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Influence of toothbrush abrasion and surface treatments on the color and translucency of resin infiltrated hybrid ceramics

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PURPOSE. The study compared the color change, lightness, and translucency of hybrid resin ceramics exposed to toothbrush abrasion and surface treatment. **MATERIALS AND METHODS.** Four hybrid ceramics [Lava Ultimate (LU), Vita Enamic (EN), Shofu HC (SH), and Crystal Ultra (CU)] were compared with a glass-ceramic (Vita Mark II) control. One hundred and twenty specimen blocks were prepared using a precision saw machine. Specimens in each material were divided into four subgroups based on the surface treatment (polishing or staining) and a storage medium (water or citric acid). Simulated tooth brushing with a mixture of 100 RDA (radioactive abrasives) with 0.3 ml distilled water was used for 3650 cycles (7300 strokes) for each specimen. Measurements for the color change, lightness, and translucency were measured after toothbrushing using a spectrophotometer. Statistical analysis compared outcomes using paired t-test, ANOVA, and Tukey post hoc test. **RESULTS.** The maximum color change was identified in SH (stained acid) [1.44 (0.40)], whereas the lowest was identified in EN (polished water) [0.66 (0.16)] material. The maximum and minimum loss of surface translucency was observed in SH (polished water) [12.3 (0.52)] and EN (stained acid) [6.5 (0.55)] specimens, respectively. Lastly, loss of lightness was the highest in VM (polished acid) [69 (0.95)], whereas the lowest was observed in CU (stained water) [56.7 (0.86)]. **CONCLUSION.** The comparison presented a significant effect of toothbrush abrasion on translucency and lightness of the hybrid resin ceramics. Color change was not significantly influenced irrespective of the storage medium employed. Surface staining demonstrated the preservation and stability of color and optical properties under the influence of toothbrush abrasion and chemical trauma. [J Adv Prosthodont 2021;13:1-11]

KEYWORDS

Hybrids; Ceramic; Dental abrasion; Stains; Dental esthetic

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INTRODUCTION

Scientists have invested efforts in the past two decades to alter the microstructure of dental ceramics to achieve optimum performance. A combination of the crystalline structure to the glassy feldspathic porcelain enhances the optical and mechanical properties.[1,2] The percentage composition and type of crystalline structure mainly influences the properties of ceramic. Feldspathic ceramic is preferably used by many dentists in the anterior region due to its ability to mimic natural tooth color.[2,3] Comparatively, combining ceramic with composite has shown mechanical and aesthetic properties similar to natural teeth in materials like Lava Ultimate and Vita Enamic (highly aesthetic and abrasion resistance).[2,3] Therefore, it proves to be a better alternative for computer-aided design/computer-aided manufacturing (CAD/CAM) ceramic restorations.[4,5]

The discovery of the polymer infiltrated glassy ceramic has developed a peculiar interest in chairside computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems.[6] The technology used not only enhances the mechanical and physical property but also equally influences the color stability and optical characteristics. Nevertheless, these restorations have displayed potential for discoloration in the oral cavity due to various factors such as foods, drinks, and vigorous brushing.[3,7] Authors have reported that a comparison between composites, indirect restorative, and glass-ceramic materials have shown higher discoloration in composites compared to ceramics.[2,3,7] Moreover, tooth brushing with abrasive toothpaste has demonstrated wearing of ceramic surface staining applied to the feldspathic ceramic surface unless they were protected by a layer of glaze.[8] However, studies have shown that extrinsic stain layer was resistant to wear on feldspathic ceramic restorations and preserved the restoration from color change.[8]

Optical characteristics such as translucency and lightness are critical in mimicking the natural appearance of teeth.[9] Translucency determines the behavior of light in an object through the phenomena of light transmission, scattering, and absorption, that aids in color perception of dental materials.[10] Surface treatments such as polishing and staining provides a smooth homogenous material surface enhancing the appearance and color matching. Studies have reported that the presence of extrinsic factors play an important role in the esthetics of the restoration.[3,10] The prolonged exposure to the acidic oral environment due to carbonated drinks and coffee, in addition to the vigorous brushing, increases surface roughness, altering the pathway of light reflection and plaque accumulation.[10]

According to a previous report,[5] the elastic modulus of composites is similar to dentine, while feldspathic ceramics show similar properties to enamel; therefore, hybrid resin ceramics can be used to restore enamel and dentin. Besides, hybrid resin ceramics are shown to be preferred over feldspathic ceramics due to their fracture resistance.[3,9] As glass ceramics show better translucency and esthetics compared to hybrid resin ceramics, contemporary hybrid resin ceramics aimed to improve esthetic properties are explored.[6] Lately, newer hybrid ceramic materials (including Crystal Ultra) have been introduced for CAD-CAM techniques of indirect restorations.[9] Studies have suggested that nano-sized particles in these hybrid ceramics display strengthening effect between the organic resin matrix and inorganic ceramic fillers.[11,12] These are also shown to reduce surface wear with greater color stability and maintenance of optical properties for longer periods. However, limited evidence on the esthetic properties of contemporary and conventional hybrid resin ceramics is available. It is hypothesized that simulated abrasion will show significant influence on the color and translucency of hybrid resin infiltrated ceramics. Therefore, the study aimed to compare the color, translucency, and lightness of hybrid resin infiltrated ceramics after exposure to toothbrush abrasion and acidic erosion.

MATERIALS AND METHODS

The study was performed in line with the checklist for reporting *in-vitro* studies (CRIS guidelines).[13] Four resin infiltrated hybrid ceramic materials, including Lava Ultimate-LU (3M ESPE), Vita Enamic-EN (Vita Zahnfabrik), Shofu HC-SH (Shofu Inc.), Crystal Ultra-CU (Digital Dental) and one feldspathic ceramic [Vita mark II-VM

(Vita Zahnfabrik)] as a control, were evaluated for the influence of tooth brushing abrasion, surface treatment (polishing and staining) and storage mediums (water and citric acid) on color, lightness, and translucency. Table 1 presents the composition and manufacturing details of materials.

One hundred and twenty specimens were cut from CAD/CAM blocks using an automated Isomet 1000 precision saw (Buehler, Bluffs, IL, USA) with a standard dimension of (12 × 14 × 2.5 mm). Using a grinding machine (Tegra Pol 15/Tegra Pol 1, Struers, Ballerup, Denmark), each specimen block was finished to a standardized thickness of 2.5 mm. Specimens in each material (n = 24) were divided into 4 subgroups based on the surface treatment and storage medium. Within each material, half the specimens were polished (n = 12), and the other half were stained (n = 12).

Half of all the specimens (n = 60) were finished and polished using a disk system. The surface was sandblasted using 400, 600, 800, and 1200-grit silicon carbide abrasives (LECO spectrum system, Bloomfield, CT, USA) under water spray. Polishing with a low speed handpiece with fine and medium-sized rubber wheels (Dedeco Red and Green Rubber Wheels, Dedeco, NY, USA) at 10,000 rpm with diamond polishing paste (9, 6, 3, 1 μm) (Meta Di Supreme, Buehler Co., Lake Bluff, IL, USA) was performed. Remaining half specimens (n = 60) were stained according to the manufacturer's instruction (Table 2). The surface was air abraded (50- μm aluminum oxide) with a mi-

Table 1. Material composition and manufacturer details

Material	Symbol	Shade/block	Manufacturer	Composition
Vitablocks Mark II	VM2	(2M2/l14)	VITA Zahnfabrik, Bad Säckingen, Germany	20 wt% feldspathic particles (average size of the particle 4 μm) glassy matrix (80 wt %)
Lava Ultimate Restorative	LU	(A2-HT/14L)	3M ESPE, St. Paul, MN, USA	Nano ceramic fillers (zirconia filler (4 - 11 nm), silica filler (20 nm) and aggregated zirconia/silica cluster filler) 80 wt% (65 vol%) cross linked polymer matrix (methacrylate-based - TEGDMA) 20 wt% (35 vol%).
Vita Enamic	EN	(2M2-HT/Em-14)	VITA Zahnfabrik, Bad Säckingen, Germany	Feldspathic ceramic material (86 wt%) acrylate polymer networks (TEGDMA) (14 wt%)
Shofu HC	SH	(A2-HT/14L)	Shofu Inc., Brooklyn, TX, USA	Silica-powder, zirconium silicate and micro fumed silica mixture (61 wt%) resin mixture of UDMA and TEGDMA (39 wt%)
Crystal Ultra	CU	(C-Block 15, 5 x 38.8 A2)	Digital Dental, Scottsdale, AZ, USA	Inorganic silicate glass filler particles (average particle size 0.8 mm [range 0.2 - 10.0 mm]) (70 wt%) highly cross-linked polymer blends (Bis-GMA, UDMA, and BUDMA) (30 wt%)

Table 2. Staining instructions for study materials

Group	Instruments and technique
SH, LU and CU groups	Coated with an adhesive (20 secs) (Scotchbond Universal Adhesive; 3M ESPE), air dried for 5 secs and light polymerization for 20 secs (Elipar Freelight 2, 3M ESPE).
EN group	Etched with HF acid (5%) for 60 seconds and rinsed for 15 seconds. Cleanser (VitaVM LC Cleaner; VITA Zahnfabrik) was applied before silanisation (Ceramic Primer II; GC Corp). Glazing agent (Vita Enamic Glaze; VITA Zahnfabrik) and polymerized as previously mentioned.
VM2 group	Mixture of glaze powder (Vita Akzent Plus Glaze Powder, VITA Zahnfabrik) and the liquid (Vita Akzent Plus Glaze Fluid, VITA Zahnfabrik) was applied. Glaze was fired at 4-min heating cycle with 80°C/min temp increase rate; 950°C firing temp for 1 min.

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cro-etcher (Sandstorm Expert Dental, Vaniman, Murrieta, CA, USA) for 10 seconds.

Following the surface treatments, specimens were categorized into two subgroups based on a storage medium; distilled water (n = 30) and 0.3% citric acid (pH 3.2) (n = 30). All specimens were stored for 7 days. Subsequently, each specimen was removed from the designated storage medium and thoroughly washed for 10 mins.

Each specimen was exposed to simulated toothbrushing using a custom made V-8 toothbrushing machine (ZMB 8, University of Zurich, Zurich, Switzerland) using a toothbrush (Oral-B, P40, Procter and Gamble, Cincinnati, OH, USA) for 3,650 cycles (7,300 toothbrushing strokes). A 2.5 N force was applied with a combination of toothpaste of 100 RDA (radioactive dentin abrasion) with 0.3 mL distilled water. The specimens were rinsed for 10 mins with distilled water after every brushing cycle (7,300 strokes) in addition to the replacement of toothpaste slurry every 3 hours.

The color of all the specimens (n = 120) was measured after simulated tooth brushing (CM-2600d spectrophotometer, Konica Minolta, Minneapolis, MN, USA) at wavelength of 360 - 740 nm that has an inbuilt integrated sphere with D65 illumination curve and 10° observation angle. The color measurement was performed against a white background for each specimen block. The color measurement was calculated using CIE2000 L*a*b* (ΔE_{00}) formula* as[14]:

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)}$$

The detailed explanation of the variables in the presented formula is explained in the work of a previous study.[13]

$$\Delta L' = L^*_2 - L^*_1$$

For the lightness, ΔL is denoted as the lightness (L*) that is defined as the difference in lightness and darkness observed against the white background, in which a* and b* were not included as they represent the psychometric chroma coordinates and indicate hue and chroma factors.

Translucency (TP) was obtained using the same spectrophotometer but over white and black backgrounds. Translucency is defined as the difference between the colors obtained against the white and black background. Each specimen translucency (TP) was measured before and after the simulated tooth brushing using the following formula*[15]:

$$TP = \sqrt{(L^*_B - L^*_w)^2 + (a^*_B - a^*_w)^2 + (b^*_B - b^*_w)^2}$$

The subscripts W and B refer to color coordinates over white and black backgrounds, respectively.

The data were computed and analyzed using statistical software (SPSS Version 21.0, IBM, Armonk, NY, USA). Kolmogorov-Smirnov test was performed to assess the normality of data. ANOVA, Tukey's test, and paired t-test were performed to determine the influence of simulated tooth brushing, surface treatment, and storage medium on color, translucency, and lightness of the specimens.

RESULTS

Table 3 presents a comparison of materials under different surface treatment and storage medium for color change. The highest mean ΔE was observed in SH (stained acid) [1.44 (0.40)], whereas the lowest mean ΔE was identified in EN (polished water) [0.66 (0.16)]. Color change under the influence of surface treatment, storage medium, and toothbrush abrasion was significant only in EN group [0.79 (0.35)], compared to VM (control) [1.14 (0.475)] and CU groups [1.18 (0.32)] (Table 2). Likewise, comparable result was observed in LU [1.04 (0.48)] and SH groups [0.96 (0.29)], respectively.

Among the materials, comparable results for color among subgroups was observed (P > .05), except in SH group, which showed a significant difference among the subgroups (P < .002) (Table 4, Fig. 1). Irrespective of the storage medium, the highest color change was observed in stained specimens with acid exposure [1.44 (0.40)], and the lowest color change was observed in the polished specimen with acid [0.71 (0.14)] immersion. Similarly, with respect to the factors assessed, polished water demonstrated a significant effect on color change among the materials (P < .002). The control (VM) [1.37 (0.60)] group presented comparable outcome to CU [1.25 (0.29)]. Likewise, LU [0.8 (0.25)], EN [0.66 (0.16)], and SH [0.71 (0.14)] showed comparable results with significant differ-

Table 3. Mean, standard deviation among study groups for surface colour

Study groups	Stained-water	Stained-acid	Polished-water	Polished-acid	*P* value[$]
VM	0.88 (0.34)	1.02 (0.66)	1.37 (0.60)	1.29 (0.30)	.066
LU	1.22 (0.51)	1.23 (0.50)	0.8 (0.25)	0.94 (0.67)	.090
EN	0.89 (0.63)	0.83 (0.49)	0.66 (0.16)	0.78 (0.15)	.395
SH	0.99 (0.46)	1.44 (0.40)	0.71 (0.14)	0.73 (0.18)	< .002
CU	1.35 (0.41)	1.2 (0.36)	1.25 (0.29)	0.95 (0.25)	.224

[$] showing effect of storage and surface treatment using ANOVA (*P* value).
Note: each group shows the degree of influence of toothbrush abrasion on the surface colour.

Table 4. Comparison between individual subgroup among the materials for surface colour

Study groups	VM	LU	EN	SH	CU	*P* value[$]
Stained-water	0.88 (0.34)	1.22 (0.51)	0.89 (0.63)	0.99 (0.46)	1.35 (0.41)	.353
Stained-acid	1.02 (0.66)	1.23 (0.50)	0.83 (0.49)	1.44 (0.40)	1.2 (0.36)	.306
Polished-water	1.37 (0.60)	0.8 (0.25)	0.66 (0.16)	0.71 (0.14)	1.25 (0.29)	< .002
Polished-acid	1.29 (0.30)	0.94 (0.67)	0.78 (0.15)	0.73 (0.18)	0.95 (0.25)	.103
Overall	1.14 (0.475)	1.04 (0.48)	0.79 (0.35)	0.96 (0.295)	1.18 (1.12)	> .01

[$] showing effect of material type using ANOVA (*P* value).
Note: each group shows the degree of influence of toothbrush abrasion on the surface colour.

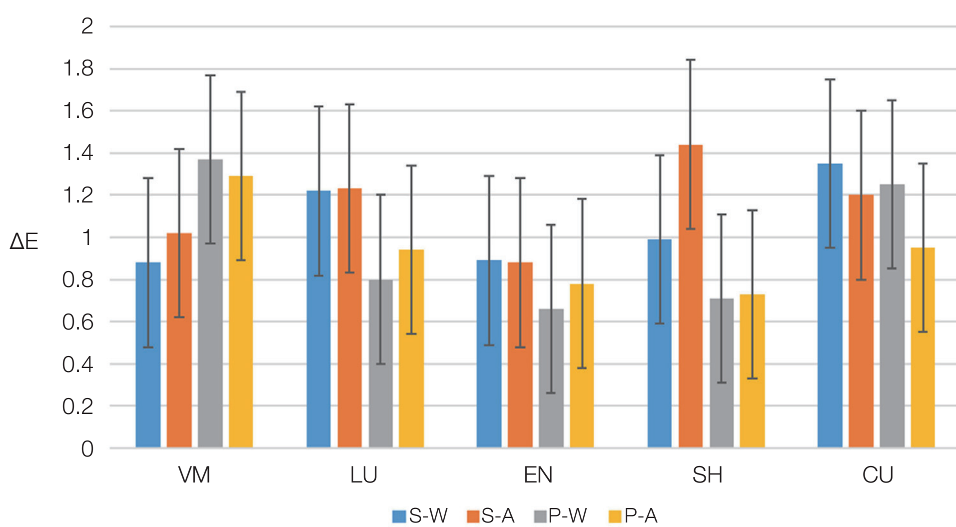

Fig. 1. Overall color change (ΔE) among the study groups.
S: Stain, P: Polish, W: Water, A: Citric acid, VM: Vita Mark II, LU: Lava Ultimate, EN: Vita Enamic, SH: Shofu HC, CU: Crystal Ultra.

ence from CU hybrid ceramic (Table 3). For toothbrush abrasion, among the stained group, each material displayed comparable results except in SH (*P* < .01). On the other hand, the polished group presented no significant difference among the subgroups except in CU (*P* < .010). Likewise, with regards to the storage medium, the comparable outcome was identified except VM specimens in acid (*P* = .02). Hence, tooth

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brushing influenced the color of study materials irrespective of surface treatment and storage medium.

Table 5 presents a comparison among the materials under different surface treatment and storage medium. The highest mean was for VM [69 (0.95)], whereas the lowest mean was shown by CU [56.7 (0.86)]. Toothbrush abrasion significantly influenced lightness in the polished groups among all materials as compared to the stained groups. Moreover, the effect of toothbrush abrasion among stained specimens treated with water was also observed in VM (control) [64 (1.63)] and SH [63.9 (1.49)] materials. Therefore, irrespective of storage medium and type of material, the lightness among polished materials was significantly influenced by toothbrush abrasion.

Among the hybrid materials, a significant difference was observed for lightness ($P < .05$) (Table 6). However, VM [66.17 (1.3)] and SH [66.34 (0.78)] displayed comparable outcome. Under the influence of toothbrush abrasion among hybrid ceramics, the highest loss of lightness was observed in SH materials with a significant reduction in mainly three subgroups; stained water [63.9 (1.49)], polished water [68.9 (0.42)], and polished acid [68.06 (0.34)]. Comparatively, only LU material sustained surface lightness against the toothbrush abrasion except in the polished acid subgroup [67.5 (0.47)], respectively.

Irrespective of the storage medium, each hybrid resin material presented with a significant difference among surface treatment subgroups (Table 6, Fig. 2).

Table 5. Mean, standard deviation among study groups for lightness

Study groups	Stained-water	Stained-acid	Polished-water	Polished-acid	*P* value[$]
VM	64 (1.63)*	62.9 (1.91)	68.8 (0.71)*	69 (0.95)*	< .01
LU	59.5 (1.79)	60.3 (2.26)	67.4 (1.15)	67.5 (0.47)*	< .01
EN	58.2 (1.46)	57.7 (1.1)	65.1 (0.37)*	64.7 (0.42)*	< .01
SH	63.9 (1.49)*	64.5 (0.9)	68.9 (0.42)*	68.06 (0.34)*	< .01
CU	56.7 (0.86)	57.3 (1.7)	63.01 (0.73)*	62.7 (0.41)*	< .01

* denote significant effect of simulated tooth brushing (t test).
[$] showing effect of storage and surface treatment using ANOVA (*P* value).

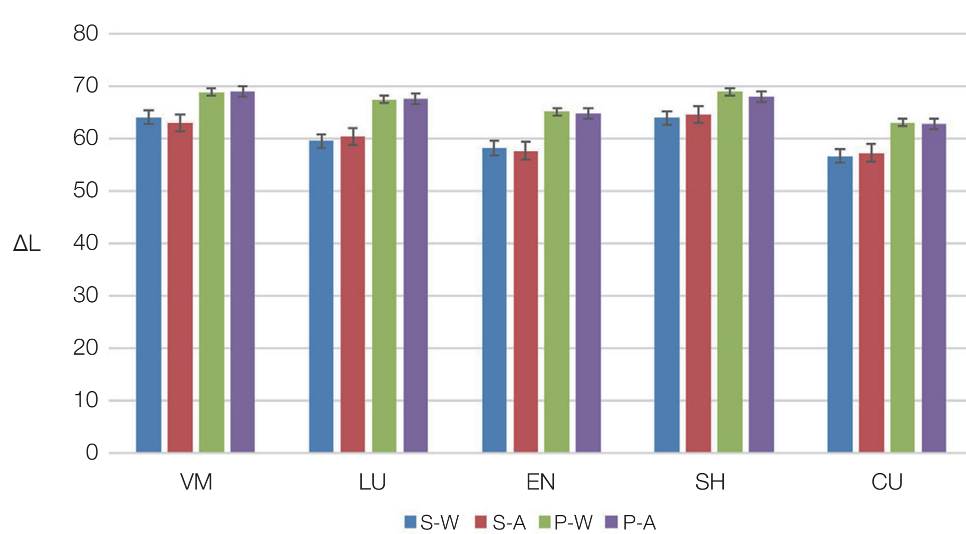

Fig. 2. Loss of lightness (ΔL) of materials among study groups.
S: Stain, P: Polish, W: Water, A: Citric acid, VM: Vita Mark II, LU: Lava Ultimate, EN: Vita Enamic, SH: Shofu HC, CU: Crystal Ultra.

Table 6. Comparison between individual subgroup among the materials for surface lightness

Study groups	VM	LU	EN	SH	CU	*P* value$
Stained-water	64 (1.63)	59.5 (1.79)	58.2 (1.46)	63.9 (1.49)*	56.7 (0.86)	< .01
Stained-acid	62.9 (1.91)	60.3 (2.26)	57.7 (1.1)	64.5 (0.9)	57.3 (1.7)	< .01
Polished-water	68.8 (0.71)	67.4 (1.15)	65.1 (0.37)*	68.9 (0.42)*	63.01 (0.73)*	< .01
Polished-acid	69 (0.95)	67.5 (0.47)*	64.7 (0.42)*	68.06 (0.34)*	62.7 (0.41)*	< .01
Overall	66 (1.3)	63.6 (1.41)	61.42 (0.83)	66.343 (0.78)	59.92 (0.92)	< .01

* denote significant effect of simulated tooth brushing (t test).
$ showing effect of material type using ANOVA (*P* value).

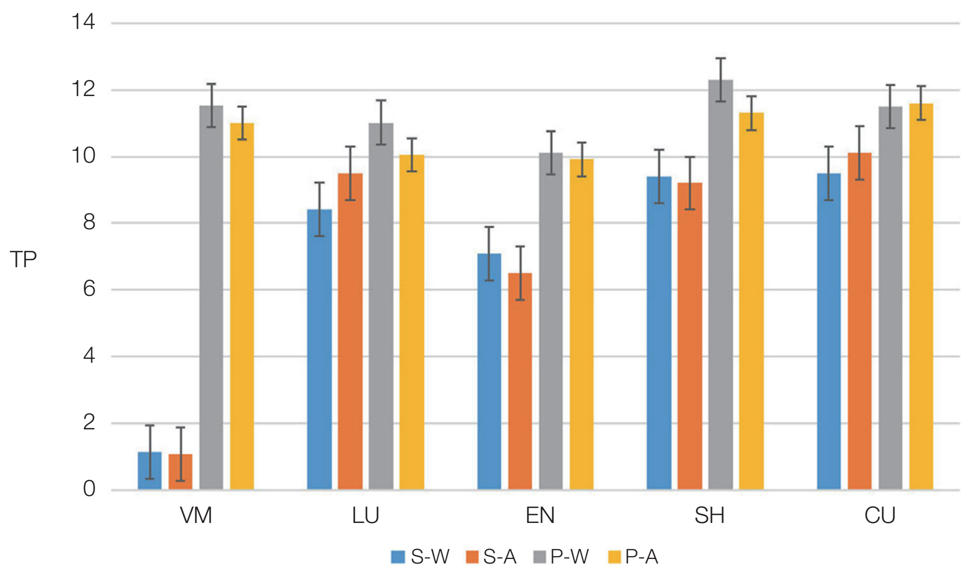

Fig. 3. Translucency comparison among study materials.
S: Stain, P: Polish, W: Water, A: Citric acid, VM: Vita Mark II, LU: Lava Ultimate, EN: Vita Enamic, SH: Shofu HC, CU: Crystal Ultra.

The control (VM) specimens presented the highest mean values compared to the hybrid resin material except in stained acid [62.9 (1.91)] subgroup. Moreover, the highest difference was observed in LU group between the stained water [59.5 (1.79)] and polished water [59.5 (1.79)], whereas comparable results were identified among the polished subgroups. Among similar surface treatments, the effect of the storage medium was not evident.

Table 7 presents a comparison among the materials under different surface treatment and storage medium. The highest mean was noted in SH (polished water) [12.3 (0.52)] specimens, whereas the lowest mean value was shown in EN (stained acid) [6.5 (0.55)] specimens. The influence of toothbrush abrasion was significant among all materials in the polished water subgroups, except for CU [11.51 (0.67)]. Nevertheless, no significant effect of toothbrushing on translucency was observed in the stained water group except for CU [9.51 (0.66)]. Therefore, the influence of surface treatment on the loss of translucency is evident; however, the storage medium did not present a significant difference. A comparison among the hybrid resin materials demonstrated a significant difference (*P* < .05) (Table 8, Fig. 3). The maximum influence of toothbrush abrasion was observed in LU treated with stain-acid [9.5 (1.11)], polished-water [11.02 (0.99)], and polished-acid [10.05 (1.021)], whereas the mini-

Table 7. Mean, standard deviation among study groups for surface translucency

Study groups	Stained-water	Stained-acid	Polished-water	Polished-acid	*P* value$
VM	1.120 (0.41)	1.07 (.200)	11.52 (0.45)*	11.009 (0.41)*	< .01
LU	8.4 (1.76)	9.5 (1.11)*	11.02 (0.99)*	10.05 (1.021)*	< .01
EN	7.09 (1.45)	6.5 (0.55)	10.1 (0.43)*	9.91 (0.37)	< .01
SH	9.4 (1.35)	9.2 (1.07)	12.3 (0.52)*	11.3 (0.65)*	< .01
CU	9.51 (0.66)*	10.1 (0.99)*	11.51 (0.67)	11.6 (0.27)	< .01

* denote significant effect of toothbrush abrasion (t test).
$ showing effect of storage and surface treatment using ANOVA (*P* value).

Table 8. Comparison between individual subgroup among study materials for surface translucency

Study groups	VM	LU	EN	SH	CU	*P* value$
Stained-water	1.12 (0.41)	8.4 (1.76)	7.09 (1.45)	9.4 (1.35)	9.5 (0.66)*	< .01
Stained-acid	1.07 (0.2)	9.5 (1.11)*	6.5 (0.55)	9.2 (1.07)	10.1 (0.99)*	< .01
Polished-water	11.52 (0.45)*	11.02 (0.99)*	10.1 (0.43)*	12.3 (0.52)*	11.51 (0.67)	< .01
Polished-acid	11.009 (0.41)*	10.05 (1.021)*	9.91 (0.37)	11.3 (0.65)*	11.6 (0.27)	< .01
Overall	6.1 (0.36)	9.7 (1.22)	8.4 (2.8)	10.55 (0.89)	10.66 (0.64)	< .01

* denote significant effect of simulated toothbrushing (t test).
$ showing effect of material type using ANOVA (*P* value).

mum value was observed in EN (polished water) [10.1 (0.43)]. Tukey post hoc test demonstrated a significant difference between VM [6.1 (0.36)], EN [8.4 (2.8)], and LU [9.7 (1.22)]. However, there was no difference between SH [10.55 (0.89)] and CU [10.66 (0.64)] (Table 8).

With regards to the storage mediums, hybrid resin materials demonstrated a higher loss of translucency in stained groups compared to the control (VM). The highest mean was observed in CU [10.1 (0.99)] with stain and acid treatment, whereas the lowest translucency was observed in EN with stain and acid treatment [6.5 (0.55)]. Likewise, among the polished groups, the highest value was observed in SH [12.3 (0.52)] polished water, whereas the lowest translucency was found in EN specimens treated with polish and acid [9.91 (0.37)]. Regardless of the surface treatment employed, EN showed the lowest translucency when treated with acid erosion. Thus, polishing showed significant improvement in translucency for all material groups, but the use of storage mediums (water or acid) did not exhibit a significant influence on the translucency of tested materials.

DISCUSSION

The present study evaluates the effect of toothbrush abrasion and acidic storage on color, translucency, and lightness of resin infiltrated hybrid ceramic in comparison to a feldspathic ceramic. The color change investigation in the present study rendered that, irrespective of the surface treatment and storage medium, the influence of toothbrush abrasion was partially evident (in EN compared to VM and CU). However, with respect to translucency and lightness, the surface treatment influence was significant under toothbrush abrasion irrespective of storage medium and type of material. Therefore, the hypothesis was accepted.

Authors have reported that optical properties, particularly translucency, influences the color perception of materials.[16] It is reported that extrinsic factors compromise the esthetic properties of polished and unpolished material surfaces.[17] Many investigators have correlated the optical properties with the surface roughness and surface stain.[17] In addition, the smooth surface of materials is reported to be directly proportional to surface light reflection and scattering, which contributes to the optical properties. A previous study[17] reported that the composition of materials and type of surface treatment employed influence the surface smoothness and resist the surface degradation over a period. It is known that color perceptions are influenced by critical factors including material's surface texture, shade (lightness), illumination conditions, and instrumental differences in color matching.[17,18] Comparison of hybrid resin ceramics used in the present study showed no significant color change irrespective of surface treatment and storage medium. However, translucency and lightness presented a significant difference among the materials with respect to surface treatment. A multitude of explanations is available for the study findings related to color change, loss of translucency, and lightness for the tested hybrid resin ceramics.

Many studies have shown that surface texture is a critical factor that affects the optical property and color perception of dental restoration.[18-20] The smooth surface plays an important role in diverting the light pathway that reflects at the same angle as it strikes the surface. This phenomenon is known as specular reflection.[21,22] Complex interaction of the oral cavity fluids (acidic medium), and mechanical factors (tooth abrasion) often roughens the surface, which results in diffuse reflection of light in different directions. Composite resin for decades has demonstrated low resistance to wear, whereas ceramics have shown excellent mechanical properties. Infiltrating glassy matrix with polymers locks the resin particles in the glass matrix, preventing it from degradation and softening. Moreover, studies have shown that the composite filler size, type, monomer content, and amount of the fillers influence the transmission of light.[21,23] The smaller size of the fillers compared to the light wavelength is less likely to scatter, absorb, and reflect light, leading to high translucency. A different author[22] observed that the inorganic filler content was directly proportional to loss of translucency. The present study reported similar findings, presenting the inorganic filler content to be maximum in SH followed by CU, LU, EN, and VM (the least).

Several studies have supported the theory of difference in refractive index between filler particle and matrix, which affects the light transmission characteristics in materials.[22,23] The maximum reflection occurs if the ceramic particles are slightly larger than the wavelength; thus, a higher refractive index leads to a greater amount of opacity.[23] Thus, the present study justified that hybrid ceramic materials with smaller size ceramic demonstrate higher translucency potential. Moreover, it has been reported that[23] a combination of tooth abrasion and fluctuating oral environment alters the surface texture. The porous and roughened surface affects the refraction of the light exhibiting a mismatched refractive index between the ceramic and resin fillers; hence, it reduces the translucency and perception of the observed color. The present study displayed the minimum loss of translucency in EN group compared to the other hybrid ceramics considerably due to the highly uniform distribution of the ceramic fillers (86%) that establishes flat surface texture. Moreover, a positive relationship is reported between the total refractive index and the thickness of the material.[23,24] A different author[15] reported that based on Lambert's law, altering the thickness of ceramic restoration alters the light transmission behaviour that changes the color perception of the dental restoration. Therefore, clinically, the increase in the thickness of the restoration was related to decreased translucency and overall color change of hybrid ceramic restoration.

The present study utilized a standard simulated brushing technique to represent the normal oral hygiene procedures that included the applied force, distance, and frequency of brushing on the samples. Authors have suggested that using large abrasive dentifrice not only is responsible for the abrasion but demonstrates a publishable action.[25] However, the increased number of brushing cycles eventually removes the matrix rich layer that is responsible for the color change.[25] Literature has reported that water absorption plays an important role in susceptibility to loss of translucency, lightness, and color change.[26] Therefore, the abraded surface exposes the resin-rich layer containing larger particles that raise the water sorption capacity, a phenomenon known as composite plasticization.[27,28] Water absorption expands and plasticizes the organic matrix, which reduces the du-

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rability of the composite resin in the material and promotes color change. Furthermore, this promotes the diffuse light reflection and solubility of internal components, leading to loss of translucency and lightness along with color change. The residual porosities and micro-cracks also act as a carrier for fluid transport and dye penetration, which stimulates the water absorption.[25] Hence, the present study supports these findings of previous studies determining CU to present with the highest color change due to large particle size compared to LU with nanoparticles.[27,28] Nevertheless, the results between the storage medium groups were comparable. Therefore, it was established that the pH (citric acid storage) does not influence the color change compared to the distilled water storage. In addition, surface topography can be correlated to the amount of color and translucency alteration for resin infiltrated ceramics, the present study did not assess the material surface morphology. Therefore further studies are recommended in this regard.

The present study complies with the previous studies demonstrating the effect of toothbrush abrasion on translucency (LU groups) and lightness (SH and CU groups); however, the color change was observed more in stained specimens compared to the polished among the hybrid ceramics.[5,7] According to a previous study,[18] the stained ceramic surface showed resistance to toothbrush abrasion over a 10 to 12 years period. Moreover, color changes appear within materials consisting of hydrophilic content like Bis-GMA, UDMA, and TEGDMA due to susceptibility to abrade and reabsorb. Therefore, in the authors' opinion, greater color change in CU (30% mixture of UMDA and Bis-GMA), SH (39% TEGDMA and UDMA), and LU 20% TEGDMA) was observed.[26] Thus, consistent polishing and staining of the material establishes a homogenous surface that is resistant to wear and exhibits color stability. Therefore, staining and polishing are critical and are recommended clinically for hybrid resin infiltrated ceramics.

Considering the oral environment, apart from tooth abrasion, food coloring and personal habits such as smoking and drinking could account for surface staining of the materials that influence these properties. Most of the staining is superficial, which is likely to be removed through brushing. However, vigorous brushing may damage the surface and worsen the discoloration and opacity of the restoration. In addition, the study was conducted using distilled water/ citric acid medium, which lacks oral environment enzymes and chromogenic bacteria contributing to color change, loss of lightness, and translucency. Nevertheless, this was not taken into account during the investigation in the present study. Moreover, the prospect of thickness was also not taken into consideration as many studies have highlighted its effects on material translucency and lightness.[12,17] Therefore, studies investigating the effects of coloring agents, chromogenic bacteria, and impact of varying material thickness on the optical properties of hybrid resin ceramics are recommended.

CONCLUSION

The comparison among the hybrid resin ceramic and glass-ceramic materials presented a significant effect of toothbrush abrasion on translucency and lightness of the hybrid resin ceramics. However, the color change was not significantly influenced irrespective of the storage medium employed. Compared to the polished surface, the surface staining demonstrated preservation and stability of the surface color and optical properties under the influence of toothbrush abrasion and the chemical trauma.

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