Al-Azhar Journal of Dentistry

Volume 10 | Issue 2 Article 51

Restorative Dentistry Issue (Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

4-1-2023

Digital Photography versus Spectrophotometry Assessment ofColor Stability of Resin Composite

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How to Cite This Article

Ezz, Eman; El-Sharkawy, Doaa; and Zaghloul, Samaa (2023) "Digital Photography versus Spectrophotometry Assessment ofColor Stability of Resin Composite," *Al-Azhar Journal of Dentistry*: Vol. 10: Iss. 2, Article 51.
DOI: https://doi.org/10.58675/2974-4164.1538

AL-AZHAR
Journal of Dentistry

The Official Publication of The Faculty of Dental Medicine For Girls, Al-Azhar University Cairo, Egypt.

Print ISSN 2974-4156 • Online ISSN 2974-4164

AZJD, Vol. 10, No. 2, April (2023) — PP. 375:382

Digital Photography versus Spectrophotometry Assessment of Color Stability of Resin Composite

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Codex : 1-11/23.04

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http://adjg.journals.ekb.eg

https://doi.org/10.58675/2974-4164.1538

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ABSTRACT

Purpose: To compare digital photography to spectrophotometry in evaluating the color stability of resin composite. **Materials and methods:** Thirty- two disc-like specimens of Filtek Z350 resin composite were prepared and color-assessed; before and after 30 days of submersion in coffee solution. For each specimen, color was assessed according to Commission Internationale de I'Eclairage (CIE) color space values using: Two different versions of Canon Digital Single Lens Reflex (DSLR) camera; with standard lenses, flash, and settings: Canon 600d (Group I) and Canon 1100d (Group II), and a digital spectrophotometer (Vita Easyshade advance 4.0; Vita Zahnfabrik, Bad Sackingen, Germany) as a control (group lll). Color change (ΔE) was recorded for individual devices, tabulated, and statistically analyzed using one-way ANOVA, then Tukey's post hoc test ($P \leq 0.05$). **Results:** Statistically, no significant difference appeared among the used devices ($P \leq 0.05$) while assessing the color stability of Filtek Z350 resin composite. **Conclusions:** Both devices are similarly valuable for color assessment of resin composite.

KEYWORDS

Digital photography, spectrophotometer, color stability, color assessment, Filtek Z350.

INTRODUCTION

The esthetic demands are progressively increasing nowadays concomitant to continuous advances in dental materials and techniques. In both restorative and prosthetic dentistry, the color matching up with the natural tooth remains one of the major prerequisites to get patient satisfaction. Color assessment could be simply achieved by direct vision; individual variation and eye fatigue, however, are the main limitations [(1)]. For decades, spectrophotometers and colorimeters are the standard color-measuring tools [(2, 3)]. Difficult application clinically in patients' mouths and high cost considering their limited uses in dental

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practice are the major obstacles to their introduction as urgency in everyday dentistry [4].

Digital dental photography, on the other hand, is growing every day more and more with expansion in daily dental uses including documenting cases, communicating with patients, dental colleagues, and technicians; assisting in the proper diagnosis and treatment plan. Education purposes add to its value as well [4- 6]. Cameras of the digital single-lens reflex (DSLR) type are the standard cameras for capturing perfect dental images [7]. However, there's still a need to assess their accuracy as color-measuring tools compared to spectrophotometers and colorimeters.

The development of resin composites was one of the leading steps in esthetic dentistry. The color-matching ability facilitated by the availability of a wide range of shades, along with rapid progress in mechanical properties, directed the patients to prefer resin composites over all other direct restoratives in both anterior and posterior teeth [8, 9]. A more important demand than color matching is the long-last maintenance of this color; a criterion referred to in the literature as "color stability". Secondary caries and intrinsic discoloration are possible causes of color change. Nonetheless, extrinsic discoloration; caused by cyclic exposure to stained food and beverages such as cola, coffee, and tea, remains the major cause of color instability in the oral environment[10- 12].

Therefore, this study aimed at comparing digital photography to spectrophotometry in assessing the color stability of resin composite.

MATERIALS AND METHODS

Ethical clearance

The Research Ethics Committee in the Faculty of Dental Medicine for Girls at Al-Azhar University approved this research (P-OP-21-02). The research included no humans or animals therefore, Helneski's declaration was not applicable.

Sample size calculation

At a confidence interval of 95% and a 16.97% margin of error, the sample size was calculated to be 32 specimens; as estimated by the sample size calculator application (www.calculator.net).

Preparation of the specimens

Thirty-two specimens in disc-shape were made from Filtek Z350 resin composite of A1 shade, by (3M ESPE, St. Paul, Minnesota, USA): Table 1 presents its composition and specifications. Specimens were prepared by packing resin composite inside individual customized circular Teflon molds with diameters and heights of 10 and 2 mm respectively [13]. For each specimen the mold was slightly overfilled and was then covered on both sides with Mylar strips, the mold was then sandwiched between two glass plates, on which a 0.5 kg static load was applied for 4 min by a dynamometer of fixed compression type (Axis; Gdansk, Poland); to flatten the surfaces and to extrude excess resin composite for future removal [14]. The specimens were light-cured using LED F (Woodpecker; Poland, Europe) for 20 seconds for each side (1700 mW/cm^2) [15]. Finishing and polishing were attempted later by Soflex finishing & polishing system by (3M ESPE, St. Paul, Minnesota, USA), and kept at room temperature for 24 hrs in distilled water [15].

Table (1) *The composition and specifications of Filtek Z350 resin composite*

Resin composite	Description	Composition		%Weight of filler	Batch no.	Manufactured by
		Resinous Matrix	Filler Type			
Filtek Z350	Nanofilled Enamel A1	Bis GMA, TEGDMA, UDMA, and Bis- EMA	Both silica nanofillers (5-75 nm) and zirconia\silica nanoclusters (0.6-1.4µm)	78.5%	2167	3M ESPE in (St. Paul, Minnesota, USA)

Devices and settings

- Two Canon DSLR cameras (Canon; Tokyo, Japan) were used; Canon EOS 1100D and Canon EOS 600D: Table 2 lists the criteria of the digital cameras used in the study. Each camera was equipped with Canon 100 mm macro lens and Godex ML- 150 mounted ring flash with 1:1 shooting power. Both cameras were adjusted at the following settings; manual mode and focus 'M', F20 aperture value, 1/125 Shutter speed, and ISO 100 [16]. Between each specimen and the digital camera, an 11 cm shooting distance was fixed using a tripod.
- A digital spectrophotometer (Vita Easyshade advance 4.0; Vita Zahnfabrik, Bad Sackingen, Germany) was utilized as the standard color-assessing device.
- A grey card (white balance card) was used as a standard background during digital imaging and spectrophotometric calibration.

Table (2) *Criteria of the digital cameras used in the study (according to manufacturer)*

Camera type	Canon 1100D	Canon600D
Sensor	12.2 megapixels	18 megapixels
Size of sensor	22.2×14.7 mms	22.3×14.9 mms
Body weight	495 g	525 g
Iso (sensor sensitivity)	100 – 6400	100 – 12800
Shutter Speed	1\ 4000 sec-30 sec	1\ 4000 sec-30 sec
Options for White balance	Auto - Daylight - Shade - Cloudy - Tungsten - White Fluorescent - Flash – Custom	Auto - Daylight - Shade - Cloudy - Tungsten Light - White Fluorescent Light - Flash – Manual – user set
File format	JPEG, RAW	JPEG, RAW

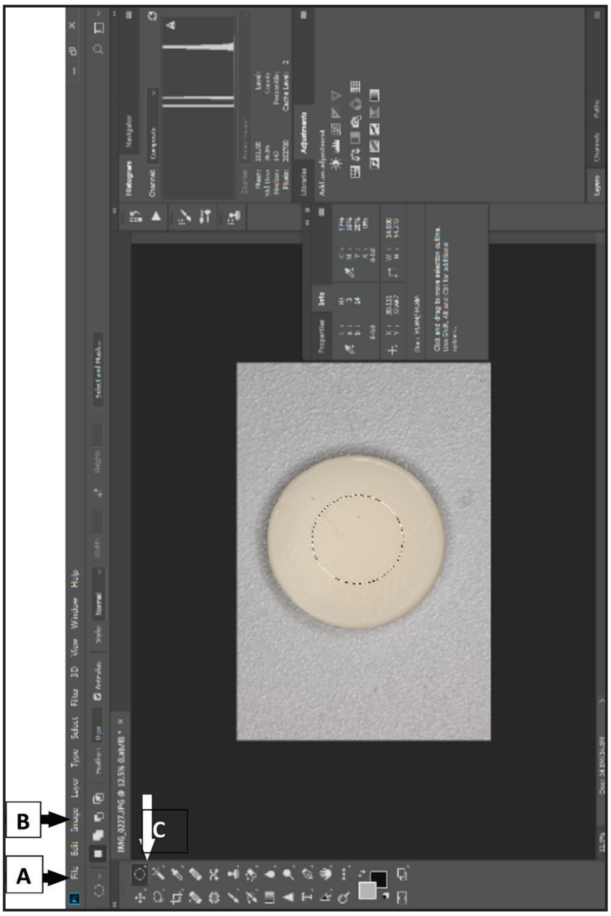
Assessment of specimens' color by digital photography

Captured images, with the previously-set digital cameras, were saved in RAW file format [4]. They were then analyzed using Adobe Photoshop CS3 software. The "file", and "menu" were selected then "open" to select the image to be analyzed from the computer (Fig. 1A) or Ctrl + O (step one). To eliminate any undesired disturbance in color (color cast), the "Levels dialogue" was opened by pressing "Ctrl + L", "Image", then "Adjust" and Levels (step2) (Figure. 1B). The "histogram" in addition to the "three eye-dropper" tools appeared; the middle one (the gray one) was selected and moved over the gray card in the picture.

The color space was changed from RGB to Lab. "Image" then "menu" were used then "Mode" and "Lab" were finally selected (Fig. 1B). The area to be measured was selected by using the magnetic lasso (the second tool on the toolbar) (step three) (Fig. 1C). The resultant CIE L*a*b values, using adobe photoshop, were then collected and recorded as baseline readings for both Canon 600D and Canon 1100D digital cameras (group I and group II) respectively.

Assessment of specimens' color by spectrophotometry

For calibration, the tip of the spectrophotometer was placed at a right angle to the calibration pad center. The tip was then applied to each specimen; with intimate contact of the tip with the specimen center [13, 15]. The tip should not be turned during measurement according to the user manual. Initially, the name of the shade appeared on the screen. A further press showed the shade in CIE L*a*b values. The obtained values were recorded as baseline readings for group III (control group).



Figure(1) The screen of Photoshop software:
A: “File”, “Menu” then “open” to open an image (step one).
B: “Image”, “Menu”, “Adjust” then “Levels” (step two).
B: “Image”, “Menu”, “Mode” then “Lab” (step three).
C: “Lasso tool” (step four).

Preparation of the staining medium and submersion of the specimens

Coffee powder (3.6 gm) (Nescafe Classic; Nestle, Switzerland) was added to boiling water (300 mL), well-stirred, then paper-filtered. The specimens were submerged in the prepared solution and kept in tightly-covered vials at room temperature; with solution renewal every two days [13]. After 30 days of submersion, each specimen was subjected to one min- wash to get rid of debris.

Reassessment and calculation of color change

Both digital photography and spectrophotometric assessments were again made for all specimens, after submersion in coffee solution. Color difference (ΔE); (After submersion measurement - baseline measurement) was obtained from the equation: $\Delta E=[(\Delta L)2 +(\Delta a)2 +(\Delta b)2]$ ½. Notably, ΔL, Δa, and Δb represent the mean differences in L, a, and b values before and after the submersion; (L2 -L1), (a2-a1), and (b2-b1) respectively [2]. The color difference assessment equation was written in an excel sheet to be applied to the entire collected data.

RESULTS

Statistical analysis

All measurements were collected, tabulated & statistically analyzed using IBM SPSS Statistics version 25 for Windows (Armonk, New York, USA). Kolmogorov-Smirnov test was used to investigate the parametric distribution of data (normality). The homogeneity of variances, however, was tested by Levene’s test. Since data showed parametric distribution and variance homogeneity, they were presented as mean and standard deviation values and were analyzed using one-way ANOVA followed by Tukey’s post hoc test for comparison between different devices. For all tests, the significance level was set at $P \leq 0.05$.

Color assessment of samples before and after coffee immersion using the tested devices

The mean and standard deviation color values of Filtek Z350 samples recorded a statistically significant difference before and after coffee immersion ($P= 0.000$).

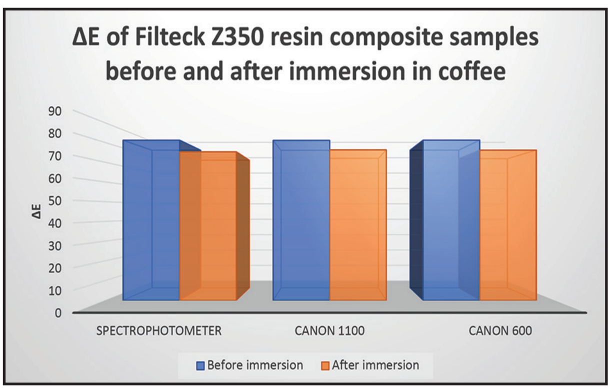
For color assessment before immersion in coffee, the highest values were recorded in samples captured by Canon 600 camera (81.12 ± 0.53), followed by samples captured by spectrophotometer (81.08 ± 0.21) while samples captured by Canon 1100 camera recorded the least values (81.01 ± 0.51). There was no statistically significant difference among the tested assessment devices ($P = 0.831$).

Regarding color assessment after immersion in coffee, the highest values were recorded in samples captured by Canon 1100 camera (76.25±0.86), followed by samples captured by Canon 600 camera (76.10±1.42), while the least values were recorded in samples captured by spectrophotometer (75.23±1.26). Similar to the samples' shades recorded before coffee immersion, there was no statistically significant difference between the three tested devices (P =0.053). Table 3 includes mean and standard deviation color values of Filtek Z350 samples before and after coffee immersion; assessed by the tested devices, while Fig. 2 shows such mean color values as assessed by the tested devices.

Table (3) *Mean and standard deviation color values of Filtek Z350 samples before and after immersion in coffee; assessed by the tested devices.*

	Spectropho-tometer		Canon 1100		Canon 600		*P*-Value
	Mean	SD	Mean	SD	Mean	SD	
Before immersion	81.08	0.21	81.01	0.51	81.12	0.53	0.831
After immersion	75.23	1.26	76.25	0.86	76.10	1.42	0.053
P-Value	0.000*		0.000*		0.000*		

** Indicates the mean difference is statistically significant at P ≤ 0.05.*



Figure(2) A bar chart showing mean color values (ΔE) of Filtek Z350 resin composite samples before and after immersion in coffee; assessed by the tested devices.

DISCUSSION

The introduction of digital cameras for color assessment was a result of technological advancements in both computing and photography. The camera-based method used the CIE Lab color space; including a* and b* parameters to determine dental hue and the L* parameter to measure brightness [17]. Professional cameras (DSLRs, or Digital Single Lens Reflex) typically last longer and offer superior options for adjusting the image quality as needed [18]. This study compared the accuracy of digital photography to the Vita Easyshade spectrophotometry in the assessment of color stability of Filtek Z350 resin composite. Vita Easyshade spectrophotometer acted as a control because of its repeatability and dependability; it yields accurate color L* a* b* values, as long as the device tip is precisely placed [3]. Filtek Z350 resin composite was selected; as one of the most widely used resin composites with good physical and esthetic criteria. However, coffee was chosen as a colorant agent due to its usual daily intake by most people, and a 30-day exposure period appears to represent around 30 months of coffee use [13].

The images of the specimens were taken with digital cameras (Canon EOS 1100D, EOS 600D), which are Canon's DSLRs with the most basic features. These cameras were fitted with a Godex ML-150 ring flash that emits light at a color temperature of 5500-5600 K; the same as daylight which is the most accurate light for shade determination [4]. The 1:1 magnification was selected because it produces the least distorted images. The tripod-fixed 11 cm shooting distance, however, allowed the entire specimen to be well captured inside the image [19].

The cameras were set to manual mode; so that the time of sensor exposure to light (shutter speed), the degree of field focus (depth of field), the "white balance", and the sensor sensitivity to light; known as (ISO); according to the International Standardization Organization, could all be customized. A fast shutter speed (minimum

1/125 sec) is required to avoid camera shake, even when using a tripod. The shutter speed was set to 1/125 sec, therefore, to obtain a sharper image [20]. For a deeper depth of field, the lens aperture (F stop) was set to F20; with such a narrow aperture, practically everything will be finely focused [21]. The "white balance" setting adjusts image colors to match the color tone of the light source; in a way that white objects in real life appear white in the image; neither cooler (i.e: bluish) nor warmer (i.e: yellowish). A grey card acted, in this study, as a reference point against which the "white balance" could be customized [22]. Light sensitivity (ISO) was kept to only 100; as increased light sensitivity (high ISO) has the drawback of causing grainy images (noise) [23]. The output of the acquired photographs was in RAW format by default, which features the captured images' data as directly resulting from the camera with minimal processing if any [24]. The photographs were later analyzed using Adobe Photoshop software to determine the precise L, a, and b values for each specimen.

Results showed that statistically, there was no significant difference between digital photography and spectrophotometry in determining the color stability of Filtek Z350 resin composite specimens. These findings are consistent with several studies[25-27], and all came to the conclusion that employing digital photography for shade matching can be a useful alternative to using spectrophotometers for shade selection in a clinical setting. Such outcomes could be attributable to the use of common lighting, settings, and camera equipment. Notably, the ΔE value, or the mean color difference between the L* a* and b* values acquired by the spectrophotometer and DSLR cameras, was less than the recommended acceptable clinically-detectable value of 2 [19]. The usage of a standardized grey reference card, as a background with both cameras and in spectrophotometer calibration as well, might have partly aided these results. According to previous studies [28, 29], the grey card was capable of overcoming the restriction of visually perceptible effects in digital photographs.

Oppositely, another study [30] concluded that the DSLR camera used in conjunction with the ring flash system and polarized filter produced the least accurate readings for their study. This finding may be related to the use of the polarized filter; resulting in values that were too far from the values reported by the spectrophotometer. Obviously, the polarized filter was absent in the current study. The outcome of this study confirms that digital dental pictures are useful in determining shade. Additionally, they enable assessment of the tint of the entire specimen rather than just one particular section or point. This would provide the ability to replicate the shade and other tooth features; rendering a restoration that looks realistic. The need for knowledge of photography and software management, however, remains one of the limiting factors. In addition, a practitioner with insufficient Adobe Photoshop experience may struggle with shade determination after digital imaging.

CONCLUSIONS

Within the investigation's constraints, digital photography and spectrophotometry are similarly valuable for color assessment of resin composite.

RECOMMENDATIONS

1. Clinical investigations involving color assessment by different versions of digital cameras are strongly recommended.
2. Digital photography training programs are highly advocated; as digital photography is being rapidly incorporated into everyday dental practice.

ACKNOWLEDGEMENT

Dr. Ayman El-Amin provided the study's spectrophotometer, which the authors are quite appreciative of.

FUNDING

No specific grant was given to the research by a funding organization in the public, private, or nonprofit sectors.

CONFLICTS OF INTEREST

The authors have made it apparent that no conflicts of interest exist that would taint the results.

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