Frontiers in Dentistry

Color Assessment of Screw-Retained Implant Prostheses Access Hole Fillings: An In-Vitro Study

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Article Info

Article type:
Original Article

Article History:
Received: 25 Nov 2023
Accepted: 10 May 2024
Published: 07 Dec 2024

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ABSTRACT

Objectives: This study aimed to investigate the aesthetic aspect of screw-retained restorations by examining three different types of filling materials used for the access cavity, highlighting the significance of aesthetics in implant restorations.

Materials and Methods: In this laboratory investigation, simulation samples of screw-retained restorations were filled with flowable composite resin (group F), opaque and flowable composite resin (group O) and porcelain plug (group P) at baseline (T0). The samples were subjected to thermocycling twice (T1 and T3), undergoing 1000 cycles in coffee, orange juice, and distilled water, followed by washing performed after each thermocycling (T2 and T4). Colorimetric analysis and surface roughness measurements were conducted, and the data were statistically analyzed using two-way analysis of variance (ANOVA), Tukey post hoc, two-way analysis of covariance (ANCOVA), and paired-t test. $P<0.05$ was considered significant.

Results: The type of filling material had a significant effect on the color difference observed between the restoration and filling materials ($P<0.05$). Notably, samples from group P exhibited a more pronounced color difference at T4, despite showing a lower color difference at T0, when compared to group O.

Conclusion: The use of porcelain plugs did not provide a notable advantage over the combination of flowable and opaque composite resins, particularly given the difficulties in fabricating and positioning porcelain plugs within the access cavity. Therefore, it is recommended to utilize flowable composite resins in conjunction with an opaque composite resin layer beneath, to effectively conceal any dark shades from the underlying metal.

Keywords: Dental Prosthesis, Implant-Supported; Dental Porcelain; Composite Resins; Spectrophotometry; Color

➢ **Cite this article as:** Sarrafzadeh A, Nakhostin A, Jadidi S, Safari M. Color Assessment of Screw-Retained Implant Prostheses Access Hole Fillings: An In-Vitro Study. *Front Dent*. 2024:21:46.

INTRODUCTION

Screw-retained and cement-retained restorations are the two types of implant-supported prostheses [1]. In the 1980s and early 1990s, screw-retained restorations had a preference due to their advantages including retrievability, being cement free, ease of peri-implant probing, and superior marginal adaptation [2,3]. Although, the access hole of a screw-retained crown is typically situated in areas that are inconspicuous or less aesthetically significant, the aesthetic merit of screw-retained restorations is often deemed questionable owing to the presence of access hole on the facial aspect of the crown when the implant is not optimally positioned [2,4]. On the other hand, although cement-retained restorations offer enhanced aesthetics, in case of incomplete removal of excess cement, they can be a major cause of peri-implantitis [2]. Taking this into consideration, many clinicians consider screw-retained restorations as the most advantageous choice [2]. However, from the patient's viewpoint, aesthetic factors are equally as critical as maintaining a healthy functional dentition [1].

In the previous studies, a variety of materials, including composite resins, have been introduced [5]. Although composite resins are common materials for filling access holes of screw-retained restorations, they exhibit certain drawbacks such as pronounced wear, elevated potential for discoloration, and microleakage [6]. Moreover, they are relatively translucent and may not adequately obscure the darkness of the underlying metal oxide layer of the access hole [1]. Furthermore, the color stability of the restorative material used is an important feature in the selection of filling materials, as it affects the long-term color match between the access hole filling and the restoration, given that composite resins, which constitute one of the materials utilized for filling access holes in these restorations, are vulnerable to various discoloring agents [7]. An alternative aesthetic solution for filling the access hole is porcelain plug, the color of which predominantly depends on its thickness [8].

Various techniques, such as altering the color of the screw, using different thicknesses of composite resins, and utilizing opaque composite resins to mask the gray shade of the metallic component of the access hole have been previously explained [1]. Nevertheless, to date, there has been no investigation that directly compares porcelain plugs with composite resins as materials for filling the access holes in screw-retained implant restorations.

In this study, focusing on the importance of the aesthetic aspect, the conventional flowable composite resins, opaque composite resins, and porcelain plugs were compared as filling materials for access holes. Furthermore, in this study, considering the effect of surface roughness on the stain susceptibility, the surface roughness of the restoration molds and the fillings were examined. It is anticipated that due to the superior color stability of porcelain in contrast to composite resins, and the congruence of material types in the porcelain plug and the surrounding porcelain, the color difference between the porcelain plug and the surrounding porcelain will be less pronounced.

MATERIALS AND METHODS

This study was planned and implemented as an in-vitro study. The study protocol with ethics code IR.ARAKMU.REC.402.101 was approved by the Ethics Committee of the Medical Ethics Group of Arak University of Medical Sciences.

Figure 1 demonstrates a schematic representation of the samples utilized in the present study. A total of Thirty-six custom-made nickel-chromium cylindrical metal molds [5] were cast featuring an outer cylinder diameter of 8mm, an inner cylinder diameter of 4mm, a total height of 5.5mm, and a depth of the access hole measuring 4.5mm. Additionally, a metallic projection was incorporated as a reference point to the cylinder, measuring 3mm in height, 1mm in width, and 1mm in depth. The upper horizontal surfaces of the metal molds, excluding the reference projections were coated with a thin layer of opaquer (Vintage Pro, Shofu, Japan), followed by the application of porcelain in shade A2 (Vintage Pro, Shofu, Japan) and subsequent glazing (Vintage Art, Shofu, Japan). Cotton pellets, measuring 2mm, were placed within the access hole [5]. Primer (Z-prime plus, Bisco, USA) was applied to the metallic walls of the access holes. Three-dimensional resin patterns were designed and utilized in the press technique to produce monolithic lithium disilicate porcelain plugs [6]. The appropriate shade of ingot (IPS e.max Press, Ivoclar Vivadent, Liechtenstein) was selected based on spectrophotometric evaluations to ensure optimal color matching with the surrounding porcelain for the porcelain plugs.

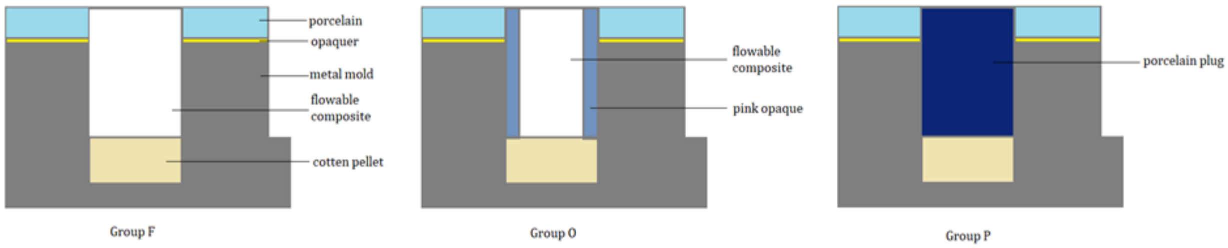

Fig 1. Schematic representations of vertical sections of the samples utilized in this investigation.

The samples were divided into three groups based on their filling materials as follows:

Group F: The access holes were filled using bonding agent (G-Premio bond, GC, Japan) prior to the application of flowable composite resin in shade A2 (DenFil Flow, Vericom, South Korea).

Group O: The access holes were filled using bonding agent (G-Premio bond, GC, Japan), followed by the application of 0.5mm of pink opaque composite resin (Creative color pink opaque, Cosmedent, USA), and subsequently topped with flowable composite resin in shade A2 (DenFil Flow, Vericom, South Korea).

Group P: The porcelain plugs were soaked with primer (Z-prime plus, Bisco, USA), and then inserted into the access holes using dual-cure cement (Dual cure glass ionomer cement, Prime Dental, USA).

All surfaces underwent polishing with a low-speed rotary instrument and polishing paste (Diamond excel, FGM, Brazil). Each group was further divided into 3 subgroups based on the beverages tested: W (distilled water), J (orange juice), and C (coffee).

Spectrophotometric analysis was conducted on both the fillings and the surrounding porcelains utilizing dental spectrophotometry (Spectroshade, MHT Optic, Switzerland) at various time points: baseline (T0), following 1000 cycles of thermocycling (5°C/55°C) with a 30-second dwell time in each beverage and a 15-second transportation time (T1) (fig 2), subsequent to rinsing after a 2-minute brushing with a manual toothbrush (Medical with soft bristles, China) and a toothpaste containing silica hydrated abrasives (White System, Signal, Iran) (T2), after repeated thermocycling (T3) (fig 3), and after repeated brushing and rinsing (T4).

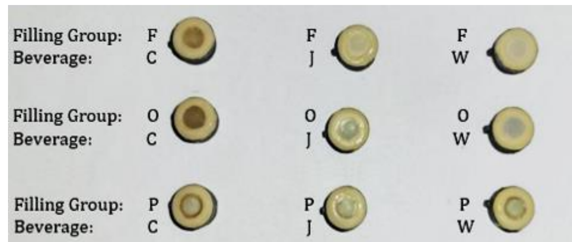

Fig 2. Samples at T1 time point. F: flowable composite resin; O: opaque and flowable composite resins; P: porcelain plug; C: coffee; J: orange juice; and W: distilled water.

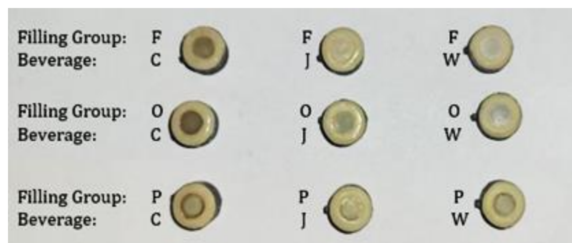

Fig 3. Samples at T3 time point. F: flowable composite resin; O: opaque and flowable composite resins; P: porcelain plug; C: coffee; J: orange juice; and W: distilled water.

Color parameters were assessed using the CIE L*a*b*color space system [9].

The color differences between the filling and the surrounding porcelain (ΔE_{fp}) at T0, T1, T2, T3 and T4, as well as the color alterations of the surfaces (i.e., the surrounding porcelain [ΔE_p] and the filling [ΔE_f]) from T0 to T1, T2, T3, and T4 were calculated using the following equations:

$$\Delta E_{fp}=\sqrt{(L_p-L_f)^2+(a_p-a_f)^2+(b_p-b_f)^2}$$

$$\Delta E_f=\sqrt{(L_{f_{Tx}}-L_{f_{T0}})^2+(a_{f_{Tx}}-a_{f_{T0}})^2+(b_{f_{Tx}}-b_{f_{T0}})^2}$$

$$\Delta E_p=\sqrt{(L_{p_{Tx}}-L_{p_{T0}})^2+(a_{p_{Tx}}-a_{p_{T0}})^2+(b_{p_{Tx}}-b_{p_{T0}})^2}$$

Surface roughness (Ra, µm) was measured at T0 and T4 using Surface roughness tester machine (TR200 with a 2.5mm cut-off, 5µm diamond stylus radius, and a 90° stylus angle, Time Group, China), with three measurements taken and the average reported as the roughness for both time points [10].
The effects of the beverage, the filling, and their interaction on ΔE_{fp}, ΔE_f and ΔE_p were assessed using a two-way analysis of variance (ANOVA), followed by the Tukey post hoc. The effect of these variables on surface roughness was assessed using a two-way analysis of covariance (ANCOVA). Further-more, a paired-t test was employed to compare Ra values between T0 and T4. Statistical analyses were conducted utilizing SPSS, with a significance threshold at a P-value of less than 0.05.

RESULTS

Color changes

Mean values and standard deviations for surface color changes (ΔE) by time in different groups are shown in Table 1.

Table 1. Means and standard deviations (SDs) of surface color changes (ΔE) by time in different groups

Filling	Measured surface	Time *	Beverage (Mean± SD)		
			W	J	C
Flowable composite resin (group F)	Filling	T0-T1	2.96±1.04	2.91±0.63	12.13±3.39
		T0-T2	2.25±0.90	2.43±0.51	7.11±2.48
		T0-T3	2.08±1.53	3.60±1.07	14.08±1.27
		T0-T4	1.81±0.57	2.46±0.82	8.59±1.21
	Surrounding porcelain	T0-T1	1.78±0.47	0.99±0.40	2.59±0.88
		T0-T2	0.70±0.32	0.72±0.26	1.69±0.42
		T0-T3	1.35±0.37	1.84±0.48	4.09±1.10
		T0-T4	0.61±0.28	0.91±0.34	2.70±0.93
Opaque and flowable composite resins (group O)	Filling	T0-T1	2.23±0.65	3.50±0.86	11.03±1.90
		T0-T2	2.37±0.63	3.22±0.98	5.36±1.30
		T0-T3	1.79±0.80	3.13±0.83	13.31±1.41
		T0-T4	1.95±0.55	2.73±1.35	6.75±0.95
	Surrounding porcelain	T0-T1	0.85±0.15	0.94±0.32	2.96±0.66
		T0-T2	0.75±0.38	0.87±0.47	2.27±1.08
		T0-T3	1.77±1.70	1.42±0.42	5.19±0.85
		T0-T4	0.62±0.20	0.50±0.13	3.33±0.69
Porcelain plug (group P)	Filling	T0-T1	2.23±1.26	1.62±1.46	6.09±2.2
		T0-T2	1.58±1.00	1.72±1.18	3.93±2.14
		T0-T3	2.03±0.99	1.54±1.36	8.69±2.26
		T0-T4	1.68±0.97	1.24±1.15	6.10±2.36
	Surrounding porcelain	T0-T1	1.39±0.65	0.52±0.33	2.22±0.91
		T0-T2	1.40±1.39	0.76±0.66	1.67±0.55
		T0-T3	1.64±1.06	0.84±0.43	4.06±2.64
		T0-T4	1.19±1.27	0.67±0.35	2.17±0.73

*Color changes were calculated between two time points; T0: baseline; T1: after 1000 cycles of thermocycling; T2: after brushing for 2 minutes and rinsing subsequently; T3: after repeating 1000 cycles of thermocycling; T4: after repeating the brushing and rinsing procedure; C: coffee; J: orange juice; W: distilled water

After T0, the group O exhibited a lower ΔE_{fp} compared to the other two groups. Notably, at T0, group O demonstrated a higher ΔE_{fp} compared to group P (Figure 4).

The type of filling had a significant effect on the ΔE_{fp} across all time points, with a statistically significant difference observed between groups F and O (P<0.05). However, no significant difference in ΔE_{fp} was found between groups P and O at any time point (Table 2).

The beverage type had a significant effect on color changes of all surfaces, including the filling material (ΔE_f) and surrounding porcelain (ΔE_p), when compared to T0 at all study times (P<0.05). The effect of filling material type on ΔE_f compared to T0 was significant at all measured time points (P<0.05) (Table 3).

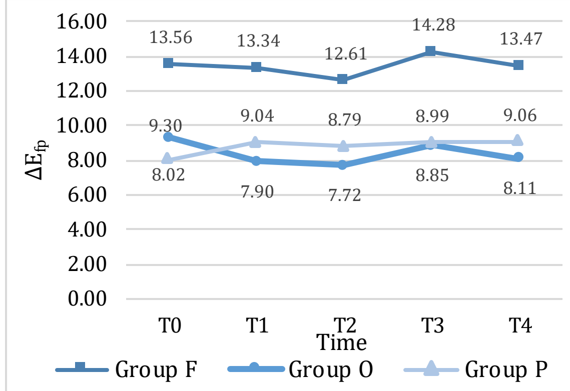

Fig 4. Chart of ΔE_{fp} over time, categorized by the type of filling materials; T0: baseline; T1: after 1000 cycles of thermocycling; T2: after brushing for 2 minutes and rinsing subsequently; T3: after repeating 1000 cycles of thermocycling; T4: after repeating the brushing and rinsing procedure; group F: flowable composite resin; group O: opaque and flowable composite resins; group P: porcelain plug

Table 2. Two-way ANOVA results for color differences between filling and surrounding porcelain (ΔE_{fp}) at different times

Time	Factor	Type III Sum of squares	df	Mean Square	F	P
T0	Filling	202.15	2	101.07	29.71	<0.001*
	Beverage	2.72	2	1.36	0.40	0.674
	Filling× Beverage	11.65	4	2.91	0.85	0.502
T1	Filling	197.24	2	98.62	18.96	<0.001*
	Beverage	15.98	2	7.99	1.53	0.233
	Filling× Beverage	38.15	4	9.53	1.83	0.151
T2	Filling	158.81	2	79.40	17.10	<0.001*
	Beverage	8.64	2	4.32	0.93	0.407
	Filling× Beverage	36.89	4	9.22	1.98	0.125
T3	Filling	229.72	2	114.86	26.16	<0.001*
	Beverage	34.68	2	17.34	3.95	0.031*
	Filling× Beverage	42.58	4	10.64	2.42	0.072
T4	Filling	195.84	2	97.92	18.58	<0.001*
	Beverage	12.26	2	6.13	1.16	0.327
	Filling× Beverage	41.94	4	10.48	1.99	0.124

T0: baseline; T1: after 1000 cycles of thermocycling; T2: after brushing for 2 minutes and rinsing subsequently; T3: after repeating 1000 cycles of thermocycling; T4: after repeating the brushing and rinsing procedure; group F: flowable composite resin; group O: opaque and flowable composite resins; group P: porcelain plug; *significant

Table 3. Two way ANOVA results for color changes (ΔE) of surfaces at different time points

Surface	Time*	Factor	Type III Sum of squares	df	Mean Square	F	P
Filling	T0-T1	Filling	50.38	2	25.19	8.57	0.001**
		Beverage	412.37	2	206.18	70.19	<0.001**
		Filling× Beverage	41.40	4	10.35	3.52	0.019**
	T0-T2	Filling	15.64	2	7.82	4.04	0.029**
		Beverage	83.10	2	41.55	21.50	<0.001**
		Filling× Beverage	10.54	4	2.63	1.36	0.272
	T0-T3	Filling	41.81	2	20.90	11.42	<0.001**
		Beverage	751.05	2	375.52	205.22	<0.001**
		Filling× Beverage	35.65	4	8.91	4.87	0.004**
	T0-T4	Filling	10.09	2	5.04	3.39	0.048**
		Beverage	214.30	2	107.15	72.09	<0.001**
		Filling× Beverage	8.50	4	2.12	1.43	0.251
Surrounding porcelain	T0-T1	Filling	0.98	2	0.49	1.41	0.26
		Beverage	19.98	2	9.99	28.71	<0.001**
		Filling× Beverage	2.37	4	0.59	1.70	0.178
	T0-T2	Filling	0.5	2	0.25	0.49	0.618
		Beverage	8.31	2	4.15	8.14	0.002**
		Filling× Beverage	1.69	4	0.42	0.83	0.517
	T0-T3	Filling	2.26	2	1.13	0.74	0.484
		Beverage	70.83	2	35.41	23.25	<0.001**
		Filling× Beverage	3.41	4	0.85	0.56	0.693
	T0-T4	Filling	0.11	2	0.05	0.13	0.878
		Beverage	31.37	2	15.68	36.11	<0.001**
		Filling× Beverage	3.81	4	0.95	2.19	0.096

*Color changes were calculated between two time points; T0: baseline; T1: after 1000 cycles of thermocycling; T2: after brushing for 2 minutes and rinsing subsequently; T3: after repeating 1000 cycles of thermocycling; T4: after repeating the brushing and rinsing procedure; **significant

Surface roughness

Mean values and standard deviations for surface roughness values in all groups are shown in Table 4. Analysis revealed no significant differences in Ra among the various fillings at T0. When comparing surface roughness, including both fillings and surrounding porcelain, no significant differences in Ra were noted between T0 and T4. Additionally, neither the type of beverage nor the filling exhibited a significant effect on any of the surfaces at T4 (Table 5).

Table 4. Means and standard deviations (SDs) of surface roughness values in all groups

Filling	Beverage	Measured Surface (Mean± SD)			
		Filling		Surrounding porcelain	
		T0	T4	T0	T4
Flowable composite resin (group F)	Distilled Water	0.03±0.02	0	0.32±0.47	0.61±1.21
	Orange Juice	0.81±1.59	0	0.12±0.22	0.17±0.29
	Coffee	0.06±0.05	0.04±0.05	0.12±0.09	0.15±0.19
	Total	0.30±0.91	0.02±0.03	0.19±0.29	0.31±0.69
Opaque and flowable composite resins (group O)	Distilled Water	0.67±0.50	0	1.00±0.72	0.01±0.01
	Orange Juice	0.58±0.75	0.29±0.53	0.41±0.47	0.12±0.16
	Coffee	0.76±0.58	0.03±0.03	0.76±0.73	0.02±0.02
	Total	0.67±0.57	0.11±0.31	0.72±0.64	0.05±0.09
Porcelain plug (group P)	Distilled Water	0	0.01±0.00	0.01	0
	Orange Juice	0.22±0.38	0.30±0.41	0.09±0.15	0.18±0.23
	Coffee	0	0.21±0.36	0.01	0.40±0.76
	Total	0.07±0.23	0.17±0.31	0.04±0.09	0.19±0.45

T0: baseline; T4: after 1000 cycles of thermocycling and subsequent brushing and rinsing procedure for two time

Table 5. Two-way ANCOVA results for surface roughness values at T4 (after 1000 cycles of thermocycling and subsequent brushing and rinsing procedure for two times)

Surface	Factor	Type III Sum of squares	df	Mean Square	F	P
Filling	Surface roughness at T0	0.10	1	0.10	1.61	0.215
	Filling	0.18	2	0.09	1.42	0.259
	Beverage	0.16	2	0.08	1.23	0.309
	Filling× Beverage	0.23	4	0.05	0.88	0.487
Surrounding porcelain	Surface roughness at T0	0.95	1	0.95	4.23	0.05
	Filling	1.16	2	0.58	2.57	0.096
	Beverage	0.01	2	0.01	0.04	0.959
	Filling× Beverage	0.93	4	0.23	1.04	0.405

T0: baseline

DISCUSSION

Cement-retained implant restorations are known for their aesthetic appeal; however, they are susceptible to complications related to cement, which can result in biological issues such as implant failure and peri-implant complications [6,11,12]. On the other hand, screw-retained restorations, although less aesthetically pleasing due to the presence of the access hole for the screw, provide enhanced biological compatibility and superior marginal adaptation [11]. Despite patient's preference for aesthetics, dentists prefer screw-retained restorations [12,13]. Composite resins are frequently employed to fill the screw access holes, yet they present challenges such as color discrepancies and concerns regarding durability. To mitigate these drawbacks, porcelain plugs have been introduced, aiming to enhance both the longevity and aesthetic quality of screw-retained restorations [5,6,11,14].

Numerous factors, including chemical degradation, stain accumulation, dehydration, water absorption, leakage, weak bonding, and surface roughness, influence the color stability of restorative materials, including composite resins and porcelains [15].

Although Wadhwani and colleagues reported on the use of porcelain plugs in a case study in 2011 [8], a comparative analysis of this filling method against conventional composite resins had not been previously undertaken. In the present study, in addition to comparing the color differences of filling materials and the surrounding porcelain at the initial time point, the color changes of the fillings over time was also examined.

The findings revealed significant color differences among the different filling materials in relation to the surrounding porcelain, with flowable composite resin exhibiting the most pronounced difference. In groups P and O, however, the color difference with the surrounding porcelain was not statistically significant. This observation aligns with the findings of Cakan et al. [5], who, through the application of various combinations of composite resins, demonstrated that the color variation between the control sample (cement-retained restoration) and the group filled with a mixture of opaquer and composite resins is less pronounced compared to other groups. Their research, however, did not explore the impact of different beverages on changes in color.

The findings of the investigation regarding ΔE_f from T0 to T4 indicate a significant difference in color changes between groups F and P. No significant difference was observed in the color changes of the groups O and P. When comparing the filling materials at T0 to absolute black, group F exhibited a color value of 66.64±3.97, group O showed 72.47±3.66, and group P recorded 70.15±4.06. The results suggest that the color of the group O filling is more akin to the surrounding porcelain (76.13±1.37), which contrasts with the findings of Acar et al [7]. The current study indicates that the color changes in lithium disilicate used for the porcelain plug did not significantly differ from those observed in opaque composite resins. However, it is important to acknowledge the limitations of their study, as the samples were subjected to staining and light-curing from both surfaces due to the in-vitro design. In our investigation, despite being in-vitro, the simulation of metal-ceramic restorations closely mirrored clinical conditions, thereby mitigating the aforementioned issues.

In the comparison of ΔE_{fp} at T4, the type of filling significantly influenced ΔE, with a marked difference between filling group F and the other two groups ($P<0.05$). However, no significant difference was found between the groups P and O. This finding is unexpected given the anticipated color stability of porcelain. The observed discrepancy may stem from variations in porosity among the porcelains utilized, which could influence their discoloration over time. Additionally, the type of beverage employed in this study had a significant impact on the values of ΔE_f and ΔE_p from T0 to T4. Coffee demonstrated a notable effect ($P<0.05$) on color changes when compared to distilled water and orange juice, thereby emphasizing the role of dietary choices in the color stability of restorations, whether composite resin materials or porcelain. Although porcelain is generally recognized for its color stability, existing literatures indicate that certain beverages, such as coffee, can provoke color changes. Other studies have also investigated the effects of various beverages on color changes in both composite resin and porcelain materials [16,17]. The results of the current study corroborate previous findings, underscoring the necessity of considering personal habits and beverage intake in the assessment of restoration color changes.

Orange juice was incorporated into the study due to its acidic nature, which may influence the surface roughness of dental materials and potentially contribute to increased staining and color changes [18,19].

Previous research has not demonstrated a significant relationship between beverage type and surface roughness after 15 and 30 days [20]; similarly, the current study found no notable effects. Surface roughness was assessed at two distinct time intervals, T0 and T4, revealing no significant differences in relation to the various beverages tested. Firouz et al. [19] investigated the impact of different beverages on porcelain and found no significant difference in surface roughness between glazed and polished samples. This suggests that occlusal adjustments, which involve the removal of the glaze from porcelain plugs, can be effectively compensated for by polishing, resulting in negligible differences in surface roughness. In the current study, the samples were also polished. Although Firouz et al. reported a significant increase in surface roughness of porcelain exposed to orange juice, this study did not replicate that finding, although an increase in surface roughness was noted for porcelain immersed in orange juice. The discrepancies in results between the studies may stem from differences in the types of porcelain used, fabrication techniques, and the number of thermocycling cycles applied. Unlike the study by Firouz et al., the present research utilized a press technique for the fabrication of porcelain plugs. Furthermore, the number of thermocycling cycles varied between the two studies, suggesting that the long-term acidity of the materials may affect surface roughness. Another notable difference is that Firouz and colleagues did not employ abrasive toothpaste; while Lepri et al. [20] indicated that the difference in surface roughness before and after the use of abrasive toothpaste was not significant, further investigation into the interaction between thermocycling and abrasive toothpaste is warranted in future research. Regarding composite resin materials, various studies have reported inconsistent effects of thermocycling on surface roughness. While certain studies have reported no significant effects after a specified number of thermocycling cycles [9,21], others have documented notable alterations in roughness levels [10]. This discrepancy suggests that various composite resins may exhibit differing responses to thermocycling. The overall findings indicate that the behavior of composite resin materials under thermocycling conditions is inconsistent across different investigations and composite resin types, underscoring the necessity for additional research in this domain.

In this research, an examination was conducted to determine the impact of surface roughness at various time intervals on color alterations. The levels of surface roughness were assessed and compared, indicating that there was no statistically significant difference between the initial and final measurements. Consequently, the color changes observed in this study can be solely attributed to the type of filling material and the specific solution used.

This investigation focused exclusively on the color differences among the restorative materials. This can be considered as a limitation of the study. Therefore, it is essential to pursue further research that encompasses other aesthetic factors as well as mechanical properties, including microleakage, wear resistance, and push-out resistance. Additionally, it is likely that the use of a uniform fabrication method for both the screw-retained restoration and porcelain plug may influence the similarity of their characteristics. Thus, further studies are warranted to identify optimal aesthetic outcomes in scenarios where cost and time efficiency are not prioritized, and aesthetic appeal is the primary concern.

CONCLUSION

The current investigation reveals that there is no notable difference in color variation when comparing porcelain plugs to opaque composite resins. Nonetheless, porcelain plugs present several drawbacks, such as the necessity for molding from an access cavity, elevated construction costs, a lengthy fabrication process, and challenges in placement within the access cavity relative to composite resins. [7]. Additionally, the cement employed exhibits considerable color change, which can detract from the aesthetic appeal of the surface. In contrast, superior outcomes are observed with the application of flowable and opaque composite resins. Furthermore, there is no significant difference between the use of porcelain plugs and a combination of flowable and opaque composite resins. It is advisable to utilize flowable composite resin in conjunction with an opaque composite resin layer beneath to effectively mask the dark hue of the underlying metal.

ACKNOWLEDGEMENT

The authors of the current article reveal that they employed artificial intelligence technology to improve the text and increase its readability. It is essential to emphasize that the research conducted for this article was performed manually, and the study described is authentic. This project received partial funding from Arak University of Medical Sciences.

CONFLICT OF INTEREST STATEMENT

None declared.

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