Effect of accelerated staining and bleaching on chairside CAD/CAM materials with high and low translucency

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The aim of the study was to assess the effect of staining and bleaching on CAD/CAM materials with high (HT) and low translucency (LT or T). Samples were stored in coffee and subsequently bleached. CIELAB parameters were recorded at baseline, after coffee immersion, after bleaching. Translucency parameter (TP), whiteness index (WID) and color changes were calculated (ΔE_{00}). Influence of staining and bleaching was analyzed with repeated-measures ANOVA and color differences between materials were analyzed with one-way ANOVA ($\alpha=0.05$). Staining and bleaching significantly affected CIELAB parameters and WID for all materials ($p<0.001$). TP was significantly influenced by staining and bleaching for Crios and Enamic ($p<0.05$). Mean color differences were significantly different between materials ($p<0.001$). The greatest color changes due to staining were observed for Lava Ultimate while the lowest for e.max CAD. Both coffee staining and bleaching induced greater color changes for HT materials of the same brand compared to LT.

Keywords: CAD/CAM, Color, Dental ceramics, Composite resin

INTRODUCTION

CAD/CAM technology has currently become one of the most challenging and dynamic domains in dentistry due to the significant advances in the image acquisition process, restoration designing and manufacturing. Furthermore, there are many highly esthetic materials specifically developed for this technique that are constantly launched to the market, increasing thus the restorative treatment possibilities.

Feldspar ceramic (Vitablocs Mark I and II) was the first material introduced for CAD/CAM processing. This material has excellent esthetic properties but is not considered a strong material to withstand high occlusal load; therefore, its clinical indications are limited to anterior veneers and crowns¹. Although strength is considered one of the most important properties for long term restorations, tougher and stronger materials like lithium disilicate reinforced ceramics or zirconium oxide do not always fulfil the highest esthetic demands. Moreover, these materials often require longer milling times, which consequently lead to faster wearing of the burs and higher maintenance costs^{2,3}.

Composite resin blocks for CAD/CAM technology were introduced to dental practice as alternatives to ceramics⁴. These materials are fabricated under controlled and highly standardized conditions, thus mechanical and optical properties are much improved compared to conventional composite resins⁵. Apart from their better machinability that allow the fabrication of very thin restorations with smooth margins, CAD/CAM resin restorations induce less antagonist wear^{3,5}.

According to their microstructure, composite resins for CAD/CAM technology can be divided into two subclasses: with dispersed fillers (DF) and polymer

infiltrated ceramic network (PICN)⁶. DF have a polymeric matrix reinforced with various inorganic fillers^{6,7}. A common term used for PICN is hybrid ceramics, because of their unique composition and architecture. Although they contain a ceramic network, according to Mainjot *et al.* these materials are still composite resins⁸. VITA Enamic, the only available hybrid ceramic, has mechanical properties between ceramic and composite resins⁹.

Dental composite resins have a tendency to absorb water because of their chemical composition and hydrophilic nature⁹. Consequently, when exposed to various liquids in the oral cavity these materials can suffer a discoloration process. Red wine, coffee, tea, and chlorhexidine are known to have a discoloring effect on resin restorations¹⁰. Since color change of resin restorations over time is inevitable, many attempts have been put to improve the altered esthetic appearance of these restorations. Surface polishing and dental bleaching are the most common treatments used for removing the staining from resin restorations¹¹.

Color stainability of composite resins is determined by calculating color differences using ΔE^*_{ab} or ΔE_{00} formulas⁴ and interpreting results according to visual color difference thresholds¹². Bleaching efficiency and stain removal from composite resins is also determined by this method. However, apart from the interpretation of color differences, the assessment of differences in CIE L^* , a^* , b^* or CIE L^* , C^* , h^0 parameters indicate the intimate modification; in addition, a one-dimensional whiteness index is effective in identifying the direction in variation of color. Lately, the use of whiteness indices for quantifying tooth whiteness has become more and more popular¹³. Additionally, a new customized whiteness index for dentistry (WID) based on CIELAB parameters

has been proposed. The WID shows a better correlation with visual perception than all other indices¹⁴.

Translucency is one of the major factors influencing the appearance of a material and its appropriate selection influences the biomimetic integration of the restoration¹⁵. Hence, most of the esthetic dental materials are formulated with different levels of translucency. Translucency is influenced by the composition of the material, mainly by the differences in the refractive index between filler and organic matrix, the amount of filler, and the filler size⁵.

To the best of our knowledge, there is no information available concerning the color stability of CAD/CAM materials with different levels of translucencies, as provided by manufacturers: low level of translucency (LT or T) and high translucency (HT). Therefore, the aim of the present study was to assess the changes in color and translucency of new composite resins, hybrid ceramics, and lithium disilicate with high and low translucency for

CAD-CAM processing after accelerated coffee staining and bleaching with 10% carbamide-peroxide gel.

The null hypotheses were: 1; There was no difference in the effect of accelerated staining and bleaching procedures on CIELAB parameters, TP, WID for direct composites, CAD-CAM composites, hybrid ceramics, lithium disilicate and feldspathic ceramics. 2; There was no difference in the effect of accelerated staining and bleaching procedures on color stability of materials with high and low levels of translucency.

MATERIALS AND METHODS

Sample preparation, staining and bleaching procedures

The materials evaluated in the present study are presented in Table 1. Sample size calculation was carried out using a statistical software (G*Power v3.1.9.2 for MacIntosh [Apple], Heinrich-Heine-Universität, Düsseldorf, Germany) with the following input

Table 1 Type, composition and codification of materials

Product	Type	Block size	Composition*	Shade	Level of translucency**	Code
Filtek Ultimate (3M ESPE, St. Paul, MN, USA)	Composite resin for direct restorations	N/A	20 nm Silica filler 4–11 nm Zirconia filler 80wt% Bis-GMA, UDMA, TEGDMA, and Bis-EMA resins	A3D	N/A	FU
Lava Ultimate (3M ESPE)	Composite resin for CAD/CAM restorations	14L	20 nm Silica filler 4–11 nm Zirconia filler 80 wt% Bis-GMA, UDMA, TEGDMA, and Bis-EMA resins	A3	HT	L_HT
				A3	LT	L_LT
Crios Brilliant (Coltène/Whaledent, Altstätten, Switzerland)	Composite resin for CAD/CAM restorations	14	Barium glass (<1.0 µm) SiO ₂ (<20 nm) 71 wt% Cross-linked methacrylates Pigments	A3	HT	CR_HT
				A3	LT	CR_LT
Shofu Blocks HC (SHOFU Dental, Ratingen, Germany)	Composite resin for CAD/CAM restorations	14	SiO ₂ , zirconium silicate, 61 wt% UDMA, TEGDMA resins	A3	HT	S_HT
				A3	LT	S_LT
VITA Enamic (VITA Zahnfabrik, Bad Sackingen, Germany)	Hybrid ceramic for CAD/CAM restorations	EM-14	SiO ₂ , Al ₂ O ₃ , Na ₂ O, 86 wt% UDMA, TEGDMA	3M2	HT	E_HT
				3M2	T	E_T
IPS e.max CAD (Ivoclar Vivadent, Schaan, Liechtenstein)	Glass-ceramic for CAD/CAM restorations	C14	Lithium disilicate reinforced ceramic	A3	HT	EX_HT
				A3	LT	EX_LT
VITABLOCS Mark II (VITA Zahnfabrik)	Glass-ceramic for CAD/CAM restorations	I14	Feldspar ceramic	A3C	N/A	VM_II

*Bis-GMA=bisphenol-A-glycidyl methacrylate; UDMA=urethane dimethacrylate; TEGDMA=triethyleneglycol dimethacrylate; Bis-EMA=bisphenol-A-polyethylene glycol diether dimethacrylate.

**HT-High Translucency, LT-Low Translucency, T-Translucent, N/A-Not Applicable

parameters for repeated measures ANOVA, within-between interaction model: effect size 0.40, α level 5%, 95% power, 12 groups, 3 measurements, correlation between measurements 0.50, and non-sphericity correction 0.75. Based on the calculations, a total sample size of 60 generated a power of 0.98, therefore the minimum sample size per group was 5.

The samples were cut to a thickness of 1.1 mm from CAD-CAM rectangular blocks using a low-speed saw under running water (Isomet 1000, Buehler, Lake Bluff, IL, USA). For IPS e.max CAD LT and HT samples a crystallization cycle was performed with the Programat furnace (Ivoclar Vivadent, Schaan, Liechtenstein) following the indications of the manufacturer. Direct composite resin samples were obtained by packing the resin in a metal sampler (Ceramic Sampler, SmileLine, Saint-Imier, Switzerland). A glass slab was pressed on the top of the resin for preventing the formation of inhibition layer on the surface of resin during curing. Light curing (Halo, Translux Wave, Haereus, Hanau, Germany) was carried out for 20 seconds on both sides of the discs. Samples with a thickness of 1.1 mm were obtained.

Sandpaper with 500, 800, 1000 grit size was used for manually polishing both sides of the samples down to a thickness of 1 mm (± 0.02 mm). The final thickness of the samples was verified with a digital micrometer (Digital Caliper, Powerfix, Jinjiang Jiaying Group, Fujian, China). One side of the samples was indented with a fine carbide bur mounted on a low speed hand-piece for marking the side used during the color measurements. An ultrasonic bath filled with distilled water was used for cleaning the samples (2 min at 20°C).

For the accelerated staining protocol, each sample was stored individually in 3 mL coffee solution (Nescafé Brasero, Nestlé, Vevey, Switzerland) at room temperature for one week (24 h/day). The coffee solution was refreshed each day. After staining procedures, the samples were stored in distilled water for 24 h, then rinsed and dried. An at-home bleaching protocol using 10% carbamide peroxide (Professional Teeth Whitening Gel, White Wash Laboratories, Billingham, UK) was applied for 6 h/day, four consecutive days. Between bleaching sessions, the samples were stored individually in distilled water at room temperature.

Color measurements and calculations

Color measurement of samples was performed on black, white, and gray backgrounds with a dental spectrophotometer (VITA Easyshade Advance 4.0, VITA Zahnfabrik, Bad Sackingen, Germany). A saturated sucrose solution was interposed between the samples and the backgrounds for ensuring an optical contact. One experienced operator did all measurements. The dental spectrophotometer was allowed to warm-up for 10 min after turning on, and before each measurement the device was calibrated. Each sample was measured three times, at three different time points: at baseline (i), after coffee staining (co), and after bleaching procedures (bl), and CIELAB parameters were recorded.

The CIELAB system allows the representation of colors in a three-dimensional space, using three parameters: L^* (lightness) that is represented on a vertical axis and can take values from 0 (black) to 100 (white), and a^* and b^* chromatic parameters that are represented on two horizontal axes, symbolizing the amount of greenness-redness or blueness-yellowness, respectively¹⁶.

Translucency parameter (TP) was calculated as follows¹⁷:

$$TP = \sqrt{(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2} \quad (1)$$

where L_B^* , a_B^* , b_B^* are color parameters recorded on black background and L_W^* , a_W^* , b_W^* are CIELAB parameters recorded on white background.

Whiteness index (WI_D) was also calculated based on CIELAB parameters¹⁴:

$$WI_D = 0.511L^* - 2.324a^* - 1.100b^* \quad (2)$$

where L^* , a^* , b^* are color parameters of samples recorded on grey background.

Color changes of the samples after coffee staining (ΔE_{00co-i}), bleaching ($\Delta E_{00bl-co}$) and between initial and final situation (ΔE_{00bl-i}) were calculated for grey background using the color difference formula CIEDE2000 (ΔE_{00}). The supplementary data file recommended by Sharma *et al.* was used for calculations¹⁸⁻²⁰.

Descriptive statistics, testing for normal distribution and data analyses were performed with statistical software (SPSS Statistics v.23 for MacIntosh [Apple], IBM, Chicago, IL, USA). The influence of staining and bleaching treatments on CIELAB parameters, TP, WI_D of materials was tested using the repeated measures ANOVA test ($\alpha=0.05$) and pairwise comparisons between groups were adjusted by least significant difference (LSD) method. The color differences between materials induced by staining or bleaching were analyzed with one-way analysis of variance (ANOVA) test ($\alpha=0.05$). Multiple comparisons between mean color differences of materials were analyzed with Tukey Honest Significant Difference (HSD) test ($\alpha=0.05$).

RESULTS

The results of the repeated measures ANOVA showed that accelerated staining and bleaching treatments had a significant effect on the L^* parameter for all tested materials ($F=983.770$, $p<0.001$) and the interaction between treatment type and material was significant ($F=121.941$, $p<0.001$). Crios Brilliant HT and Lava Ultimate HT showed the greatest decrease in lightness after staining, while VITA Enamic T the lowest. After bleaching procedure, the lightness of the samples did not return to the initial level, for none of the tested materials. However, the greatest bleaching effect was observed for Shofu Blocks HT and LT, Filtek Ultimate and Lava Ultimate LT.

Accelerated staining and bleaching treatments had a significant effect on both a^* and b^* chromatic

parameters for all tested materials ($F=1149.910$, $p<0.001$ and $F=1679.145$, $p<0.001$ respectively) and the interaction between treatment type and material was also significant ($F=41.754$, $p<0.001$ and $F=104.019$, $p<0.001$ respectively). Accelerated staining induced the greatest increase in a^* parameter for Lava Ultimate LT and HT, Crios Brilliant LT and HT. Bleaching did not restore the initial level for a^* , yet for Crios Brilliant LT, Lava Ultimate LT and HT the greatest bleaching effect was observed. After coffee staining, Filtek Ultimate and Lava Ultimate LT had the greatest increase in b^* parameter.

The tested materials showed different values of

WID at baseline (Table 2). Accelerated staining and bleaching treatments significantly influenced the values of the whiteness index for all tested materials ($F=1963.820$, $p<0.001$), with the interaction effect also significant ($F=88.360$, $p<0.001$). However, the multiple comparisons showed no significant change in WID after accelerated staining and bleaching for e.max CAD LT and HT ($p>0.05$). Lava Ultimate HT showed the greatest decrease in whiteness after coffee staining, followed by Filtek Ultimate and Lava Ultimate LT. Moreover, after coffee staining and bleaching HT samples showed greater variation in WID than LT, for all CAD/CAM composite materials.

Table 2 Mean differences and standard deviations of whiteness indexes after coffee staining ($\Delta WID_{co,i}$), bleaching ($\Delta WID_{bl,co}$), and the residual difference compared to baseline ($\Delta WID_{bl,i}$)

	WID _i	$\Delta WID_{co,i}$	$\Delta WID_{bl,co}$	$\Delta WID_{bl,i}$
Filtek Ultimate	25.33 (0.52)	-6.67 (1.24)	3.92 (1.05)	-2.75 (0.34)
Lava HT	28.98 (0.43)	-8.06 (2.25)	5.45 (1.24)	-2.62 (1.21)
Lava LT	18.65 (0.43)	-6.61 (1.00)	3.95 (1.38)	-2.66 (0.46)
Crios HT	24.72 (0.24)	-6.36 (1.41)	4.23 (1.60)	-2.13 (0.56)
Crios LT	0.84 (0.47)	-5.41 (1.18)	4.57 (1.03)	-0.83 (0.60)
Shofu HT	27.27 (0.21)	-4.64 (0.49)	2.12 (0.32)	-2.51 (0.48)
Shofu LT	15.79 (0.20)	-4.12 (0.49)	1.46 (0.67)	-2.66 (0.55)
Enamic HT	9.21 (0.50)	-1.51 (0.25)	1.36 (0.51)	-0.15 (0.31)
Enamic T	-9.36 (0.41)	-1.73 (0.67)	2.17 (0.77)	0.44 (0.28)
e.max CAD HT	35.28 (0.22)	0.36 (0.17)	0.42 (0.36)	0.78 (0.31)
e.max CAD LT	23.30 (0.62)	-0.29 (0.55)	0.70 (0.52)	0.40 (0.20)
VITA Mark II	25.46 (0.37)	-1.86 (0.48)	0.97 (0.55)	-0.89 (0.28)

Table 3 Mean differences and standard deviations of TP after coffee staining ($\Delta TP_{co,i}$), bleaching ($\Delta TP_{bl,co}$), and the residual difference compared to baseline ($\Delta TP_{bl,i}$)

	TP _i	$\Delta TP_{co,i}$	$\Delta TP_{bl,co}$	$\Delta TP_{bl,i}$
Filtek Ultimate	21.65 (0.62)	-0.31 (0.53)	0.20 (0.43)	-0.11 (0.32)
Lava HT	21.93 (0.38)	-0.63 (0.35)	0.46 (1.15)	-0.17 (1.11)
Lava LT	21.16 (0.14)	-0.21 (0.49)	0.03 (0.35)	-0.17 (0.23)
Crios HT	21.81 (0.16)	-0.97 (0.32)	-0.24 (0.63)	-1.21 (0.38)
Crios LT	19.88 (0.52)	-0.44 (0.48)	-0.33 (1.02)	-0.77 (1.13)
Shofu HT	23.02 (0.22)	-0.36 (0.31)	0.40 (0.24)	0.04 (0.21)
Shofu LT	21.74 (0.45)	-0.14 (0.17)	0.27 (0.13)	0.12 (0.12)
Enamic HT	18.84 (0.54)	-0.07 (0.36)	-0.47 (0.33)	-0.54 (0.27)
Enamic T	16.37 (0.25)	-0.10 (0.25)	-0.25 (0.22)	-0.35 (0.31)
e.max CAD HT	18.87 (0.32)	0.24 (0.24)	-0.18 (0.23)	0.05 (0.10)
e.max CAD LT	17.79 (0.24)	0.13 (0.24)	-0.13 (0.32)	0.01 (0.14)
VITA Mark II	19.88 (0.27)	-0.35 (0.21)	0.23 (0.15)	-0.12 (0.17)

Table 4 Summary of one-way ANOVA for testing the differences in ΔE_{00} between groups of materials after coffee staining, bleaching, and the residual color difference

Source	Sum of squares	df	Mean square	F	p
$\Delta E_{00\text{co}_i}$	151.555	11	13.778	130.814	<0.001
$\Delta E_{00\text{bl}_{co}}$	85.193	11	7.745	119.010	<0.001
$\Delta E_{00\text{bl}_i}$	26.576	11	2.416	45.553	<0.001

Fig. 1 Mean color differences after coffee staining ($\Delta E_{00\text{co}_i}$), bleaching ($\Delta E_{00\text{bl}_{co}}$), and the residual color difference ($\Delta E_{00\text{bl}_i}$) of 1-mm A3 sample groups (CIEDE2000 50:50% Perceptibility threshold = 0.8, CIEDE2000 50:50% Acceptability threshold = 1.8).

The results of the repeated measures ANOVA revealed that TP was also significantly influenced by staining and bleaching ($F=38.757$, $p<0.001$). The interaction effect between material and treatment was significant ($F=7.973$, $p<0.001$). The multiple comparisons showed significant changes in TP only for Crios Brilliant LT and HT, and VITA Enamic T and HT ($p<0.05$, Table 3).

The one-way ANOVA revealed that mean color differences ($\Delta E_{00\text{co}_i}$, $\Delta E_{00\text{bl}_{co}}$, $\Delta E_{00\text{bl}_i}$) were significantly different between materials ($p<0.001$, Table 4). The color differences induced by staining and bleaching are presented in Fig. 1. The greatest color changes due to coffee staining were observed for Lava Ultimate LT and HT, Filtek Ultimate, and Crios Brilliant HT (above the acceptability threshold of 1.8).

IPS e.max CAD LT and HT, VITA Enamic T and HT showed the smallest color variations (below the perceptibility threshold of 0.8). Multiple comparison tests showed no significant differences between the mean color differences calculated for these materials ($p>0.05$). The color differences after coffee staining calculated for Crios Brilliant LT, Shofu Blocks LT and HT were situated between 50:50% PT and 50:50% AT.

The greatest color changes induced by bleaching were observed for Lava Ultimate HT and Crios Brilliant HT (above 50:50% AT), while the smallest were detected for Shofu Blocks LT and HT, VITA Enamic T and HT,

IPS e.max CAD LT and HT, and Vitablocs Mark II (below 50:50% PT).

Both coffee staining and bleaching procedures induced higher color changes for HT materials compared to LT, for the same brand. However, for VITA Enamic T and HT, IPS e.max CAD LT and HT the differences were not statistically significant ($p>0.05$).

The residual color difference ($\Delta E_{00\text{bl}_i}$) was below the 50:50% PT only for Crios Brilliant LT, VITA Enamic T and HT, IPS e.max CAD LT and HT, and Vitablocs Mark II.

DISCUSSION

The major cause of color differences resulted after staining and bleaching between materials tested is the difference in their chemical composition and structural organization. Among all, ceramics based on lithium disilicate or feldspar which are highly dense materials showed the best color stability. These results are in accordance with previous studies^{1,4,5,10}. It was shown that the organic matrix is mainly responsible for discoloration. Hybrid ceramics, materials that have a low content of organic component showed also color differences below perceptibility threshold. Composite-based materials have in their composition an increased percentage of organic matrix which is linked to a lower color stability. HT composite resin blocks have less inorganic particles

compared to LT materials and therefore this could explain their inferior resistance to staining.

The first null hypothesis was rejected since direct composites and CAD/CAM composites underwent greater color changes than ceramic-based materials after accelerated coffee staining and bleaching. Filtek Ultimate, Lava Ultimate LT and HT showed the greatest stain susceptibility, which may have occurred because of their chemical composition. Bis-GMA monomers, that are found in the composition of Filtek Ultimate and Lava Ultimate are more hydrophilic compared to UDMA or TEGDMA^{5,21,22}). Moreover, the final color is perceivable differently in comparison with the initial situation (after staining and bleaching), which means that the effect of the whitening gel did not neutralize entirely the pigmentation. Lithium-disilicate, feldspar ceramic and hybrid ceramic proved the best color stability.

Discoloration of dental materials can be caused by different factors. Among the extrinsic factors producing discoloration of dental restorations are dental plaque accumulation and surface staining⁹. Surface polishing and professional cleaning or bleaching can remove superficial staining. However, if the discoloration involves deeper layers, these treatment methods are no longer efficient and restoration replacement should be considered. The color change is influenced by the type of resin, degree of polymerization, photoinitiator system, surface finishing, colorant type, contact time between staining agents and resins, oral hygiene habits^{5,23–26}). Previous studies reported that the type of resin significantly influences the amount of discoloration^{5,21,22,27}). Because of its lower hydrophilic properties, UDMA appears to be more color stable than Bis-GMA. TEGDMA also seems to be more color-resistant than Bis-GMA. Therefore, most of the composite resins recently introduced to the market are mainly formulated based on TEGDMA and UDMA.

The second null hypothesis was also rejected because significant differences in color stability were found between LT and HT materials of the same brand and color. HT materials showed greater color differences than LT, although the color differences were not perceivable for ceramic-based materials. An explanation could be the different ratio between organic matrix and inorganic filler among different translucencies of composite-based materials. The difference in color stability between HT and LT CAD/CAM composite resins has an important clinical significance particularly in the case of several restorations placed one next to the other, as is the case of veneers and full coverage crowns in the upper frontal area.

The discoloration effect induced by staining agents on teeth or various dental materials can be appreciated by calculating color differences between CIELAB parameters of the samples before and after treatment. In this respect, the most widely used color difference formula is ΔE^*_{ab} . The more recently introduced color difference formula, CIEDE2000, has been proved to be better correlated to visual perception and thus should be used in color calculations¹⁸). Regardless of which

formula is used, the interpretation of the color difference values has to be related to the perceptibility (PT) and acceptability thresholds (AT) for having the true clinical significance of the data. In a recent multicentric study it was found that the 50:50% PT and 50:50% AT in Dentistry are 0.8 and 1.8 respectively for ΔE^*_{00} , and 1.2 and 2.7 respectively for ΔE^*_{ab} ²⁸).

In the present study, the color changes induced by staining and bleaching were below the perceptibility threshold only for hybrid ceramics, lithium disilicate and feldspar ceramics. Accelerated coffee staining induced a significant decrease in lightness and a color shifting towards reddish-yellowish for composite based materials. Additionally, coffee staining and bleaching induced greater variation of the WID for HT samples than for LT. Although the variation of the WID showed more significant changes for CAD/CAM composite resins and direct composites, as the color difference formula also proved, the clinical interpretation of the WID values is not possible since visual thresholds are not yet available.

One-week immersion of samples in coffee solution was used in the present study. This protocol was followed since previous research demonstrated that within this time interval composites take up significant staining. This immersion time is equivalent to seven months of coffee drinking^{10,29,30}). For the bleaching procedures, an at-home bleaching protocol with 10% carbamide-peroxide was used as it is one of the most accepted bleaching treatment by patients, with the least side effects³¹).

Bleaching effect of different agents on restorative materials was tested in several previous studies^{10,11,32}). One study found no significant differences in bleaching efficiency of 10% carbamide-peroxide over composite resins³²). In our study, except lithium-disilicate, the bleaching procedure with 10% carbamide-peroxide could not effectively remove the staining from the surface of the samples. Similar results are presented by Alharbi *et al.* in a recent study¹¹). They concluded that bleaching with 40% hydrogen-peroxide was able to remove the stains to a clinically acceptable level only for hybrid ceramics and feldspar ceramics.

Translucency parameter was first introduced as a direct measure of translucency for maxillo-facial elastomers, and it was calculated as the color difference between CIELAB parameters of the sample with specified thickness placed in optical contact over black and white backings¹⁷). Translucency and opacity are material properties that vary in time and can be modified by water absorption, chemical degradation, and microfractures of the composite resins³³). In the present study, the initial translucency of the tested materials at 1 mm thickness was different, VITA Enamic T being the least translucent whereas Shofu Blocks HT the most translucent. Staining and bleaching procedures significantly affected TP only in the case of Crios Brilliant HT and LT, and VITA Enamic HT and T. The decrease in translucency after coffee immersion could have occurred because of the stains absorbed on the surface of the samples.

A limitation of the present study is that the samples did not follow any clinical polishing or glazing procedures. However, a standardized fabrication protocol was used for all the samples. Another limitation is that only 1 mm A3 shaded samples were investigated. Further studies should be conducted for other clinically relevant thicknesses and shades.

CONCLUSIONS

Within the limitation of the present study, it can be concluded that color changes induced by accelerated staining and bleaching procedures were clinically significant for direct and CAD/CAM composite materials. Additionally, the discoloration was more important for HT materials than for LT. The ceramic based materials did not exhibit perceivable color changes after staining and bleaching.

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