COLOR STABILITY AND FRACTURE RESISTANCE OF LAMINATE VENEERS USING DIFFERENT RESTORATIVE MATERIALS AND TECHNIQUES

Shereen M El Sayed,* Rasha Ramadan Basheer ** and Sherif Fayez Ahmed Bahgat ***

ABSTRACT

Objectives: The aim of this study was to examine the color stability and fracture resistance of laminate veneers constructed by indirect hybrid all ceramic material, indirect all-ceramic material and direct nanohybrid composite material.

Materials and Methods: A maxillary right central incisor in a student typodont was selected. Incisal lap preparation for esthetic laminate veneers was done. Impression of the prepared tooth was taken and poured into epoxy resin material to obtain epoxy resin dies. Forty five epoxy resin dies were randomly divided into three equal groups (n=15) according to the materials used for construction of the laminate veneers: Group I: Fifteen ceramic laminate veneers constructed form dental hybrid ceramic (Vita Enamic, VITA Zahnfabrik, Germany); Group II: Fifteen ceramic laminate veneers constructed from lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent AG Schann, Liechtenstein); Group III: Fifteen composite laminate veneers constructed from nanohybrid composite (IPS Empress Direct, Ivoclar Vivadent AG Schann, Liechtenstein). Each group was further subdivided into three equal subgroups (n=5) according to the immersion media used: Subgroup A: Tea, Subgroup B: Coffee, Subgroup C: Coca-cola. Vita Enamic and IPS e.max CAD veneers were constructed using CAD/CAM technology. IPS Empress Direct composite was applied directly on the epoxy resin dies. Color measurements were done before and after the immersion cycles using spectrophotometer (Vita Easyshade) and ΔE values were calculated. Fracture resistance testing was done for all specimens of the three groups (n=45) using a universal testing machine. Data were then collected, tabulated and statistically analyzed.

Results: Regarding color stability, the Empress Direct composite showed the highest ΔE values (9.53 ± 0.41) followed by Vita Enamic (7.95 ± 0.36) while IPS e.max CAD showed the least ΔE value (7.29 ± 0.32). Regarding the immersion media, the Coffee showed the higher ΔE values (9.67 ± 0.43) followed by Tea (7.98 ± 0.38) while the Coca-Cola showed the least ΔE value (7.16 ± 0.29). Concerning the fracture resistance, the Vita Enamic showed the highest fracture resistance values (255.35 ± 7.72 N) followed by IPS e.max CAD (244.42 ± 8.61 N) while IPS Empress Direct resin composite showed the least fracture resistance value (159.20 ± 8.04 N).

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**Conclusions:** Within the limitations of this study, it can be concluded that: Nanohybrid composite veneers are more susceptible to discoloration than the hybrid ceramics and lithium disilicate glass ceramics. Coffee among the three tested immersion solutions has the highest ability to stain all the tested laminate veneer materials. Lithium disilicate glass ceramics and hybrid ceramics are more suitable than direct nanohybrid composite in laminate veneers construction as they are more durable in terms of fracture resistance.

**KEYWORDS:** Vita Enamic, Empress Direct, IPS e.max CAD, hybrid ceramic, lithium disilicate ceramic, CAD/CAM, color stability, fracture resistance.

**INTRODUCTION**

The success and longevity of any intra-oral restoration are related to the fulfillment of three main criteria of strength, fit and esthetics \(^{(1,2)}\). Patient’s aesthetic demands and expectations in addition to the new material choices and manufacturing techniques are main factors behind selection of the material when restoring teeth \(^{(3)}\). Laminate veneers are considered as one of the conservative methods of restoring the discolored, pitted or fractured anterior teeth \(^{(4,5)}\). The challenge with laminate veneers is to achieve ideal esthetics including color matching and subsequent color stability \(^{(5)}\). Thus, the ideal color match to the adjacent tooth is mandatory not only at the time of insertion of the restoration but also over a long period of time \(^{(6)}\).

Laminate veneers can be constructed not only using various techniques whether direct or indirect but also using several restorative materials extending from the resin composite up to various types of ceramics. The brittle nature of ceramic materials and the large shrinkage which occurs during processing have led to the shift to the polymeric/composite counterparts. However, the tendency for gradual discoloration of polymeric dental materials has been reported \(^{(7)}\).

Furthermore it was reported that one of the factors that might influence esthetics under clinical conditions is the discoloration that may occur over time when subjected to various media such as tea, coffee, coca-cola, chlorohexidine or bleaching agent \(^{(5,8)}\). Several studies have been done to evaluate the color stability of composite restorations and it has been proven that composite resins are vulnerable to color changes over long periods of time \(^{(1)}\). However, composite laminate veneer is still one-visit treatment option for esthetic restorations.

Although ceramics are considered to be color stable, discoloration of esthetic restorations whether ceramics or composites may occur due to intrinsic or extrinsic factors. Intrinsic factors include changes within the material itself, while extrinsic factors involve adsorption or absorption of stains from the oral cavity. The smoothness of the surface of the restoration is one of the factors affecting extrinsic staining \(^{(1)}\). Additionally, according to the literature, color stability has been proven to be dependent on many factors, among which the brand and shade of the restorative material, exposure time and intensity of different food and beverages intake and finishing techniques \(^{(9)}\).

To date the group of glass ceramics is still offering the best esthetic characteristics including optimal light transmission, high translucency and natural tooth-like restorations \(^{(2)}\). A significant improvement in clinical performance was observed by lithium disilicate glass ceramic machinable restorations including high flexural strength and very appealing translucency \(^{(10)}\). With the introduction of the IPS e.max, the translucency was further improved as a result of development of its crystalline volume and refractive index \(^{(5)}\).

Recently, an innovative hybrid ceramic material has been introduced in the market. This hybrid material combines the characteristics of a ceramic and a composite. It is composed of a porous ceramic
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matrix with the pores being filled with a polymer material. In addition to a high degree of elasticity, this hybrid ceramic ensures high strength after adhesive bonding, therefore enabling the reduction of wall thicknesses for minimally-invasive restorations. Moreover, this tooth-colored material offers material properties that are almost identical to those of natural teeth including excellent light conductivity.

One of the most commonly used materials for construction of direct laminate veneers is the nanohybrid composites in which the esthetics of the ceramic was combined with the convenience of composites. The development of the nanoscaled fillers offers the advantage of great esthetics, exceptional polishability and high strength.

Since one of the important criteria for the success of esthetic material is the color stability, therefore assessment of color changes using color measuring devices such as colorimeters and spectrophotometers have become popular. They offer accuracy, standardization and numerical expression of color. The data is reported in the CIE L*a*b* system which uses three-dimensional colorimetric measurements: L* measures the brightness of the color, a* measures the red-green content, and b* measures the yellow-blue content. Then the color changes (∆E) are calculated using L* a* b*. The color changes (∆E) reveals whether a change in overall shade can be detected by a human observer. Several studies considered color differences greater than 3.5 unit clinically unacceptable.

Many studies have been done on color stability of different esthetic restorative materials in several commonly used beverages. Some of the researchers show that changes in color stability are greatest in tea, others showed coffee to have the most significant effect in color changes. Hence, the aim of this study was to evaluate the color stability of three different aesthetic restorative materials used for construction of laminate veneers after exposure to three commonly consumed beverages. The effect of different beverages on the newly introduced hybrid ceramic material with ceramic and polymer networks in comparison to commonly used lithium disilicate and nanohybrid composite was fully studied. The null hypotheses were: 1. laminate veneers constructed from hybrid ceramics and lithium disilicate would not change color after exposure to different beverages. 2. Laminate veneers constructed from nanohybrid composite would change color after exposure to different beverages.

Furthermore, according to literature the most commonly reported failure modes with laminate veneers are either fracture or debonding. However, fractures of laminate veneers represented 67% of the total failures over 15 years period of clinical performance.

As there is little information available in the literature on the survival rates of different laminate materials, with no evidence whether indirect laminates are better than direct ones, it seemed of value to evaluate the fracture resistance of the three aforementioned aesthetic restorative materials used for construction of laminate veneers. The null hypothesis was: Laminate veneers constructed from hybrid ceramics and lithium disilicate would have the highest fracture resistance and laminate veneers constructed from nanohybrid composite would have the lowest fracture resistance.

MATERIALS AND METHODS

A maxillary right central incisor in a student typodont (Frasaco, TeHnang, Germany) was selected. Incisal lap preparation for ceramic laminate veneers was done with 1.5mm incisal edge reduction, 0.7mm labial reduction extended to proximal contact area, and a chamfer finish line extended 1.5mm lingual to the incisal edge on the palatal surface.

Impression of the prepared tooth was taken using addition silicon impression material (Imprint II, 3M ESPE, St.Paul, MN, USA). The impression was poured into epoxy resin material (Chema poxy150, CMB chemicals, Egypt) to obtain epoxy resin die. This procedure was repeated for forty five times to
obtain forty five epoxy resin dies. Epoxy resin dies were left for 24 hours to ensure complete setting and then separated from the silicon impression material, and checked for any imperfections using magnification loupes (Zeiss EyeMagPro, 5X-300, Carl Zeiss Meditec AG, Germany)

**Samples grouping:**

The forty five epoxy resin dies were randomly divided into three equal groups (n=15) according to the materials used for construction of the laminate veneers: Group I: Fifteen ceramic laminate veneers constructed form dental hybrid ceramic (Vita Enamic, VITA Zahnfabrik, Germany); Group II: Fifteen ceramic laminate veneers constructed from lithium disilicate glass ceramic (IPS e.max CAD, Ivoclar Vivadent AG Schann, Liechtenstein); Group III: Fifteen composite laminate veneers constructed from nanohybrid composite (IPS Empress Direct, Ivoclar Vivadent AG Schann, Liechtenstein). Each group will be further subdivided into three equal subgroups (n=5) according to the immersion media: Subgroup A: Red tea; Subgroup B: Coffee; Subgroup C: Coca-Cola.

**TABLE (1) Samples’ grouping:**

<table>
<thead>
<tr>
<th>Subgroups (Immersion solutions)</th>
<th>Group I Vita Enamic</th>
<th>Group II IPS e.max CAD</th>
<th>Group III IPS Empress Direct resin composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgroup A: Tea (n=5)</td>
<td></td>
<td>Subgroup A: Tea (n=5)</td>
<td>Subgroup A: Tea (n=5)</td>
</tr>
<tr>
<td>Subgroup B: Coffee (n=5)</td>
<td></td>
<td>Subgroup B: Coffee (n=5)</td>
<td>Subgroup B: Coffee (n=5)</td>
</tr>
<tr>
<td>Subgroup C: Coca-Cola (n=5)</td>
<td></td>
<td>Subgroup C: Coca-Cola (n=5)</td>
<td>Subgroup C: Coca-Cola (n=5)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>45 samples</td>
</tr>
</tbody>
</table>

**TABLE (2) Chemical composition and manufacturers of the materials used in this study.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental hybrid ceramic</td>
<td>Ceramic part: 86% wt. SiO₂ (58 – 63%), Al₂O₃ (20 – 23%), Na₂O (9-11%), K₂O (4-6%), B₂O₃ (0.5-2%), ZrO₂ (&lt;1%), KaO (&lt;1%).</td>
<td>VITA Zahnfabrik, Germany</td>
</tr>
<tr>
<td>Vita Enamic</td>
<td>Polymer part: 14 % wt (UDMA, TEGDMA).</td>
<td></td>
</tr>
<tr>
<td>Lithium disilicate glass ceramic</td>
<td>57–80% SiO₂, 11-19% Li₂O, K₂O, MgO, Al₂O₃, P₂O₅ and other oxides.</td>
<td>Ivoclar Vivadent AG Schann, Liechtenstein</td>
</tr>
<tr>
<td>IPS e.max CAD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nanohybrid IPS Empress</td>
<td>UDMA(10-25%), Bis-GMA(2.5-10%), TEG-DMA(2.5-10%), barium glass, ytterbium trifluoride, mixed oxide, silicon dioxide and copolymer (52-59%).</td>
<td>Ivoclar Vivadent AG Schann, Liechtenstein</td>
</tr>
<tr>
<td>Direct composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total etch Variolink</td>
<td>Dimethacrylates, Inorganic fillers, Ytterbium trifluoride, Catalysts and stabilizers, Pigments.</td>
<td>Ivoclar Vivadent AG Schann, Liechtenstein</td>
</tr>
<tr>
<td>veneer adhesive resin cement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cola. Samples’ grouping is illustrated in table (1), chemical composition and manufacturers of the materials used in this study are presented in table (2).

**Ceramic laminate veneers fabrication (Groups I, II):**

Impression of the previously prepared typodont tooth was done using polyvinyl siloxane impression material (Imprint II, 3M ESPE, Germany). An extra hard type IV special stone material (special stone CAM base VITA dentonapident) was poured inside the impression according to manufacturer instructions to obtain special stone model ready for scanning. The stone model was scanned in the inLab scanner (CerecinLab, Sirona Dental Company, Germany) and the image of the scanned prepared tooth appeared on the screen. The acquired image was transferred to the CAD software for the designing step. Laminate veneer design was selected in the CAD/CAM software (InLab 3D version 2.90, Sirona Dental Company, Germany) where all parameters were set. After selection of the required anatomy and the extensions for the laminate veneers, the thickness of the veneer was adjusted to be 0.7mm labially and 1.5mm incisally. The design was saved to be ready for the milling step. The laminate veneers were milled in the CAD/CAM milling machine (Sirona CerecinLab MC XL milling machine) after choosing the type of the block.

Fifteen ceramic laminate veneers were constructed using Vita Enamic blocks, shade A₂ (Group I). After milling, finishing and polishing were done according to manufacturer instructions without any sintering or crystallization. IPS e.max CAD blocks, shade A₂ were used to mill fifteen laminate veneers (Group II). After milling, the veneers were crystallized in an Ivoclar Vivadent ceramic furnace (Programat P500) according to manufacturer instructions.

**Cementation of ceramic laminate veneers (Groups I, II):**

The fitting surface of all ceramic laminate veneers of groups I and II was etched with 5% hydrofluoric acid (IPS Ceramic etching gel, Ivoclar, Vivadent) for 20 seconds, rinsed off then cleaned in ultrasonic bath for three minutes. Silane coupling agent (Variolink S bond; Ivoclar Vivadent) was applied to the fitting surface of the veneer and allowed to dry for one minute then dispersed to obtain a thin coat. Freshly mixed resin cement (Variolink; Ivoclar Vivadent) was applied on the fitting surface of each laminate veneer and was seated on the epoxy model using finger pressure. Excess cement was removed and the resin cement was light cured for 60 seconds from the palatal surface then from the labial surface Figure (1).

**Composite laminate veneer fabrication (Group III):**

Vacuum forming thermoplastic template sheet was used to fabricate a template over the previously cemented IPS e.max CAD laminate veneers. This was done to standardize the thickness of the composite veneers with the same thickness of the ceramic veneers. Figure (2)

IPS Empress Direct resin composite, shade A₂, was applied inside the previously constructed template which was placed over the epoxy resin after
the application and light curing of the bonding agent (Solobond M, Voco, Germany) according to manufacturer instructions. The excess resin composite was removed before curing. The veneer was light cured for 20 seconds on each side using light curing unit (Mini LED, 1250mW/cm², Satelec, Acteon). Composite laminate veneers were polished using abrasive discs for 10 seconds (Soflex, 3M, ESPE, St.Paul, MN, USA).

Color measurements:

All the specimens were stored in distilled water for 24 hours in an incubator (Future Tech. Digital incubator, f120, China) at 37°C before the baseline color measurement. Baseline colors of all specimens were measured with a spectrophotometer (Vita Easyshade, Ivoclar VivadentAG, Schaan, Liechtenstein) \(^{(23, 24)}\) using the CIELAB scale and L*, a*, b*. The measurements were done over a white background in the same lightening conditions. The probe tip of the Vita Easy shade was placed on the central part of the laminate veneer and the color was measured. The spectrophotometer was recalibrated after color data collection of each group. The probe tip was firmly placed in the calibration part and held steadily in place until a beep was heard to indicate that calibration was completed.

The epoxy resin was lubricated using glycerine in order not to exhibit color change during the immersion cycles. After baseline color measurement, each group of laminate veneers was randomly subdivided and the veneers were subjected to different immersion solutions (Tea, Coffee, Coca-cola). Immersions were carried out twice daily for ten minutes at room temperature for thirty days. After each immersion process, the veneers were washed with distilled water and then stored in artificial saliva at room temperature in the intervals between the cycles. The immersion solutions were renewed after each application. In subgroup A, the veneers were immersed in a tea solution. The tea solution was prepared by dipping a tea bag in boiling distilled water five times. In subgroup B, the veneers were immersed in coffee. The coffee solution was prepared by adding 5 gm of coffee to 200 mL of boiling distilled water. In subgroup C, the veneers were immersed in 4°C cold coca-cola.

After thirty days of immersion cycles, the veneers were rinsed with distilled water for five minutes and blotted dry with absorbent tissue paper before the final color measurements. The color values of each specimen were remeasured using the same spectrophotometer and the color change values (ΔE) was calculated by the following equation:

\[
\Delta E = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}
\]

L* stands for lightness, a* for green-red and b* for blue-yellow.

ΔL*, Δa*, Δb* correspond to the differences before and after immersion cycles.

All color measurements were performed three times for each specimen and the average of the three readings were calculated. All the color measurement procedures were done by the same operator.

Fracture resistance testing

For fracture resistance testing, each of the forty five samples of bonded laminate veneers from the three tested aesthetic restorative materials (Vita Enamic, IPS e.max CAD and IPS Empress Direct resin composite) was embedded in a block of acrylic resin of 3 cm x 4 cm x 3 cm dimensions. The block was placed in a specially constructed jig to allow
the load to be applied at an angle of 135° during fracture test to simulate the clinical situation (19).

All samples were individually mounted on a computer controlled materials testing machine (Model 3345; Instron Industrial Products, Norwood, MA, USA) with a loadcell of 5kN and data were recorded using computer software (Instron® Bluehill Lite Software). Samples were secured to the lower fixed compartment of the testing machine by tightening screws. Fracture test was done by compressive mode of load applied at 135° angle (through housing the sample in the specially designed 45° angle jig) to the lingual portion of the laminate veneers using a metallic rod with flat tip (5 mm diameter) attached to the upper movable compartment of testing machine traveling at cross-head speed of 1mm/min. Figure (3). The load at failure manifested by an audible crack and confirmed by a sharp drop at load-deflection curve recorded using computer software (Instron® Bluehill Lite Software). The load required to fracture was recorded in Newton.

**Statistical Analysis**

Data presented as mean and standard deviation (SD) values. Data explored for normality using D’Agostino-Pearson test for normal distribution. ∆E and fracture strength (N) showed normal distribution, so One-Way ANOVA between different materials within each immersion medium and vice versa. The significance level was set at P ≤ 0.05.

Table (3) Means and standard deviations (SD) of ∆E for different groups.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Empress Direct Composite</th>
<th>Vita Enamic</th>
<th>IPS e.max CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>∆E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>9.44A&lt;sup&gt;B&lt;/sup&gt;</td>
<td>0.38</td>
<td>7.78B&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>Coffee</td>
<td>10.36A&lt;sup&gt;A&lt;/sup&gt;</td>
<td>0.60</td>
<td>9.58A&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Coca Cola</td>
<td>8.92A&lt;sup&gt;B&lt;/sup&gt;</td>
<td>0.25</td>
<td>6.50C&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Means with the same upper case letter within each column indicates a non-significant difference at p≤0.001
*Means with the same lower case letter within each row indicates a non-significant difference at p≤0.001
For each material, the results showed a statistically significant difference between all the tested immersion media where the Coffee showed the higher ∆E values (9.67 ± 0.43) followed by Tea (7.98 ± 0.38) while the Coca-Cola showed the least ∆E value (7.16 ± 0.29) with one exception in the Empress Direct composite group where there was no statistically significant difference between Tea and Coca-Cola.

2. Effect of different Variables on mean Fracture resistance (N)

Means and standard deviations (SD) of fracture strength (N) for different materials presented in table (4) and figure (6). The results showed a statistically significant difference between Empress Direct composite (159.20±8.04 N) and the two other groups while there was no statistically significant difference between Vita Enamic (255.35±7.72N) and IPS e.max CAD (244.42±8.61 N).

<table>
<thead>
<tr>
<th>Materials</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Empress Direct Composite</td>
<td>Mean: 159.20</td>
<td>SD: 8.04</td>
<td>Vita Enamic</td>
<td>Mean: 255.35</td>
<td>SD: 7.77</td>
<td>IPS e.max CAD</td>
<td>Mean: 244.42</td>
</tr>
<tr>
<td>p-value</td>
<td>≤0.001</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Means with the same letter within each row indicates a non-significant difference at p≤0.001
and IPS e.max CAD (244.42±8.61N) where Enamic showed a slightly higher mean fracture strength value.

**DISCUSSION**

Color stability is an important esthetic parameter for tooth colored restorations (25). The susceptibility to staining of laminate veneers has gained a great interest in numerous studies (17,26-28). Electronic color measuring devices such as colorimeters and spectrophotometers have become a popular method for assessing such discoloration (6,29,30). These devices eliminate the human eye subjectivity and assure standardization with numerical expression of color (31). Thus this study aimed to examine the color stability of laminate veneers constructed from newly introduced materials using clinically applied spectrophotometer device (Easyshade).

Coffee, tea and coca cola were selected as immersion solutions because they are considered among frequently consumed beverages. The design of our tested samples was chosen to be clinically simulating veneers that were bonded to epoxy resin dies and were exposed to immersion solution. The aim of this study was to compare the staining potential of the tested materials hence the samples were not exposed to any polishing or brushing after the 30 days immersion cycles.

The immersion cycles were selected to be 10 minutes twice daily for 30 days inorder to simulate the brief contact of laminate veneers to tea, coffee and coca-cola before being washed away with saliva. Between the immersion cycles the veneers were kept in artificial saliva to simulate the neutralizing effect of saliva.

Based on the color stability results of this study the first null hypothesis was rejected while the second null hypothesis was confirmed. IPS e.max CAD and Vita Enamic revealed color change after exposure to different beverages. However, IPS e.max CAD veneers exhibited the best color stability values in this study (ΔE= 7.29 ± 0.32) followed by Vita Enamic veneers (ΔE= 7.95 ± 0.36) although there was no significant difference between them. Nano hybrid composite veneers showed the least color stability values (ΔE= 9.53 ± 0.41) for all the three beverages used with statistically significant difference between them and the other two materials.

The insignificant difference between the IPS e.max CAD and Vita Enamic samples may be attributed to the fact that the Vita Enamic contains 86% ceramic filler in addition to the high degree of conversion of the resin polymer may render the material to act more like a ceramic material than a resin material (12).

The color change of the hybrid ceramic may be attributed to their composition where the pores of the structured sintered ceramic matrix were filled with a polymer material rendering it a hybrid material with dual network structure. The polymer network is composed of a mixture of triethylene glycol dimethacrylate (TEGDMA) and hydrophobic urethane dimethacrylate (UDMA). TGDMA exhibited a degree of water absorption thus allowed the penetration of the hydrophilic colorant into the resin matrix (32). Therefore Vita Enamic hybrid ceramic was able to show discoloration within the three types of immersion solutions used. Acar et al (33) confirmed the previous assumption as they
concluded that there was color change for the hybrid ceramic samples when exposed to hot and cold coffee.

Both Empress Direct composite and Vita Enamic contain UDMA and TEGDMA in their composition, however there was a statistically significant difference between them and the Empress Direct exhibited higher ΔE values. This may be presumably due to the percentage of the ceramic filler compared to the resin matrix. For the Vita Enamic veneers the filler percentage is 86% and 14% resin opposed to 55% filler and 45% resin in the Empress Direct, thus the resin is responsible for fluid absorption leading to hydrolysis of the interface between resin and filler causing detachment of the fillers which accounts for most of the color change (34).

Not only the filler/resin ratio is better in Vita Enamic but also the type of the resin that may contribute to the color change, as some resin monomers can be classified as stain resistant and others as non-stain resistant. UDMA is a hydrophobic monomer rendering it more stain resistant whereas TGDMA exhibits a degree of water absorption thus allows penetration of the hydrophilic colorant into the resin matrix. BIS-GMA is the worst stain resistant monomer (8), UDMA weight percentage found in Enamic is 66% while that of TEGDMA is 33% with no BIS-GMA opposed to 25% UDMA and 20% mixture of TEGDMA and BIS-GMA (12,13) in Empress Direct. This is consistent with the conclusion of Bagher et al (35) that water absorption of BIS-GMA based resin was increased from 3-6% upon increasing TEGDMA proportion from 0 to 1%.

The mechanism of color change in composite resin has been discussed previously and related to several factors. Extrinsic and intrinsic discoloration has been reported in the color change process of composite resin (36). Intrinsic discoloration has been related to the chemical composition of the resin matrix and degeneration of the bond between the matrix and the filler (37). This is usually affected by initiators, inhibitor agents, filler and monomer types and the degree of conversion (38). Kheraif (39) declared that the degree of polymer conversion and proper polymerization can affect color stability as the residual monomer can lead to the formation of colorimetric degradation products and lead to penetration of solvents into the polymeric network (25). On the other hand, extrinsic factors are related to adsorption or absorption of extrinsic stains from colored food or drinks and are affected by surface roughness, integrity and polishing regime (8).

Previous color stability studies (37,40-43) revealed that different drinks, food and mouth rinses might have varying degrees of staining on different restorative materials. However, the staining degree of these drinks or food differs according to their composition and properties in addition to the finishing and polishing quality of the restorative materials used.

In the present study the color change values were dependent on the immersion solutions and the staining increased in an ascending order with the coca cola, tea and coffee within all the tested materials. The coffee exhibited the highest ΔE values due to absorption and adsorption of colorants into the organic part of the material and compatibility of the polymeric materials with the yellow colorants present in coffee (8,25). On the other hand discoloration by tea may be due to adsorption only of the yellow colorants on the surface. Alkheraif et al (25) and Um and Ruyter (44) supported the previous explanation. As regard to coca cola the lack of yellow colorant may be the cause for the least values of the color change. These results were in agreement with Bagheri et al (35) and Alkheraif et al (25) who concluded that coffee and tea caused more discoloration than coca cola. In addition, Tuncer et al (45) reported that although the cola with the lowest PH values might cause damage to the surface integrity of resin composite materials, yet it caused lower discoloration than coffee due to the lack of yellow colorant.
The use of the epoxy resin dies is considered a limitation within this study as they might have affected the results through their influence as a background to the veneers. This may give a logic explanation to the high ΔE values in this study for all the groups which was mostly noticed with the translucent IPS e.max CAD veneers.

It is hard to relate the results of this study to the clinical conditions as the color stability of restorative materials cannot be related to a single beverage but it is the consequence of complex reaction of different chemicals for different food, drinks and mouth rinses. However, the results of this study can give an idea about the performance of different laminate veneer materials upon exposure to different beverages. Thus dentists may inform the patients about the negative effects of these beverages on their veneers and the need for further repolishing, reglazing or even replacement. This would affect also the clinicians’ choice of the restorative materials according to the dietary habits of the patients.

Further investigations are needed to assess the effect of polishing and glazing of the discolored composite and ceramic laminate veneers on the improvement of the discoloration.

A variety of dental materials used for laminate veneer restorations whether direct or indirect showed technical advantages and disadvantages for each technique. This variety offers many alternatives according to indications and contraindications for each situation intraorally. Thus the aim of the fracture resistance test was to examine the fracture process which is primarily affected by the mechanical properties of the material.

The different tested laminate veneers exhibited numerous values for fracture resistance testing. Contrary to the expectations, the highest mean fracture resistance values were found for the Vita Enamic laminate veneers (255.35 N). This may be due to the improved mechanical properties of this new hybrid material, due to the presence of interconnected phases within this material which led to the limitation of the crack propagation as a result of interfacial crack deflection. The phase with higher strain to failure enhances the fracture resistance by bridging the cracks introduced to the other phase.

Recently there is a favorable shift of permanent dental restorative materials towards the materials matching the physical properties of the tooth structure rather than the materials with very high flexural strength values. Among these recent materials developed nowadays are those classified as interpenetrating phase composites or hybrid materials (polymer infiltrated glass ceramics). The increased polymer part within these materials on the expense of the ceramic proportion resulted in lower elastic modulus (near that of dentin) which enables the absorption of functional stresses through deformation, along with increased flexural strength, fatigue resistance and strain at failure. This was proved by several previous studies who concluded that the infiltration of a ductile phase to the ceramic might have improved the strength and toughness significantly. Travitzky and Shlayen proposed that the fracture resistance of interpenetrating phase composites was enhanced with crack bridging by polymer phase.

Moreover, He and Swain stated that upon approximation of the modulus of elasticity of Vita Enamic to the natural tooth, a more uniform stress distribution during loading was predicted. Stawarczyk et al reported a very good structural reliability to Vita Enamic within their study concluding that this material is very homogenous, however the study done by Della bona et al revealed few microcracks in the network boundaries, by high magnification microscopy, which can decrease the mechanical properties the polymer infiltrated ceramic network materials.

Kelly et al 2010 proved that the performance of Vita Enamic restorations was comparable to that of lithium disilicate restorations. This was coinciding with this study although the values
of the IPS e.max CAD veneers (244.42 N) were slightly lower than Vita Enamic. This may be due to the brittle nature of the lithium disilicate material which revealed high initial flexural strength but spontaneous fracture might have occurred owing to the brittleness of the material. On the other hand the hybrid material containing composites exhibited higher deformation which decreases the spontaneous fracture probability. A previous study \(^{(51)}\) highlighted the previous assumption and the importance of these mechanical properties especially with thin restorations as laminate veneers.

The direct composite laminate veneers showed the least mean fracture strength (159.20 N) among the three tested materials. This may be due to the material composition and microstructure. Although the composite and the Vita Enamic are supposed to be composed of polymer and fillers, the microstructural differences can be highlighted. In the composite materials, no interconnections were found between inorganic filler particles and the polymer matrix. On the contrary, the Vita Enamic contains two phases (ceramic and polymer) with interconnections at which crack deflection occurs \(^{(47)}\). This behavior emphasized the damage tolerance of polymer interpenetrating phase composites.

Contradicting to the results of this study, Abdul Khaliq and Al-Rawi \(^{(21)}\), proved that the direct composite veneers exhibited higher fracture resistance values than IPS e.max CAD. This may be due to the difference in the test conditions as they used human teeth in their study. They related their finding to the distribution of tensions in a homogenous way in the resin nanoceramic veneer resulting in increased capacity for plastic deformations and therefore preservation of the adhesive interface. They also explained the low fracture resistance of the IPS e.max CAD veneers by the combination of the high strength and high modulus of elasticity resulting in load transfer to the cement layer which is the weak link within the system.

The use of the epoxy resin dies is contributed to the standardization of the in vitro testing. Small differences in the fracture resistance values were found in a previous study \(^{(5)}\) when the composite and ceramic veneers were constructed on artificial teeth and human teeth. However the simulation of the intra oral environment such as thermal and mechanical cyclic loading was not included which is considered a limitation within this study.

As with any new procedure, in vitro studies are required to analyze the different aspects of this new system, which are important for clinical functioning. And finally, in vivo studies are still needed to assess the ultimate clinical efficacy of such restorations. Therefore, laboratory studies focusing on the most important parameters in prediction of the clinical efficacy of laminate veneers have been reviewed and further clinical studies will be needed to guarantee their survival rate. Further investigation will be needed to study the fracture resistance of direct and indirect laminate veneers with different preparation designs after thermocycling and artificial aging.

**CONCLUSIONS**

Within the limitations of this study, it can be concluded that:

1. All the tested materials showed varying degrees of staining upon exposure to coca-cola, tea and coffee.
2. Nanohybrid composite veneers are more susceptible to discoloration than the hybrid ceramics and lithium disilicate ceramics.
3. Coffee among the three tested immersion solutions has the highest ability to stain all the tested laminate veneer materials.
4. Lithium disilicate ceramics and hybrid ceramics are more suitable than direct nanohybrid composite in laminate veneers construction as they are more durable in terms of fracture resistance.
REFERENCES


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