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Translucency and contrast ratio of dimethacrylate resin based dental materials after bleaching: an in-vitro study

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Abstract

Objective To compare the translucency and contrast ratio of 13 different resin based restorative materials and to evaluate the effect of 2 different bleaching methods on the translucency and contrast ratio of these materials.

Methods In this study, a total of 260 samples were prepared, 20 from each of 13 different dimethacrylate-based restorative materials. Then, each material group was divided into 4 subgroups. While two different bleaching methods (home and office) were applied to two of these groups, the other two groups were created as separate control groups for each bleaching group. After the bleaching process, Translucency Parameters (TP) and Contrast Ratio (CR) were calculated with a spectrophotometer. The data obtained were analyzed using two-way ANOVA and Tukey post-hoc tests ($p < 0.05$).

Results When the bleaching groups were compared in terms of the differences between the TP values in general, it was seen that the TP values decreased in all groups, but this decrease was least in Opalescence PF. In terms of materials, the greatest change in TP and CR values was seen in composite materials, while the least change was seen in hybrid CAD/CAM materials.

Conclusions Within the limitations of this in vitro study, the effect of bleaching agents on the translucency and contrast ratio of restorative materials depends on the material used and the bleaching method applied. Composite-based materials have been found to be more risky in terms of bleaching. For this reason, the clinician should take this into consideration, especially when performing office bleaching on teeth with restorations.

Keywords Translucency, Contrast Ratio, Bleaching, Hybrid Dental Ceramic, Composite Resin

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Introduction

Restorative dentistry aims to recreate natural tooth structures both functionally and esthetically. The structural and optical compatibility of the restoration within the tooth structure and with adjacent teeth is a critical factor for the patient's acceptance and satisfaction with dental esthetic treatment. Resins composite are frequently used in modern dentistry thanks to their esthetic properties [1]. Current developments in dental resins composite have mainly focused on the mechanical properties of materials, improvement of wear resistance, polymerization shrinkage and color stability in order to obtain long-lasting restorations [2, 3]. With the advent of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) technology in dentistry, esthetic materials suitable for CAD/CAM processing have increased significantly in recent years [4, 5]. The most important disadvantages of composite resins are polymerization shrinkage, pores, inhomogeneity and color change [2]. To overcome these disadvantages, resin-containing ceramics that allow the use of CAD/CAM have been produced by adding resin to ceramics [4, 5].

Vital bleaching is a widely used clinical procedure to improve the esthetic appearance of teeth and remove pigmentation and stains due to internal and external factors [6]. At home and in-office tooth bleaching techniques can be applied to solve the discoloration problem on teeth [6, 7]. Performed under professional supervision in a dental office, the in-office bleaching technique typically uses high concentrations of hydrogen peroxide (HP) as the active ingredient. Home type bleaching technique is a method that patients can apply themselves or under the supervision of a dentist. Agents used in this method often contain carbamide peroxide (CP) or HP at lower concentrations. While office type bleaching has advantages such as not requiring a personal apparatus, giving good results in a short time, having few side effects due to being under the control of a physician, being applicable to even a single tooth and not requiring patient cooperation, it also has disadvantages such as using high concentrations of agents and being costly. Home type bleaching treatment has advantages such as using low concentrations of peroxide, ease of application, having few side effects and being costly, but it has disadvantages such as long treatment period, changes in soft tissues and being dependent on the patient's application. Bleaching agents provide their bleaching effect by easily diffusing the low molecular weight HP in their structure into enamel and dentin and oxidizing the pigments there [6, 7]. While the agents are applied to the teeth during the bleaching process, it is important to know the effect of these agents on the materials, as the filling materials on the teeth are also exposed to these agents. Since a wide range of materials are used in the mouth, from composite resin to ceramics, the effectiveness levels of these agents may vary depending on the material [8, 9].

Apart from the mechanical properties of restorations, an important measure of their clinical success is their ability to closely mimic the optical properties of natural teeth. Making a restoration that fully meets the patient's expectations requires the clinician to know the optical properties of the materials very well. Translucency has an important role in mimicking the optical properties of enamel and dentin [10]. Translucency is the state in which a material transmits light and the background is visible. Different methods can be used to calculate translucency, including Contrast Ratio (CR) and Translucency Parameter (TP). CR is defined as the ratio of the reflectance of a specimen placed over a black backing to that over a white one of known reflectance, and it is defined as an estimate of opacity [11]. TP is a value obtained by measuring the color difference of a material of a certain thickness on black and white backgrounds [12–14]. The use of spectrophotometers is recommended for translucency evaluations [1, 13, 15]. TP is a reliable method to evaluate translucency, and several studies have investigated the TP values of resin composites and dental porcelain [1, 13, 16–19].

There are various studies investigating the effect of bleaching agents on restorative materials [8, 9, 20]. Studies generally examine the effects of bleaching on the mechanical properties of restorative materials. However, in the literature, the effect of in-office and at-home bleaching on the TP of restorative materials with different structures containing resin is limited. The aim of this study is to compare the translucency of 13 different resin-containing restorative materials and to evaluate the effect of 2 different bleaching systems (Office and Home bleaching) on the TP and CR of these materials.
Null hypotheses of the study:

1. Bleaching procedures do not affect the TP and CR of restorative materials.
2. There is no difference between materials in terms of TP and CR changes after bleaching.

Materials and methods

In this study, the effect of two different bleaching methods on the translucency of 13 different dimethacrylate resin-based materials was examined. Information about the materials used and their contents was shown in Table 1.

Sample size determination

As a result of the power analysis performed using the G*Power 3.1.9.4 program (Heinrich-Heine Dusseldorf University, Dusseldorf, Germany), it was determined that the total number of samples for 13 groups should be

Table 1 Information on the restorative materials used in the study

Materials	Type	Contents	Manufacturer	LOT
Fuji II LC	Resin modified glass ionomer	HEMA 25–50%, UDMA 1–5%, DMA 1–5%, Al2O3-SiO2-CaF2 glass, Polyacrylic acid	GC International, Tokyo, Japan	181,001 A
Glasiosite	Compomer	BISGMA 10–25%, UDMA 5–10%, TEGDMA 2,5–5%, glass ceramics, silicates, initiators, additives	Voco, Cuxhaven, Germany	1,834,229
Beautifil II	Giomer	BISGMA 7.5% w, TEGDMA < 5% w, Alüminofloro-Borosilicat	Shofu Inc, Kyoto, Japan	011911
Clearfil Majesty Posterior	Posterior composite resin	BISGMA < 3%, TEGDMA < 3%, Silanated glass ceramics	Kuraray Co.,Ltd, Osaka, Japan	480,070
Clearfil Majesty Estetic	Anterior composite resin	BISGMA < 15%, Silanated barium glass filler	Kuraray Co.,Ltd, Osaka, Japan	7A0191
Filtek Bulk Fill Posterior Restorative	Bulk fill composite resin	Aromatic UDMA %10–20, UDMA % 1–10, Silanated ceramic and silica	3 M ESPE, MN, USA	N994343
Filtek Bulk Fill Flowable	Akıcı bulk fill composite resin	UDMA % 10–20, BISEMA % 1–10, BISGMA % 1–10, TEGDMA < %1 Silanated ceramic	3 M ESPE, MN, USA	NA62428
Admira	Ormocer	Ormocer (10–25%), BISGMA (5–10%), UDMA (5–10%), TEGDMA, Ba-Al-B-silicate glass	Voco, Cuxhaven, Germany	1,939,470
GrandioSO inley system	Indirect composite resin	TEGDMA 2,5–5%, BISGMA 2,5–5%, BISEMA 2,5–5%	Voco, Cuxhaven, Germany	1,945,406
Lava Ultimate	Hybrid ceramic	BISGMA, BISEMA, TEGDMA, UDMA, SiO_2, ZrO_2, aggregated ZrO_2 /SiO_2 cluster	3 M ESPE USA	N574684
Cerasmart	Hybrid ceramic	UDMA, DMA, %71 silica and barium nanoparticles	GC Europa	1,601,221
Grandio Blocs	Hybrid ceramic	UDMA + DMA %14, %86 nanohybrid fillers	Voco, Cuxhaven, Germany	1,946,127
Vita Enamic	Hybrid ceramic	UDMA, TEGDMA, SiO_2, ZrO_2, Al_2O_3, Na_2O, K_2O	VITA Zahnfabrik, Germany	54,230

BISGMA: Bisphenol A glycerolate dimethacrylate, HEMA: 2- hydroxyethyl methacrylate, UDMA: Urethane dimethacrylate, TEGDMA: Triethylene glycol dimethacrylate, BISEMA: Bisphenol A ethoxylate dimethacrylate, DMA: Dimethacrylate minimum 248 with a test power of 0.95, an effect size of 0.32 and a error of 0.05. In this case, it is sufficient to have 9 samples in each subgroup. This study was conducted on a total of 260 samples, 10 samples in each subgroup.

Sample preparation

Restorative materials in A2 color were filled into molds with dimensions of 5 × 5 × 2 mm. The materials, with mylar strip (Hawe Transparent Strip, Kerr Hawe, Bioggio, Switzerland) placed on the bottom and top, were compressed between two microscope glasses and all polymerization processes were based on the manufacturer's instructions. Except for glasiosite materials, polymerization was achieved using an LED light device (Elipar Freelight II, 3 M Oral Care, St. Paul, MN, USA, light intensity: 1200 mW/cm^2, wavelength 430–480 nm). Admira materials were polymerized for 40 s, and other materials for 20 s. Glasiosite materials were polymerized for 40 s with a halogen light device (Hilux 200 / Benlioğlu Dental, Istanbul, Turkey, 450 mW/cm^2). The power of the light source was checked before polymerization for every five samples. The light intensity of the light curing unit was checked using a radiometer (Hilux UltraPlus Curing Units, Benlioglu Dental, Istanbul, Turkey). After the preparation of the composite samples, CAD/CAM blocks of the same dimensions were prepared using an IsoMet Diamond Wafering Blades (Buehler, Lake Bluff, IL, USA) cutting device under water cooling. A total of 260 samples were prepared from 13 restorative materials ($n = 20$). The samples polished with medium, fine and superfine aluminum oxide discs (Sof-Lex, 3 M ESPE, St. Paul, MN, USA) and then the samples were stored in distilled water for 24 h.

Bleaching process

Each group of samples obtained from restorative materials was divided into 4 subgroups. Two of these groups were created for Office (Opalescence Boost %40 Ultradent Products INC, South Jordan, Utah, USA) and home (Opalescence PF %16 Ultradent Products INC, South Jordan, Utah, USA) bleaching. In the other two groups, a separate control group was created for each bleaching method, since the samples were exposed to the agents for different periods of time in accordance with the manufacturer's recommendations.

Bleaching agents were applied to the materials according to the manufacturer's instructions. Accordingly, the office type agent (40% hydrogen peroxide) was applied to the sample surfaces in 2 periods of 20 min, while the home type agent (16% carbamide peroxide) was applied for 4 h every day for 14 days. Following the bleaching process, the samples were washed, dried and transferred to glass tubes containing 1 ml of ethanol/water each. While bleaching agents were applied in both bleaching methods, samples in the control groups were removed from ethanol and kept in a dark and dry environment in parallel with the exposure time of the experimental groups to the bleaching agent. Thus, the continued release of monomer in the samples in the control group was prevented while the bleaching agents were applied. After the applications, all samples were put back into ethanol. After the bleaching process was completed, translucency measurements were repeated for all samples.

Translucency parameter (TP) and contrast ratio (CR) analysis

L, a and b values of all samples were obtained on both white and black backgrounds using a spectrophotometer (SpectroShade Micro device; Medical High Technologies, Milan, Italy) before and after the bleaching process. The device was calibrated before measurements and measurements were made three times for each sample. The average of the obtained values was taken and Translucency Parameters (TP) values were obtained according to the formula below: [21, 22]

$TP = [(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{½}$.

L_B, a_B and b_B values represent the CIE L* a* b* values of the samples measured on a black background, and L_W, a_W and b_W values represent the CIE L* a* b* values measured on a white background. Higher TP values represent greater translucency.

The L* coordinates values measured on white and black background were used to calculate the luminance from Color Space CIEXYZ, as follows: [11]

$$Y = \left(\frac{L + 16}{116}\right)^3 \times \ Y_n$$

Y values of the specimens recorded on white (Yw) and black (Yb) backgrounds were used to calculate Contrast Ratio (CR) as follows: [11]

$$CR = \frac{Y_B}{Y_W}$$

Statistical analysis

The data obtained were analyzed using the SPSS 20 (IBM, Chicago, IL, USA) statistical package program. First, the distribution and variance homogeneity of the data were analyzed by using Kolmogorov-Smirnov and Levene's tests. Two-way ANOVA and Tukey post-hoc tests were applied for intergroup comparisons for bleaching method and materials. In comparing the TP and CR values of restorative materials before and after bleaching, the analysis was made by taking into account the difference between these two applications. The statistical significance level was taken as $p < 0.05$.

Results

The results of two-way analysis of variance for the data obtained for TP are given in Table 2. Considering the results obtained from the analysis, all interactions between groups were found to be statistically significant ($p < 0.05$). When the differences in TP values for each material before and after bleaching were compared, it was found that TP values mostly decreased (Table 3). This difference was statistically significant only in the Beautifil II, Filtek Bulk Fill Posterior, Filtek Bulk Fill Flowable and Lava Ultimate groups ($p < 0.05$). When the bleaching groups were generally compared in terms of differences in TP values, it was determined that TP values decreased in all groups, but this decrease was the least in Opalescence PF, and there was no significant difference between the other groups ($p > 0.05$). The findings obtained from the general comparison of the differences in TP values in terms of materials are given in Fig. 1. It was found that the materials with the highest decrease in TP values were composite-based materials, followed by indirect composite and hybrid CAD/CAM materials. Table 4 shows the L*, a*, b* values obtained from restorative materials before and after bleaching. A minimal increase was detected in the L* values, but a decrease was mostly detected in the b* values.

The results of two-way analysis of variance for the data obtained for CR are given in Table 5. Considering the results obtained from the analysis, all interactions between groups were found to be statistically significant ($p < 0.05$). When the differences in CR values for each material before and after bleaching were compared, it was found that CR values mostly increased (Table 6). This difference was statistically significant only in the Beautifil II, Filtek Bulk Fill Posterior, Filtek Bulk Fill Flowable and Cerasmart groups ($p < 0.05$). The findings obtained from the general comparison of the differences between CR values in terms of materials are given in Fig. 2. It was found that the materials with the greatest increase in CR values were composite-based materials, followed by indirect composite and hybrid CAD/CAM materials.

Discussion

As a result of esthetic demands, restorations in the mouth may also be exposed to agents during the bleaching process, which has become a frequently applied procedure. During the bleaching process, agents affect the optical properties of restorative materials, which are important for esthetics [9, 23, 24]. Since natural teeth are translucent, maintaining the transparency of restorative materials is an important criterion. Therefore, this study aimed to investigate the effect of different bleaching procedures on the translucency and contrast ratio of resin-containing restorative materials. In the present study, it was observed that the translucency and opacity values of the tested materials with the translucency calculation method (TP) and contrast ratio (CR) varied in a wide range and there were significant differences in terms of TP and CR values between both bleaching methods and materials ($p < 0.05$). While the bleaching process caused an increase in the CR values of the materials, it caused a decrease in the TP values. It was found that Opalescence PF caused a less decrease in TP values compared to the office group. It was reported that the materials that caused the most change in TP and CR values were composite materials. As a result, both hypotheses were rejected.

It has been reported in the literature that L* and b* values are more decisive than other parameters in determining translucency, that translucency is mainly affected by changes in brightness, and that the yellow-blue coordinate (CIE b*) also plays an important role [17]. The decrease in TP values in most of our samples may be due to the materials becoming opaque after bleaching. In the present study, an increase in the CR values of the materials was detected. The increase in CR values also favors the opacity of the materials. Higher CR values and lower TP values correspond to more opaque materials, whereas lower CR and higher TP correspond to materials with higher translucency. The CR ranges from 0 to 1, with 0 indicating a completely transparent material and 1 indicating complete opacity [11]. It has been shown that bleaching causes surface dissolution in materials. In addition to the bleaching effect, it has been reported that small pores on the surface caused by matrix dissolution in the materials and differences in optical properties between air and water may have increased the reflection on the surface, which may have led to a partial increase in L* values as in the present study [25]. The decrease in b* values can also be associated with a decrease in yellowish color along with a tendency towards opacification.

Natural teeth have a translucent structure and restorative materials are expected to have translucent properties similar to natural teeth. For this reason, it is important not only for the material to be translucent but also to preserve the translucency of the material. It is known that bleaching affects the physical properties of restorative materials. Previous studies have reported that the effect of bleaching treatment on restorative materials depends on the concentration of the bleach, the exposure time, and the amount of resin matrix of the restorative materials [20, 25–27]. The results of the present study

Table 2 Results of two-way ANOVA for TP

Source	SS	df	MS	F	*p*
Materials	182.591	12	15.216	6.661	0.000*
Bleaching	41.225	3	13.742	6.016	0.001*
Materials * Bleaching	179.262	36	4.980	2.180	0.000*

SS: Sum of squares, MS: mean of squares, *$p < 0.05$ significant

Table 3 TP (mean ± standard deviation) values of the groups and statistical comparison results

Materials	Bleaching Groups	Before Bleaching (TP1)	After Bleaching (TP2)	TP1-TP2
Fuji II LC	OB	9.22 ± 1.44	6.44 ± 0.52	2.78 ± 1.33[a]
	OBC	9.85 ± 1.63	9.5 ± 2.26	0.35 ± 3.1[a]
	OPF	9.22 ± 1.44	7.28 ± 0.79	1.94 ± 1.92[a]
	OPFC	9.85 ± 1.63	8.19 ± 0.94	1.66 ± 1.66[a]
Glasiosite	OB	16.23 ± 0.78	14.58 ± 0.82	1.65 ± 1.45[a]
	OBC	16.33 ± 0.33	15.22 ± 0.73	1.11 ± 0.85[a]
	OPF	16.23 ± 0.78	15.66 ± 1.08	0.58 ± 1.36[a]
	OPFC	16.33 ± 0.33	15.53 ± 0.8	0.8 ± 0.87[a]
Beautifil II	OB	13.15 ± 1.11	11.08 ± 1.25	2.08 ± 2.24[ab]
	OBC	14.83 ± 0.73	11.35 ± 1.3	3.48 ± 1.7[b]
	OPF	13.15 ± 1.11	13.18 ± 1.18	-0.02 ± 1.78[a]
	OPFC	14.83 ± 0.73	11.93 ± 0.84	2.9 ± 1.41[ab]
Clearfil Majesty Posterior	OB	14.06 ± 0.83	12.74 ± 1.14	1.33 ± 0.64[a]
	OBC	14.02 ± 0.62	11.44 ± 0.43	2.58 ± 0.57[a]
	OPF	14.06 ± 0.83	12.44 ± 0.65	1.62 ± 1.47[a]
	OPFC	14.02 ± 0.62	11.8 ± 0.24	2.22 ± 0.5[a]
Clearfil Majesty Esthetic	OB	13.87 ± 0.78	11.03 ± 0.49	2.85 ± 1.16[a]
	OBC	13.79 ± 0.51	10.63 ± 1.12	3.16 ± 1.29[a]
	OPF	13.87 ± 0.78	12.27 ± 1.3	1.6 ± 1.33[a]
	OPFC	13.79 ± 0.51	10.54 ± 0.9	3.25 ± 1.34[a]
Filtek Bulk Fill Posterior Restorative	OB	18.25 ± 0.43	16.45 ± 0.23	1.8 ± 0.62[b]
	OBC	18.48 ± 0.64	17.03 ± 0.93	1.45 ± 1.46[ab]
	OPF	18.25 ± 0.43	18.29 ± 0.48	-0.04 ± 0.23[a]
	OPFC	18.48 ± 0.64	17.5 ± 1.14	0.98 ± 1.05[ab]
Filtek Bulk Fill Flowable	OB	19.64 ± 0.54	17.45 ± 1.69	2.19 ± 1.34[b]
	OBC	20.51 ± 0.66	16.98 ± 1.1	3.53 ± 1.04[b]
	OPF	19.64 ± 0.54	20.26 ± 1.55	-0.62 ± 1.43[a]
	OPFC	20.51 ± 0.66	19.07 ± 1.24	1.44 ± 1.7[ab]
Admira	OB	14.86 ± 0.78	13.27 ± 1.09	1.59 ± 1.82[a]
	OBC	14.86 ± 0.88	13.53 ± 0.84	1.33 ± 1.17[a]
	OPF	14.86 ± 0.78	14.58 ± 1.2	0.28 ± 0.98[a]
	OPFC	14.86 ± 0.88	12.83 ± 0.9	2.03 ± 1.18[a]
GrandioSO	OB	12.2 ± 0.6	11.91 ± 0.86	0.3 ± 1.07[a]
	OBC	12.66 ± 1.1	11.83 ± 0.48	0.83 ± 1.32[a]
	OPF	12.2 ± 0.6	12.43 ± 1.12	-0.23 ± 0.92[a]
	OPFC	12.66 ± 1.1	11.75 ± 0.98	0.92 ± 0.83[a]
Lava Ultimate	OB	13.87 ± 0.7	15.24 ± 0.46	-1.37 ± 0.81[a]
	OBC	15.16 ± 1.14	13.83 ± 0.9	1.33 ± 1.75[b]
	OPF	13.87 ± 0.7	14.6 ± 0.95	-0.73 ± 1.45[ab]
	OPFC	15.16 ± 1.14	13.93 ± 0.52	1.23 ± 1.54[b]
Cerasmart	OB	17.74 ± 1.2	15.44 ± 1.23	2.3 ± 1.02[a]
	OBC	16.26 ± 1.76	15.66 ± 2.64	0.6 ± 3.67[a]
	OPF	17.74 ± 1.2	13.94 ± 1.16	3.79 ± 1.83[a]
	OPFC	16.26 ± 1.76	16.45 ± 1.86	-0.19 ± 2.11[a]
Grandio Blocs	OB	14.09 ± 0.84	14.16 ± 0.93	-0.07 ± 1.48[a]
	OBC	14.27 ± 0.58	14.29 ± 0.86	-0.02 ± 0.98[a]
	OPF	14.09 ± 0.84	15.55 ± 2.6	-1.46 ± 3.1[a]
	OPFC	14.27 ± 0.58	13.85 ± 1.48	0.42 ± 1.5[a]
Vita Enamic	OB	8.65 ± 0.56	8.19 ± 0.47	0.46 ± 0.85[a]
	OBC	8.51 ± 0.48	8.3 ± 0.72	0.22 ± 0.88[a]
	OPF	8.65 ± 0.56	8.56 ± 1	0.09 ± 1.23[a]
	OPFC	8.51 ± 0.48	8.24 ± 0.68	0.28 ± 1.12[a]

OB: Opalescence Boost. OBC: Opalescence Boost Control. OPF: Opalescence PF. OPFC: Opalescence PF Control. Lower case letters show the comparison results of bleaching groups for each material (one-way ANOVA, Tukey post-hoc test). Different letters indicate statistical significance

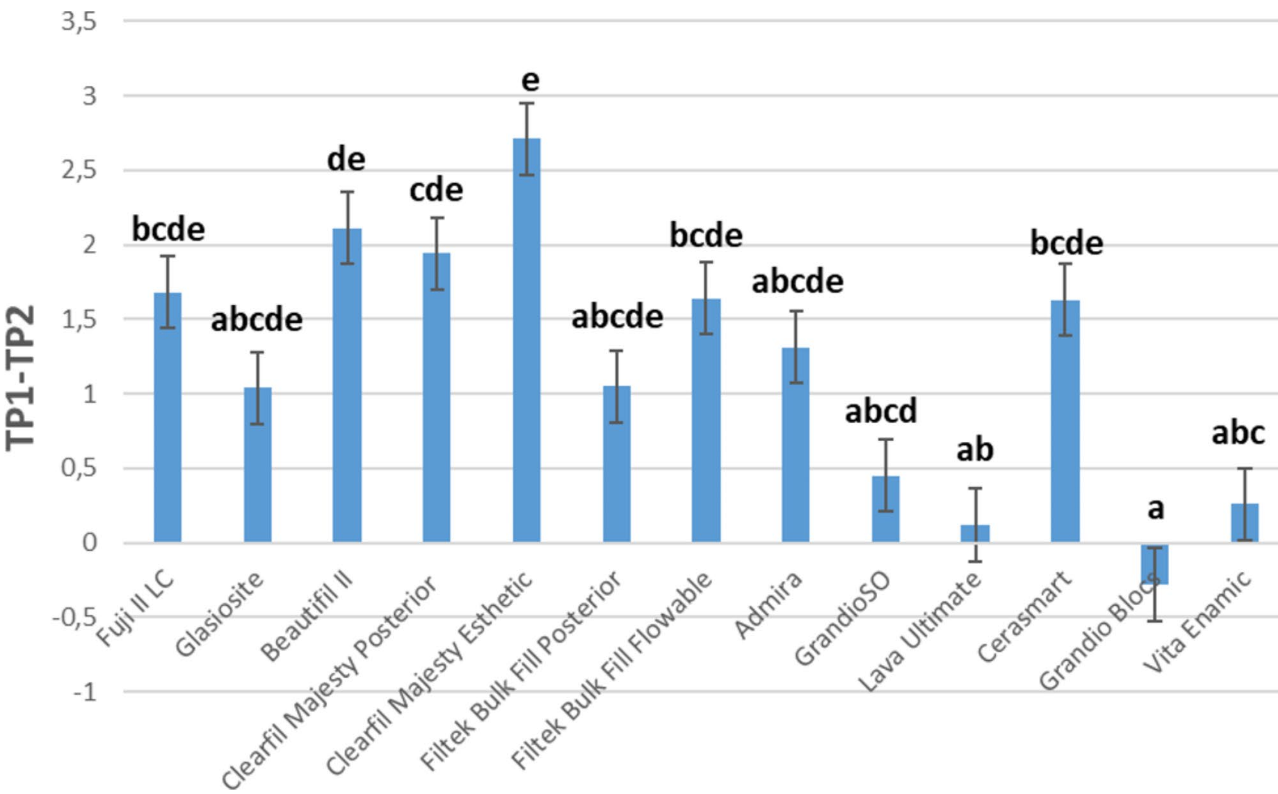

Fig. 1 The findings obtained from the general comparison of the differences in TP values in terms of materials

revealed that different bleaching methods have different effects on the translucency of resin-containing materials. Previous studies have shown that bleaching agents increase the surface roughness and reduce the translucency of resin composites [8, 26]. In the present study, bleaching agents containing 16% carbamide peroxide and 40% hydrogen peroxide were used and a decrease in TP values was observed. After home bleaching, 16% carbamide peroxide decomposes into 5.8% hydrogen peroxide, urea, ammonia and carbon dioxide [28]. Yılmaz et al. [29] found that bleaching with 10% carbamide peroxide did not affect the translucency of resin composites. In the present study, it was found that office bleaching caused a greater decrease in TP values than home bleaching.

In studies examining the effects of bleaching on restorative materials, it has been reported that hydrogen peroxide may interact with carbon-carbon single or double bonds in the materials and cause deterioration in the polymer structure of the composite [12, 17]. It has been reported that as a result of the deterioration in the structure of the composite, solvents can penetrate the structure of the material and the diffusion of the monomers contained in the composite will also increase [12, 20].

The aqueous environment to which the materials are exposed in the mouth is an environment between water and more aggressive solutions such as ethanol, methanol and acetonitrile. A 75% ethanol-water solution was used to mimic this environment in vitro. The United States Federal Drug Administration has also reported that a 75% ethanol-water solution can be used to mimic the oral environment [30]. Based on this, 75% ethanol-water solution was used as the storage solution in the present study. The fact that office bleaching caused a greater decrease in translucency in the present study may be due to the fact that office bleaching disrupts the structure of the materials more due to its high content of HP and, as a result, the material absorbs more ethanol.

Translucency also depends on thickness, and in this study, a thickness of 2 mm was used because restorative materials are clinically applied at a thickness of 2 mm. A higher value for TP represents greater translucency; if the material is completely opaque, the TP value is zero [31]. TP has been used in several studies to evaluate the translucency of restorative materials [1, 11, 13, 21, 22, 32–34].

The fact that the polymerization depth of light-cured composites is limited to 2 mm and that layered application takes time is a significant disadvantage today. Bulk-fill composites produced to eliminate this disadvantage can be applied in thick layers due to improving photoinitiator dynamics and increasing translucency properties [35]. This can be explained by the fact that bulk fill composite materials were found to be the most translucent material among composite materials in the present study. Günal and Ulusoy [36] reported TP (CIELAB)

Table 4 L*, a*, b* values measured before and after bleaching of restorative materials

Materials	Bleaching Groups	Before Bleaching			After Bleaching		
		L	a	b	L	a	b
Fuji II LC	OB	83,2 ± 0,66	2,74 ± 0,11	13,2 ± 0,48	85,98 ± 0,98	2,24 ± 0,18	6,58 ± 0,41
	OBC	83,18 ± 0,66	2,7 ± 0,29	13,16 ± 0,55	84,18 ± 0,68	3,34 ± 0,15	11,24 ± 0,27
	OPF	83,2 ± 0,66	2,74 ± 0,11	13,2 ± 0,48	85,38 ± 0,94	2,98 ± 0,18	8,8 ± 0,31
	OPFC	83,18 ± 0,66	2,7 ± 0,29	13,16 ± 0,55	83,56 ± 0,46	3,34 ± 0,27	10,76 ± 0,36
Glasiosite	OB	79,08 ± 1,65	1,98 ± 0,38	19,84 ± 1,11	79,18 ± 1,92	2,72 ± 0,28	17,62 ± 1,86
	OBC	79,36 ± 1,34	2,06 ± 0,18	19,42 ± 1,68	78,4 ± 2,65	2,28 ± 0,36	19,14 ± 1,67
	OPF	79,08 ± 1,65	1,98 ± 0,38	19,84 ± 1,11	78,78 ± 1,46	2,18 ± 0,3	18,56 ± 1,16
	OPFC	79,36 ± 1,34	2,06 ± 0,18	19,42 ± 1,68	79,76 ± 0,27	2,12 ± 0,16	17,94 ± 1,46
Beautifil II	OB	78,24 ± 1,96	3,98 ± 0,24	21,86 ± 0,83	82,04 ± 1,78	4,52 ± 0,61	16,08 ± 3,38
	OBC	79,46 ± 0,75	4,08 ± 0,11	21,52 ± 1,07	82,74 ± 1,11	3,98 ± 0,38	15,24 ± 2,35
	OPF	78,24 ± 1,96	3,98 ± 0,24	21,86 ± 0,83	81,48 ± 0,59	4,32 ± 0,16	18,28 ± 0,78
	OPFC	79,46 ± 0,75	4,08 ± 0,11	21,52 ± 1,07	80,62 ± 2,02	4,48 ± 0,52	17,94 ± 3,1
Clearfil Majesty Posterior	OB	79,2 ± 0,31	1,62 ± 0,19	17,56 ± 0,34	81,56 ± 0,30	1,98 ± 0,13	14,66 ± 0,64
	OBC	79,16 ± 1,24	1,72 ± 0,19	17,62 ± 0,67	81,42 ± 1,04	1,86 ± 0,05	13,96 ± 0,54
	OPF	79,2 ± 0,31	1,62 ± 0,19	17,56 ± 0,34	81,1 ± 0,6	1,68 ± 0,13	14,38 ± 0,53
	OPFC	79,16 ± 1,24	1,72 ± 0,19	17,62 ± 0,67	81,56 ± 0,88	1,74 ± 0,13	13,68 ± 0,7
Clearfil Majesty Esthetic	OB	77,14 ± 0,73	2,82 ± 0,13	17,32 ± 0,75	80,84 ± 0,46	3,42 ± 0,16	10,8 ± 0,56
	OBC	77,32 ± 0,34	2,84 ± 0,19	17,48 ± 0,63	81,3 ± 0,86	2,82 ± 0,26	10,5 ± 1,39
	OPF	77,14 ± 0,73	2,82 ± 0,13	17,32 ± 0,75	79,22 ± 0,94	3,14 ± 0,26	13,1 ± 0,48
	OPFC	77,32 ± 0,34	2,84 ± 0,19	17,48 ± 0,63	81,22 ± 0,62	2,74 ± 0,17	10,04 ± 0,66
Filtek Bulk Fill Posterior Restorative	OB	80,82 ± 0,98	-0,08 ± 0,29	17,44 ± 0,44	80,98 ± 0,79	1,8 ± 0,1	15,22 ± 0,6
	OBC	80,84 ± 1,25	-0,06 ± 0,25	17,54 ± 0,61	81,44 ± 0,22	0,92 ± 0,13	14,94 ± 0,96
	OPF	80,82 ± 0,98	-0,08 ± 0,29	17,44 ± 0,44	81,08 ± 0,51	1,1 ± 0,1	15,28 ± 0,54
	OPFC	80,84 ± 1,25	-0,06 ± 0,25	17,54 ± 0,61	81,32 ± 1,54	1,06 ± 0,23	15,06 ± 0,68
Filtek Bulk Fill Flowable	OB	78,66 ± 1,06	1,32 ± 0,35	23,12 ± 0,52	79,4 ± 0,81	2,58 ± 0,19	19,98 ± 1,53
	OBC	78,54 ± 0,36	1,12 ± 0,19	23,4 ± 1,07	80,86 ± 0,59	1,7 ± 0,12	18,74 ± 1,38
	OPF	78,66 ± 1,06	1,32 ± 0,35	23,12 ± 0,52	79,44 ± 0,71	1,64 ± 0,13	21,18 ± 0,44
	OPFC	78,54 ± 0,36	1,12 ± 0,19	23,4 ± 1,07	80,9 ± 0,35	1,76 ± 0,05	19,56 ± 0,72
Admira	OB	79,94 ± 0,56	1,52 ± 0,31	17,26 ± 1,57	79,64 ± 1,05	2,36 ± 0,11	15 ± 1
	OBC	79,88 ± 0,74	1,4 ± 0,44	19,1 ± 1,64	80,2 ± 0,74	2,14 ± 0,05	14,88 ± 1,32
	OPF	79,94 ± 0,56	1,52 ± 0,31	17,26 ± 1,57	80,2 ± 0,92	2,04 ± 0,05	15,18 ± 0,49
	OPFC	79,88 ± 0,74	1,4 ± 0,44	19,1 ± 1,64	80,56 ± 0,47	2,08 ± 0,2	14,02 ± 1,37
GrandioSO	OB	79,58 ± 0,62	1,76 ± 0,18	19,62 ± 0,54	80,58 ± 2,12	2,6 ± 0,22	16,46 ± 2,6
	OBC	79,7 ± 0,43	1,78 ± 0,2	19,98 ± 0,7	80,46 ± 1,47	2,34 ± 0,11	16,5 ± 1,51
	OPF	79,58 ± 0,62	1,76 ± 0,18	19,62 ± 0,54	80,12 ± 0,33	2,34 ± 0,09	16,98 ± 0,59
	OPFC	79,7 ± 0,43	1,78 ± 0,2	19,98 ± 0,7	81,22 ± 0,73	2,32 ± 0,16	15,24 ± 1,28
Lava Ultimate	OB	81,28 ± 0,64	**0**,76 ± 0,05	17,32 ± 0,38	82,32 ± 0,24	**0**,7 ± 0,14	17,94 ± 1,07
	OBC	81,64 ± 0,75	**0**,8 ± 0,1	18,7 ± 1,09	82,06 ± 0,63	**0**,66 ± 0,09	17,76 ± 0,5

Table 4 (continued)

Materials	Bleaching Groups	Before Bleaching			After Bleaching		
		L	a	b	L	a	b
	OPF	81,28 ± 0,64	**0,76** ± 0,05	17,32 ± 0,38	82,36 ± 0,45	0,68 ± 0,13	18,1 ± 0,84
	OPFC	81,64 ± 0,75	**0,8** ± 0,1	18,7 ± 1,09	81,92 ± 0,98	**0,74** ± 0,09	17,74 ± 0,82
Cerasmart	OB	82,8 ± 0,69	**0,1** ± 0,39	17,2 ± 2,24	82,28 ± 0,54	**0,88** ± 0,41	19,9 ± 2,23
	OBC	81,78 ± 1,2	**0,46** ± 0,43	19,52 ± 1,82	82,4 ± 0,94	**0,64** ± 0,46	18,16 ± 1,87
	OPF	82,8 ± 0,69	**0,1** ± 0,39	17,2 ± 2,24	80,34 ± 0,75	**2,72** ± 0,25	22,6 ± 0,78
	OPFC	81,78 ± 1,2	**0,46** ± 0,43	19,52 ± 1,82	82,56 ± 0,76	**0,7** ± 0,5	18,7 ± 2,48
Grandio Blocs	OB	80,44 ± 0,78	2,8 ± 0,31	23,56 ± 1,03	81,02 ± 0,46	2,88 ± 0,23	22,8 ± 0,77
	OBC	80,32 ± 1,01	2,66 ± 0,34	22,88 ± 1,09	81,02 ± 0,37	2,74 ± 0,21	22,26 ± 1,17
	OPF	80,44 ± 0,78	2,8 ± 0,31	23,56 ± 1,03	82,62 ± 0,88	0,66 ± 0,48	18,36 ± 2,84
	OPFC	80,32 ± 1,01	2,66 ± 0,34	22,88 ± 1,09	79,98 ± 1,39	2,62 ± 0,13	21,56 ± 0,56
Vita Enamic	OB	78,46 ± 1,04	3,36 ± 0,22	20,22 ± 0,54	79,34 ± 0,41	3,2 ± 0,23	19,76 ± 0,69
	OBC	78,78 ± 0,61	3,34 ± 0,25	20,68 ± 0,93	78,84 ± 0,17	3,24 ± 0,11	19,48 ± 1,07
	OPF	78,46 ± 1,04	3,36 ± 0,22	20,22 ± 0,54	79,78 ± 0,48	3,18 ± 0,13	20,24 ± 0,63
	OPFC	78,78 ± 0,61	3,34 ± 0,25	20,68 ± 0,93	79,22 ± 0,32	3,16 ± 0,15	19,22 ± 1,13

OB: Opalescence Boost. OBC: Opalescence Boost Control. OPF: Opalescence PF. OPFC: Opalescence PF Control

values of 18.64 and 17.93 for Cerasmart and Lava Ultimate samples, respectively, similar to the findings of the present study. Günal Abduljalil et al. [37] reported that Cerasmart is the most translucent material compared to Voco Grandio, Brilliant Crios and Lava Ultimate. Cerasmart's higher TP value may be due to its lack of opacifying compounds and its composition of aluminum barium silicate particles embedded in a polymer network that increases light transmission [38]. As the crystal content increases, material durability increases. However, this also causes increased opacity [11]. In the present study, the reason why VITA Enamic has lower translucency than other resin-ceramic hybrid materials may be related to its Al_2O_3 content (about 23% by weight).

As a result of the present study, the largest decrease in TP values was found in the composite materials. Several common monomers found in the composite resin matrix have hydrophilic properties and can often cause discoloration due to excess water absorption. It has also been reported in the literature that the presence of low TEGDMA content may limit water uptake and consequently color changes caused by the absorption of the staining solution [39]. TEGDMA content of composite materials may have caused more fluid uptake and decreased translucency. The decrease in TP after bleaching was statistically significant in the Beautifil II, Filtek Bulk Fill Posterior, Filtek Bulk Fill Flowable and Lava Ultimate groups ($p < 0.05$). Beautifil II (Giomer) is a hybrid aesthetic restorative material based on pre-reacted glass ionomer "PRG" technology, using pre-reacted glass ionomer cements as fillers [40]. This significant decrease in the TP value of Beautifil II may be due to its nano-hybrid gyomer filler content.

The production of Ormocers is based on hydrolysis and polycondensation reactions (sol-gel processing) to form a molecule with a long-chain inorganic silica backbone and lateral organic chains [41]. It is claimed that Ormocer-containing composites exhibit higher conversion, minimum polymerization shrinkage, color stability, toughness and increased surface hardness as a result of the formation of a more highly cross-linked polymer network. Another advantage of Ormocer is that the amount of free unreacted monomers in the polymer network decreases with the increase in the number of chemical bonds between methacrylate groups [42]. In this case, our expectation was that the translucency change would be less than the composites after bleaching, depending on the structure of the material. However, in this study, when the resin composites and Ormocer values were examined, no statistically significant difference was found between the initial and post-bleaching TP and CR values.

In the present study, it was found that the change in TP and CR was less in hybrid ceramic groups than in composite groups. During the production of ceramic

Table 5 Results of two-way ANOVA for CR

Source	SS	df	MS	F	*p*
Materials	0.183	12	0.016	12.395	0.000*
Bleaching	0.027	3	0.009	6.921	0.000*
Materials * Bleaching	0.146	36	0.004	3.131	0.000*

SS: Sum of squares, MS: mean of squares, CR: Contrast Ratio, *$p < 0.05$ significant

materials in an industrial environment, subjecting them to processes such as ceramic powder sintering, resin composite polymerization, etc. minimizes the defects in the structure of the material and makes the material more homogeneous and durable [43]. It also has a high reducing capacity by producing peroxides, free radicals and oxides [44]. Peroxides have been reported to induce oxidative cleavage of polymer chains [45]. Tight polymer chains limit the effect of peroxide. If a material contains tight cross-links formed by high molecular weight polymer molecules, more time will be required for the bleach to diffuse into the material [46]. The differences observed between resin matrix ceramics and composite resin groups may be related to the structures of the materials and the production technique.

As a result, the translucency of materials is affected by both the structure of the material and the bleaching method applied. There are limited studies in the literature examining the changes in translucency as a result of bleaching of materials. This study is important in terms of simultaneously examining a wide range of materials used for restorative purposes and comparing the results.

The limitation of this study is that since it was studied in vitro, the thermal, mechanical and chemical effects that the restorative material is exposed to in the mouth cannot be reflected exactly on the material. Studies on materials are generally conducted in vitro, tending to focus on material properties and procedures. Although this has contributed to the development process of materials, it should not be forgotten that in vivo studies and evaluation of follow-up procedures can provide valuable information to the literature.

Conclusion

Within the limitations of this in vitro study, the effect of bleaching agents on the translucency and contrast ratio of restorative materials depends on the material used and the bleaching method. Home bleaching method carries less risk in terms of affecting the translucency of the materials. The clinician should take this into consideration in bleaching applications and be more careful when using office type bleaching. In addition, it has been determined that the translucency properties of hybrid ceramics are the materials least affected by the bleaching process. The use of hybrid ceramics may be preferred in the selection of materials for restoration in the clinic.

Table 6 CR (mean ± standard deviation) values of the groups and statistical comparison results

Materials	Bleaching Groups	Before Bleaching (CR1)	After Bleaching (CR2)	CR1-CR2
Fuji II LC	OB	0,77 ± 0,4	0,85 ± 0,01	-0,08 ± 0,03[a]
	OBC	0,76 ± 0,4	0,76 ± 0,06	-0,01 ± 0,08[a]
	OPF	0,77 ± 0,4	0,82 ± 0,02	-0,05 ± 0,05[a]
	OPFC	0,76 ± 0,4	0,8 ± 0,03	-0,04 ± 0,04[a]
Glasiosite	OB	0,62 ± 0,02	0,66 ± 0,03	-0,04 ± 0,04[a]
	OBC	0,61 ± 0,01	0,65 ± 0,01	-0,03 ± 0,02[a]
	OPF	0,62 ± 0,02	0,63 ± 0,03	-0,01 ± 0,03[a]
	OPFC	0,61 ± 0,01	0,64 ± 0,01	-0,03 ± 0,01[a]
Beautifil II	OB	0,72 ± 0,04	0,77 ± 0,03	-0,06 ± 0,07[ab]
	OBC	0,67 ± 0,02	0,77 ± 0,03	-0,1 ± 0,04[a]
	OPF	0,72 ± 0,04	0,72 ± 0,02	0 ± 0,05[b]
	OPFC	0,67 ± 0,02	0,74 ± 0,03	-0,07 ± 0,04[ab]
Clearfil Majesty Posterior	OB	0,68 ± 0,02	0,74 ± 0,03	-0,06 ± 0,02[a]
	OBC	0,68 ± 0,01	0,76 ± 0	-0,08 ± 0,01[a]
	OPF	0,68 ± 0,02	0,73 ± 0,02	-0,05 ± 0,03[a]
	OPFC	0,68 ± 0,01	0,75 ± 0,01	-0,07 ± 0,02[a]
Clearfil Majesty Esthetic	OB	0,68 ± 0,02	0,77 ± 0,01	-0,08 ± 0,03[a]
	OBC	0,69 ± 0,1	0,78 ± 0,03	-0,09 ± 0,03[a]
	OPF	0,68 ± 0,02	0,73 ± 0,04	-0,05 ± 0,04[a]
	OPFC	0,69 ± 0,01	0,78 ± 0,02	-0,09 ± 0,02[a]
Filtek Bulk Fill Posterior Restorative	OB	0,56 ± 0,01	0,61 ± 0,01	-0,04 ± 0,01[a]
	OBC	0,56 ± 0,01	0,6 ± 0,02	-0,04 ± 0,03[ab]
	OPF	0,56 ± 0,01	0,57 ± 0,01	0 ± 0,01[b]
	OPFC	0,56 ± 0,01	0,59 ± 0,2	-0,03 ± 0,02[ab]
Filtek Bulk Fill Flowable	OB	0,54 ± 0,01	0,61 ± 0,03	-0,07 ± 0,03[a]
	OBC	0,52 ± 0,01	0,62 ± 0,03	-0,09 ± 0,03[a]
	OPF	0,54 ± 0,01	0,54 ± 0,03	0 ± 0,03[b]
	OPFC	0,52 ± 0,01	0,57 ± 0,03	-0,05 ± 0,03[a]
Admira	OB	0,65 ± 0,02	0,7 ± 0,03	-0,05 ± 0,05[a]
	OBC	0,66 ± 0,03	0,71 ± 0,03	-0,05 ± 0,02[a]
	OPF	0,65 ± 0,02	0,67 ± 0,02	-0,02 ± 0,02[a]
	OPFC	0,66 ± 0,03	0,71 ± 0,01	-0,05 ± 0,03[a]
GrandioSO	OB	0,72 ± 0,01	0,74 ± 0,03	-0,02 ± 0,03[a]
	OBC	0,71 ± 0,02	0,73 ± 0,02	-0,03 ± 0,03[a]
	OPF	0,72 ± 0,01	0,72 ± 0,03	0 ± 0,02[a]
	OPFC	0,71 ± 0,02	0,73 ± 0,03	-0,02 ± 0,02[a]
Lava Ultimate	OB	0,68 ± 0,01	0,66 ± 0,01	0,02 ± 0,02[a]
	OBC	0,66 ± 0,02	0,69 ± 0,02	-0,02 ± 0,04[a]
	OPF	0,68 ± 0,01	0,67 ± 0,02	0,01 ± 0,03[a]
	OPFC	0,66 ± 0,02	0,68 ± 0,01	-0,2 ± 0,03[a]
Cerasmart	OB	0,57 ± 0,03	0,64 ± 0,03	-0,06 ± 0,03[ab]
	OBC	0,61 ± 0,04	0,63 ± 0,06	-0,01 ± 0,08[b]
	OPF	0,57 ± 0,03	0,71 ± 0,02	-0,13 ± 0,04[a]
	OPFC	0,61 ± 0,04	0,61 ± 0,05	0 ± 0,05[b]
Grandio Blocs	OB	0,71 ± 0,01	0,7 ± 0,02	0,01 ± 0,02[a]
	OBC	0,7 ± 0,01	0,7 ± 0,01	0 ± 0,02[a]
	OPF	0,71 ± 0,01	0,63 ± 0,06	0,08 ± 0,07[a]
	OPFC	0,7 ± 0,01	0,71 ± 0,03	0 ± 0,03[a]
Vita Enamic	OB	0,8 ± 0,02	0,8 ± 0,01	-0,01 ± 0,02[a]
	OBC	0,8 ± 0,01	0,8 ± 0,01	0 ± 0,02[a]
	OPF	0,8 ± 0,02	0,79 ± 0,03	0 ± 0,03[a]
	OPFC	0,8 ± 0,01	0,8 ± 0,02	0 ± 0,03[a]

OB: Opalescence Boost. OBC: Opalescence Boost Control. OPF: Opalescence PF. OPFC: Opalescence PF Control. Lower case letters show the comparison results of bleaching groups for each material (one-way ANOVA, **Tukey post-hoc test**). Different letters indicate statistical significance

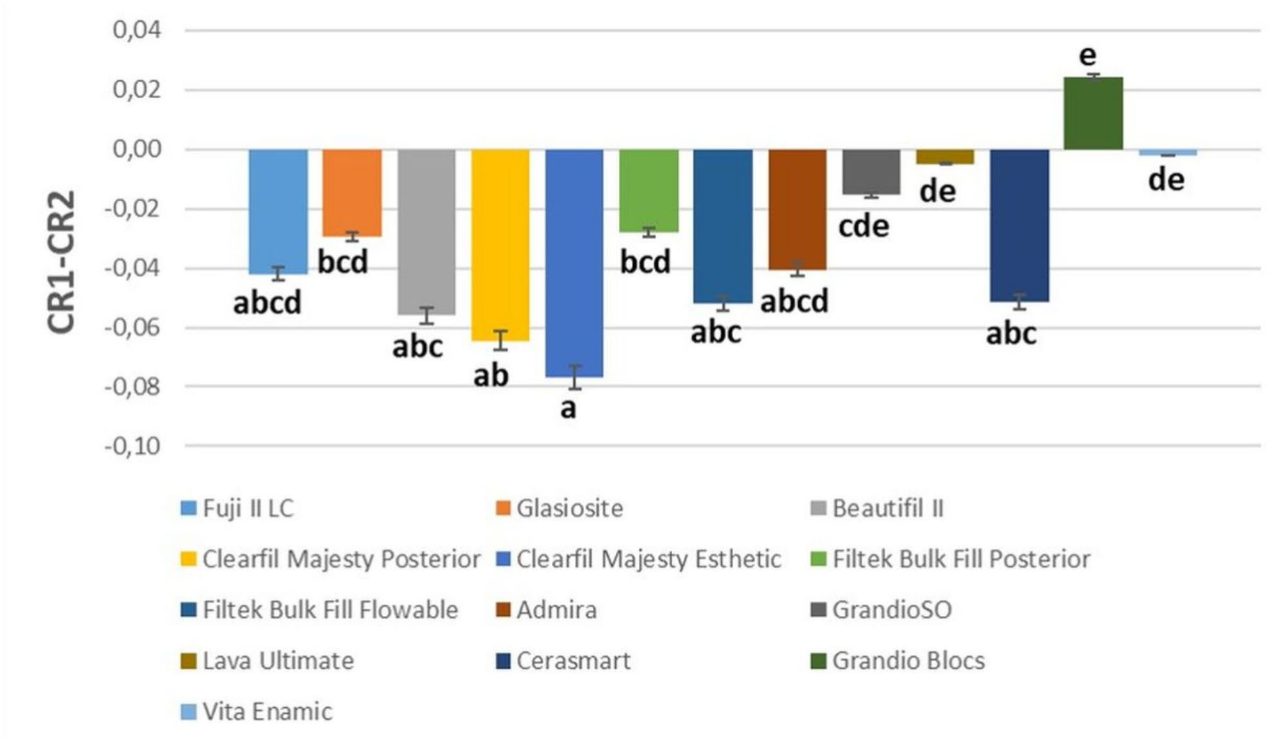

Fig. 2 The findings obtained from the general comparison of the differences in CR values in terms of materials

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Author contributions
NA, contributed to the design and to the writing of the manuscript, MNY to and implementation and the analysis of the results of the manuscript. Each author as sumes individual accountability for their contributions and commits to addressing any inquiries regarding the accuracy or integrity of the work, including aspects where they were not directly involved. All authors approved the final version of the manuscript.

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Data availability
The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Declarations

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References

1. Huynh N, Tran A, Truong T, Le T, Tran C, Tran N, et al. Correlation of resin composite translucency and IOS accuracy: an in-vitro study. J Clin Exp Dent. 2024;16:e678–84. https://doi.org/10.4317/jced.61620.
2. Ferracane JL. Resin composite - state of the art. Dent Mater. 2011;27:29–38. https://doi.org/10.1016/j.dental.2010.10.020.
3. Hajdu AI, Dumitrescu R, Balean O, Lalescu DV, Buzatu BLR, Bolchis V, et al. Enhancing esthetics in Direct Dental Resin Composite: investigating Surface Roughness and Color Stability. J Funct Biomater. 2024;15:208. https://doi.org/10.3390/jfb15080208.
4. Mainjot A, Dupont N, Oudkerk JC, Dewael TY, Sadoun MJ. From Artisanal to CAD-CAM blocks. J Dent Res. 2016;95:487–95. https://doi.org/10.1177/0022034516634286.
5. Marchesi G, Camurri Piloni A, Nicolin V, Turco G, Di Lenarda R. Chairside CAD/CAM materials: current trends of Clinical uses. Biology (Basel). 2021;10:1170. https://doi.org/10.3390/biology10111170.
6. Aragão WAB, Chemelo VS, Alencar C, de Silva M, Pessanha CM, Reis S. Biological action of bleaching agents on tooth structure: a review. Histol Histopathol. 2024;39:1229–43. https://doi.org/10.14670/HH-18-726.
7. Alqahtani MQ. Tooth-bleaching procedures and their controversial effects: a literature review. Saudi Dent J. 2014;26:33–46. https://doi.org/10.1016/j.sdentj.2014.02.002.
8. Hafez R, Ahmed D, Yousry M, El-Badrawy W, El-Mowafy O. Effect of In-Office bleaching on Color and Surface Roughness of Composite Restoratives. Eur J Dent. 2010;04:118–27. https://doi.org/10.1055/s-0039-1697819.
9. Alshali RZ, AlQahtani MA, Bukhary DM, Alzahrani MA, Alsoraihi SS, Alqahtani MA. The effect of bleaching on surface roughness and gloss of different CAD/CAM ceramic and hybrid ceramic materials. J Appl Biomater Funct Mater. 2023;21. https://doi.org/10.1177/22808000231152566.
10. Quek SHQ, Yap AUJ, Rosa V, Tan KBC, Teoh KH. Effect of staining beverages on color and translucency of CAD/CAM composites. J Esthet Restor Dent. 2018;30:E9–17. https://doi.org/10.1111/jerd.12359.
11. Vichi A, Balestra D, Scotti N, et al. Translucency of CAD/CAM and 3D printable composite materials for Permanent Dental restorations. Polym (Basel). 2023;15:1443. https://doi.org/10.3390/polym15061443.
12. Yu B, Ahn JS, Lee YK. Measurement of translucency of tooth enamel and dentin. Acta Odontol Scand. 2009;67:57–64. https://doi.org/10.1080/00016350802577818.

13. Paolone G, Baldani S, De Masi N, Mandurino M, Collivasone G, Scotti N, et al. Translucency of bulk-fill composite materials: a systematic review. J Esthet Restor Dent. 2024;36:995–1009. https://doi.org/10.1111/jerd.13241.
14. Youm JH, Jeong IJ, Kwon JS, Lim BS, Oh MH, Kim KM. The optical property measuring methods for resin composite using multiple spectrophotometers. Dent Mater J. 2024;43:2023–312. https://doi.org/10.4012/dmj.2023-312.
15. Pérez MM, Pecho OE, Ghinea R, Pulgar R, Della Bona A. Recent advances in Color and whiteness evaluations in Dentistry. Curr Dent. 2019;1:23–9. https://doi.org/10.2174/2542579X01666180719125137.
16. Arimoto A, Nakajima M, Hosaka K, Nishimura K, Ikeda M, Foxton RM, et al. Translucency, opalescence and light transmission characteristics of light-cured resin composites. Dent Mater. 2010;26:1090–7. https://doi.org/10.1016/j.dental.2010.07.009.
17. Yu B, Lee Y-K. Influence of color parameters of resin composites on their translucency. Dent Mater. 2008;24:1236–42. https://doi.org/10.1016/j.dental.2008.01.016.
18. Duzyol M, Duzyol E, Çarıkçıoğlu B. Assessing one-shade composite resin color stability in response to everyday drinks. BMC Oral Health. 2024;24:821. https://doi.org/10.1186/s12903-024-04612-z.
19. Omara AA, Othman HI, Aldamaty MF, Metwally MF. Effect of acidic environment on color and translucency of different indirect restorative materials. BMC Oral Health. 2024;24:472. https://doi.org/10.1186/s12903-024-04218-5.
20. Yılmaz MN, Gul P. Monomer release from dental restorative materials containing dimethacrylate resin after bleaching. Clin Oral Investig. 2022;26:4647–62. https://doi.org/10.1007/s00784-022-04446-5.
21. Lee C-H, Lee I-B. Effect of translucency and absorbance of composite on temperature change during photopolymerization. Dent Mater J. 2023;42:2023–143. https://doi.org/10.4012/dmj.2023-143.
22. Morel LL, de Holanda GA, Perroni AP, de Moraes RR, Boscato N. Effect of shade and opacity on color differences and translucency of resin composite veneers over lighter and darker substrates. Odontology.
23. Vıllarroel M, Fahl N, De Sousa AM, De Olıveıra OB. Direct esthetic restorations based on translucency and opacity of Composite resins. J Esthet Restor Dent. 2011;23:73–87. https://doi.org/10.1111/j.1708-8240.2010.00392.x.
24. Erturk-Avunduk AT, Delikan E, Cengiz-Yanardag E, Karakaya I. Effect of whitening concepts on surface roughness and optical characteristics of resin-based composites: an AFM study. Microsc Res Tech. 2024;87:214–28. https://doi.org/10.1002/jemt.24424.
25. Li Q, Yu H, Wang Y. Colour and surface analysis of carbamide peroxide bleaching effects on the dental restorative materials in situ. J Dent. 2009;37:348–56. https://doi.org/10.1016/j.jdent.2009.01.003.
26. Rattacaso RMB, Garcia L, de FR, Aguilar FG, Consani S, Pires-de F D C. P. Bleaching Agent Action on Color Stability, Surface Roughness and Microhardness of composites submitted to accelerated Artificial Aging. Eur J Dent. 2011;05:143–9. https://doi.org/10.1055/s-0039-1698871.
27. El-Murr J, Ruel D, St-Georges AJ. Effects of external bleaching on restorative materials: a review. J Can Dent Assoc. 2011;77:b59.
28. Canay S, Cehreli MC. The effect of current bleaching agents on the color of light-polymerized composites in vitro. J Prosthet Dent. 2003;89:474–8. https://doi.org/10.1016/S0022391303001689.
29. Kurtulmus-Yilmaz S, Cengiz E, Ulusoy N, Ozak ST, Yuksel E. The effect of home-bleaching application on the color and translucency of five resin composites. J Dent. 2013;41:e70–5. https://doi.org/10.1016/j.jdent.2012.12.007.
30. Gul P, Alp HH, Özcan M. Monomer release from bulk-fill composite resins in different curing protocol. J Oral Sci. 2020;62:288–92. https://doi.org/10.2334/josnusd.19-0221.
31. Yu B, Lee YK. Translucency of varied brand and shade of resin composites. Am J Dent. 2008;21:229–32.
32. Rosado L, Münchow E, de Oliveira E, Lacerda-Santos R, Freitas DQ, Carlo HL, et al. Translucency and Radiopacity of Dental Resin composites – is there a direct relation? Oper Dent. 2023;48(3). https://doi.org/10.2341/22-056-L.
33. Babina K, Polyakova M, Sokhova I, Doroshina V, Zaytsev A, Nikonova EE, et al. Translucency and Color Stability of a simplified Shade Nanohybrid Composite after Ultrasonic scaling and air-powder polishing. Nanomaterials. 2022;12:4465. https://doi.org/10.3390/nano12244465.
34. Koc Vural U, Atalay C, Miletić I, Gurgan S. Effects of different whitening agents on the Color and Translucency of different Resin composites. Acta Stomatol Croat. 2023;57:316–28. https://doi.org/10.15644/asc57/4/3.
35. Alrahlah A, Silikas N, Watts DC. Post-cure depth of cure of bulk fill dental resin-composites. Dent Mater. 2014;30:149–54. https://doi.org/10.1016/j.dental.2013.10.011.
36. Gunal B, Ulusoy MM. Optical properties of contemporary monolithic CAD-CAM restorative materials at different thicknesses. J Esthet Restor Dent. 2018;30:434–41. https://doi.org/10.1111/jerd.12382.
37. Günal Abduljalil B, Ongun S, Önöral Ö. How will surface conditioning methods influence the translucency and color properties of CAD-CAM resin-matrix ceramics with different thicknesses? J Esthet Restor Dent. 2021;33:925–34. https://doi.org/10.1111/jerd.12667.
38. Sartori N, Knezevic A, Peruchi LD, Phark JH, Duarte S Jr. Effects of light attenuation through dental tissues on cure depth of composite resins. Acta Stomatol Croat. 2019;53:95–105. https://doi.org/10.15644/asc53/2/1.
39. Fontes ST, Fernández MR, de Moura CM, Meireles SS. Color stability of a nanofill composite: Effect of different immersion media. J Appl Oral Sci. 2009;17:388–91. https://doi.org/10.1590/S1678-77572009000500007.
40. Tian F, Yap AUJ, Wang X, Gao X. Effect of staining solutions on color of pre-reacted glass-ionomer containing composites. Dent Mater J. 2012;31:384–8. https://doi.org/10.4012/dmj.2011-223.
41. Klauer E, Belli R, Petschelt A, Lohbauer U. Mechanical and hydrolytic degradation of an Ormocer®-based Bis-GMA-free resin composite. Clin Oral Investig. 2019;23:2113–21. https://doi.org/10.1007/s00784-018-2651-3.
42. Torres C, Augusto M, Mathias-Santamaria I, Di Nicoló R, Borges AB. Pure Ormocer vs Methacrylate composites on posterior teeth: a double-blinded Randomized Clinical Trial. Oper Dent. 2020;45:359–67. https://doi.org/10.2341/19-079-C.
43. Wendler M, Belli R, Petschelt A, Mevec D, Harrer W, Lube T, et al. Chairside CAD/CAM materials. Part 2: flexural strength testing. Dent Mater. 2017;33:99–109. https://doi.org/10.1016/j.dental.2016.10.008.
44. Wattanapayungkul P, Yap AU. Effects of in-office bleaching products on surface finish of tooth-colored restorations. Oper Dent. 2003;28:15–9.
45. Hannig C, Duong S, Becker K, Brunner E, Kahler E, Attin T. Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. Dent Mater. 2007;23:198–203. https://doi.org/10.1016/j.dental.2006.01.008.
46. Gökay O, Yilmaz F, Akin S, Tunçbìlek M, Ertan R. Penetration of the Pulp Chamber by Bleaching Agents in Teeth restored with various restorative materials. J Endod. 2000;26:92–4. https://doi.org/10.1097/00004770-200002000-00008.

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