* study was to verify the efficacy of two spectrophotometer-based shade matching systems (VITA Easyshade and ColorEye) for color matching of ceramics after AAA. The *null* hypothesis is that there is no significant difference in the efficacy of the VITA Easyshade and ColorEye spectrophotometers for color matching of ceramics after AAA.

## MATERIAL AND METHODS

### Sample-size estimation

Sample-size estimation was performed using a computer-based power analysis software (nQuery Advisor 5.0, Statistical Solutions, Saugus, MA, USA). It was estimated that inclusion of 10 samples per group would give a 90% power to the study.

### Preparation of specimens

Seventy disc-shaped specimens (thickness x diameter, 0.5 mm x 10 mm) of B1 shade were prepared according to the manufacturer's instructions from high translucency lithium disilicate blocks (Inoclar Vivadent AG, Schaan, Liechtenstein). The ceramic surfaces were finished and polished (LUSTER® LUS80 e.max®, Tx, USA) to assure surface standardization; and coated on one side with a layer of neutral-shade glaze, and fired at 765 °C (Programat CS3 Ivoclar Vivadent, Schaan, Liechtenstein, Germany). Crystallization and sintering were done adhering to the manufacturer's recommendations. Glazing and crystallization was done in one firing phase in accordance with the manufacturer's recommendations.

### Grouping and cementation protocol

In the present experimental study, the primary focus was on the efficacy of two spectrophotometer-based shade matching systems for evaluation of optical properties of ceramics after induction of aging using the Commission Internationale de l'Eclairage (CIE)

LAB system. Complete workflow from scanning to designing and the milling was done by using Ceramill CAD/CAM system (Amann Girrbach, Dürrenweg, Germany). Seven discs were milled from each block. Five discs (size C14) were obtained from each IPS e.max® CAD HT Blocks.

The samples were divided into 7 groups (10 specimens per group) according to the resin cement used (Table I). Prior to cementation, the porcelain surfaces were etched with 9% hydrofluoric acid (IPS Ceramic Etching Gel; Ivoclar Vivadent, Schaan, Liechtenstein) for 20s and dried with oil-free compressed air. A layer of silane (prosil; FGM) was applied with a microbrush, left undisturbed for 1 minute, and air dried for 30 seconds. Ceramic primer (Mono bond S) for Variolink Esthetics dual cure, Variolink Esthetics light cure and Variolink Veneers; RelyX Ceramic Primer for RelyX Veneers, RelyX ultimate, RelyX unicem were applied for 5 s and dried. Bonding was performed using Adper Single Bond 2 Adhesive for the RelyX group. Light-cured resin cements were applied directly from a syringe. Dual-cured resins were mixed on a separate mixing pad and applied onto the unglazed surface of the specimens, using a plastic instrument. Light-cured resin cements were applied directly from a syringe. Dual-cured resins were mixed on a separate mixing pad and applied onto the unglazed surface of the specimens using a plastic instrument; a clean glass slide was placed onto the resin mixture, and a 1-kg weight was placed on top for 20 seconds to form a 0.1-mm-thick cement layer. In order to simulate clinical conditions, the top surfaces of all specimens were light-cured (Elipar S10; 3M ESPE) for 40 seconds. After cementation, irregularities from excessive resin cement were adjusted with 600-grit wet silicon-carbide paper (Norton Abrasives, MA, USA), and the specimen thicknesses were calibrated and standardized at 0.6 mm for all specimens.

### Aging process

After the cementation procedure, all specimens were placed in a silicone index; the glazed surfaces were in direct contact with water while the cemented sides were protected by the silicone index. All specimens were thermocycled (Thermocycler 1100 SD Mechatronik GmbH, Germany) in water for 3,500 cycles between 5 °C and 55 °C, with dwell times of 30 seconds in each bath and a transfer time of 10 seconds between baths.

### Color measurement

The color difference ( $\Delta E$ ) was determined in the control group (only ceramic) using the equation:  $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ . Color measurements were performed three times using two spectrophotometers, namely VITA Easyshade (Vita Zahnfabrik GmbH & Co. KG, Bad Säckingen, Germany) and ColorEye (X-Rite Europe GmbH Regensdorf, Switzerland) using a viewing booth under D65 standard illumination on a white background, based on International Organization for Standardization (ISO) standards (ISO 7491; <https://www.iso.org/standard/26857.html>). A baseline color reading was performed 24 hours after cementation. The samples were stored in distilled water at 37°C. After aging induction, the specimens were removed from the distilled water, dried with paper towels, and the  $L^*a^*b^*$  coordinates were measured. Before the experimental measurements, the spectrophotometer was calibrated according to the manufacturer's instructions. The spectrophotometer was positioned in the middle of each specimen and each specimen was measured three times consecutively. The color measurements of the specimens were performed under the same conditions as used

for the control group specimens, as described above, before and after aging. CIE  $L^*a^*b^*$  notations were used for all color measurements. The CIE color difference was calculated before the cementation 'control group' with the equation:

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

where  $L^*$  refers to the brightness,  $a^*$  for redness to greenness, and  $b^*$  for yellowness to blueness. A high  $\Delta E$  value indicates great color difference. All assessments were done by a trained and calibrated investigator (FA; Kappa score 0.94).

### Statistical analysis

The group comparisons were performed using a statistical software (SPSS version 20, Chicago, IL, USA). The means and standard deviations of the color changes were calculated. The paired t-test was used to analyze the differences between the groups. Level of significance was set at  $P < 0.05$ .

## RESULTS

The mean differences in color ( $\Delta E$ ) values obtained from EasyShade spectrophotometer for light- and dual-cured cements, were  $0.843 \pm 0.89$  (L-RV),  $4.11 \pm 0.69$  (L-VV) and  $0.833 \pm 0.47$  (L-VE); and  $2.22 \pm 0.64$  (D-RU),  $3.37 \pm 0.83$  (D-RC) and  $0.38 \pm 0.92$  (D-VE), respectively. The mean differences in color ( $\Delta E$ ) values obtained from ColorEye spectrophotometer for light- and dual-cured cements, were  $0.68 \pm 0.86$  (L-RV),  $4.55 \pm 0.83$  (L-VV) and  $2.68 \pm 0.26$  (L-VE); and  $2.06 \pm 0.84$  (D-RU),  $1.8 \pm 1.08$  (D-RC) and  $0.96 \pm 0.71$  (D-VE), respectively. There was no significant difference in the mean  $\Delta E$  values among the groups (Table II).

**Table I** - Allocation of specimens in the study groups

Light cured cements					Dual cured cements					CO group
Samples (n)	Material used	Manufacturer	Composition	Lot	Samples (n)	Material used	Manufacturer	Composition	Lot	
10	L-RV	3M ESPE, Seefeld, Germany	BisGMA TEGDMA Zirconia/silica and fumed silica Pigments Photoinitiator	N664127	10	D-RU	3M ESPE, Seefeld, Germany	Methacrylate monomers Aalkaline (basic) fillers Initiator Stabilizers Rheological additives Fluorescence dye Dark cure activator Universal adhesive	583365	No cementation (n= 10)
10	L-VV	Ivoclar Vivadent, Schaan, Liechtenstein	Dimethacrylates Inorganic fillers Ytterbium trifluoride Catalysts and stabilizers Pigments	T28526	10	D-RC	3M ESPE, Seefeld, Germany	Powder: glass fillers, silica, calcium hydroxide, self-curing initiators, pigments, light-curing initiators Liquid: methacrylated phosphoric esters, dimethacrylates, acetate, stabilizers, self-curing initiators, light-curing initiators	590099	
10	L-VE	Ivoclar Vivadent, Schaan, Liechtenstein	Urethane dimethacrylate Methacrylate monomers. Ytterbium trifluoride and spheroid mixed oxide. Initiators, stabilizers and pigments	T28801	10	D-VE	Ivoclar Vivadent, Schaan, Liechtenstein	Urethane dimethacrylate and further methacrylate monomers. The inorganic fillers are ytterbium trifluoride and spheroid mixed oxide. Initiators, stabilizers and pigments	T28801	

CO: Control group  
D-RU: RelyX Ultimate

L-RV: RelyX Veneer  
D-RC: RelyX Unicem

L-VV: Variolink Veneer  
D-VE: Variolink Esthetic

L-VE: Variolink Esthetic

**Table II** - Mean and standard deviation of DeltaE ( $\Delta E$ ) measured by the two spectrophotometers and the results of paired t-test

Cure type	Cement	$\Delta E$ (Easshade)	$\Delta E$ (ColorEye)	p-value
Light-cured	L-RV	0.843±0.89	0.68±0.86	0.293
	L-VV	4.11±0.69	4.55±0.83	0.820
	L-VE	0.833±0.47	2.68±0.26	0.145
Dual-cured	D-RU	2.22±0.64	2.06±0.84	0.725
	D-RC	3.37±0.83	1.8±1.08	0.246
	D-VE	0.38±0.92	0.96±0.71	0.587

L-RV: RelyX Veneer  
D-RU: RelyX Ultimate

L-VV: Variolink Veneer  
D-RC: RelyX Unicem

L-VE: Variolink Esthetic  
D-VE: Variolink Esthetics

## DISCUSSION

An attractive esthetic smile is a principal goal in prosthetic and restorative dental sciences [8-10]. This is challenging because the human eye can detect and discern the subtlest color variations particularly in the aesthetic zone. There are numerous studies in indexed literature that have compared the efficacy of spectrophotometry with visual analysis in terms of shade selection for porcelain-based dental prosthesis [11-14]. Results from such studies have clearly demonstrated that spectrophotometric assessment of shade for porcelain-based prosthesis is more reliable as compared to visual assessment [11-14]. For this reason, visual assessment of shade of the veneers was not performed in the current investigation.

Spectrophotometers are modern and accurate devices that gauge the quantity of light reflected from an object at 1–25 nm intervals along the visible spectrum. They are often used in clinical dentistry and related research for the purpose of color matching [15]. It has also been reported that in contrast to visual assessment of shade, spectrophotometers are 33% more accurate and offer a more objective match in over 93% cases [16]. There are few studies that have compared the efficacy of different spectrophotometers in terms of determining the precise shade for porcelain-based prosthetic veneers [17,18]. According to the results of the present *in-vitro* study, there was no difference in the efficacy of the two spectrophotometers used. One justification for this is that both spectrometric systems used in the present experiment are spot measurement devices that need to be brought into direct contact with the surface under investigation [17]. Moreover, both spectrophotometric analyses offer additional benefits based upon the CIE  $L^*a^*b^*$  systems for the detection of color changes that are not visible to the human eye [19]. Furthermore, strict standardization criteria were imposed in the present experiment. For instance, all specimens were standardized in terms of their dimensions (diameter x width 10 x 0.5 mm) and

were polished prior to experimentation. Moreover, all specimens were thermocycled in water for 3,500 cycles between 5 °C and 55 °C, with dwell times of 30 seconds in each bath and a transfer time of 10 seconds between baths. Based upon such stringent yet standardized eligibility criteria comparable changes in color between the two spectrophotometers assessed in the present study. In terms of use of light and dual-cure cements, it has been reported that Lithium disilicate ceramics are currently preferred for ceramic veneers and can be made thinner while masking the background [20]. Barizon et al. [20] reported that the biggest advantage of lithium disilicate porcelain is the possibility of fabricating thinner veneers without compromising strength and thereby allow considerably more translucent restorations. However, additional studies are needed to observe the influence of the type of cement on the final color of lithium disilicate ceramic.

To replicate a clinical scenario of aged restorations, the authors induced AAA in the samples. In the present study, 3,500 cycles was selected as it corresponds to the one-year clinical evaluation [21]. The concept of AAA has been imposed in several *in-vitro* investigations and has been recognized as a reliable technique to assess the color stability and fracture resistance of ceramics in experimentally aged restorations [22-27]. This may be considered a limitation of the present study as the outcomes were entirely based upon laboratory-based evaluations. It is also noteworthy that under clinical scenarios, extrinsic stains of varying intensity predominantly on aged veneers may influence the reliability of spectrophotometers. However, further studies are needed to justify this hypothesis.

## CONCLUSION

Within the limitations of the present study, it is concluded that the VITA Easyshade and ColorEye shade matching systems are comparable in terms of their efficacy for color matching of ceramics after AAA.

### Conflict of interest and financial disclosure

The authors declare that they have no conflict of interest and there was no external source of funding for the present study.

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