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Comparative Evaluation of Color Stability of Two CAD-CAM Restorative Materials Used in Laminate Veneers: An In Vitro Study

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Abstract

Aim: This in vitro investigation aimed to compare the color stability of two CAD-CAM restorative materials—monolithic zirconia and lithium disilicate—used for laminate veneers following exposure to coffee thermocycling.

Materials and method: CAD-CAM blocks of zirconia (Upcera Explore) and lithium disilicate (IPS e.max CAD) were used to create 20 rectangular samples, with 10 specimens from each group. To replicate veneer thickness, the samples were standardized to dimensions of 25 mm × 7 mm × 0.7 mm. A spectrophotometer was used to measure baseline color in the CIELAB color space (L*, a*, b*) under uniform lighting circumstances. The specimens were subsequently exposed to 6,000 thermocycles in a coffee solution between 5°C and 55°C. Following thermocycling, the color difference (ΔE) values were computed and final measurements of color were noted.

Results: In comparison to zirconia (mean ΔE = 1.04), lithium disilicate showed greater color change values (mean ΔE ≈ 1.74). The unpaired samples t-test evaluated intergroup changes after thermocycling, but there was no statistically significant difference in the color change value among all tested groups. (P>0.05).

Conclusion: Within the limitations of this in-vitro study, monolithic zirconia demonstrated similar color stability to lithium disilicate following coffee thermocycling. On the other hand, color variations in both materials were within clinically acceptable bounds.

Keywords: Color stability, CAD-CAM, Zirconia, Lithium Disilicate, Thermocycling, Veneers.

Introduction

In modern prosthodontics, laminate veneers are frequently utilized to restore anterior teeth in a conservative and aesthetically pleasing manner [1,2]. Long-term optical stability is more important than mechanical durability since even slight discolouration can affect clinical acceptance [1]. The regulated microstructure, repeatability, and enhanced aesthetic qualities of CAD-CAM ceramics have made them widely recognized materials [3].

Monolithic zirconia and lithium disilicate are two essentially distinct ceramic systems that are frequently recommended for veneer restoration [4,5]. Lithium disilicate is a glass-ceramic that improves translucency and enamel-like light transmission due to its interconnecting crystalline network [6,7]. On the other hand, extrinsic staining and surface modification may be more likely when a glass phase is present [8]. Monolithic zirconia, on the other hand, is primarily polycrystalline and provides more strength; new high-translucency formulations are intended to enhance anterior aesthetics [9]. After aging, variations in yttria content and microstructure may affect translucency and color stability[10].

Intrinsic elements like translucency and crystalline composition, as well as external elements such as dietary chromogens, surface roughness, and heat stress, all affect the color stability of CAD-CAM ceramics [11,12]. Multiple firing cycles and surface polishing techniques may also alter optical behavior [13]. Thermocycling has been linked to changes in mechanical and optical properties and is frequently used to mimic intraoral temperature variations [14].

Coffee's excellent chromogenic ability and therapeutic relevance make it a popular staining medium [6,8]. Lithium disilicate, zirconia, and other CAD-CAM materials have shown quantifiable increases in ΔE values when thermocycling and coffee immersion are used [5]. Additionally, by altering light transmission and substrate masking, veneer thickness and resin cement shade may have a major impact on the final color perception [15,16].

Thereby, to promote reliable choice of materials in anterior dental restoration, a controlled in vitro assessment evaluating the color stability of monolithic zirconia and lithium disilicate at laminate veneer thickness after standardized coffee thermocycling is required.

Materials And Method

Zirconia (Upcera Explore) and lithium disilicate glass-ceramic (IPS e.max CAD), two different CAD-CAM materials, are used for standardizing the manufacture of rectangle specimens at the start of the investigation. The CAD-CAM blocks were precisely sectioned to dimensions of 25 mm in length, 7 mm in width, and 0.7 mm in thickness using an IsoMetTM 4000 Linear Precision Saw fitted with a slow-speed diamond blade as shown in figure 1, In order to precisely depict the clinical proportions of a porcelain laminate veneer, this particular thickness was chosen. To guarantee complete conformity to the study guidelines, each specimen's final dimensions will be confirmed using a digital calliper.

To reduce background interference, each specimen was positioned separately on a standardized white background under standardized D65 illuminant illumination. Before measurements, a spectrophotometer (VITA Easy shade Advanced V), shown in figure 2, was calibrated using integrated white and black reference tiles. Three replicate readings were acquired for each specimen in CIELAB color space (L*, a*, b*; 10° observer angle) using the tip of the probe placed perpendicular (90°) to the sample center. The values were averaged to provide baseline color coordinates.

Specimens were wrapped in fabric mesh and secured with metal wire. A coffee solution was prepared at a ratio of 15 mL water to 1 mL coffee. Specimens were placed in an incubator for thermocycling, 84-second cycles alternating between hot (55°C) and cold (5°C) baths containing the coffee solution, with 30 seconds dwell time, 2 seconds hold time, and 10 seconds transfer time. Fresh coffee solution was added to the hot and cold tanks every eight hours. A total of 6000 cycles were completed**.**

Post-thermocycling, specimens were removed from mesh bags and gently cleaned using a soft-bristled toothbrush with non-abrasive toothpaste under lukewarm running distilled water to simulate clinical brushing and remove surface stains without altering intrinsic color. Following a thorough rinsing, the specimens were allowed to air dry for five minutes at ambient temperature.

The same baseline procedure was used for the final spectrophotometric measurements: three replicate CIELAB L*, a*, and b* readings (D65 illuminant, 10° observer) were obtained perpendicularly at the specimen center against the calibrated white background, and the values were averaged.

Total color difference (ΔE) was calculated using the formula,

$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$, where subscripts 1 and 2 denote pre- and post-aging coordinates, respectively.

All data were analyzed using IBM SPSS Statistics and expressed as mean ± standard deviation (SD). Levene's test was performed to assess homogeneity of variances before intergroup comparisons. The independent samples t-test was used to compare color parameters (L*, a*, b*) between groups, while the unpaired samples t-test evaluated intergroup changes before and after thermocycling. All statistical tests were two-tailed, with a p value < 0.05 considered statistically significant. Clinical relevance of color differences was interpreted using CIEDE2000 thresholds, with the perceptibility threshold set at 1.30 ΔE_{00} units and the acceptability threshold at 2.25 ΔE_{00} units, to determine the clinical significance of observed color changes.

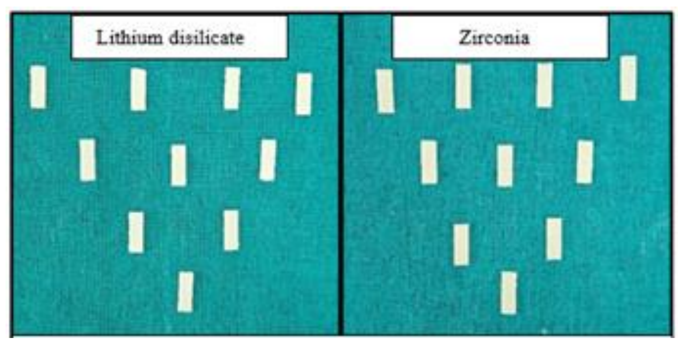

Figure 1: Specimen preparation

Figure 2: Spectrophotometer measurement

Results

Table 1: Intergroup comparison of Color Stability

Variable	Group	N	Mean	SD	SE	t-value	df	p-value	Mean Difference	95% CI (Lower–Upper)
Material	Lithium	10	1.7421	1.0719	0.339	1.814	18	0.086	0.7039	-0.1113 to 1.5191
	Zirconia	10	1.0382	0.5973	0.1889					

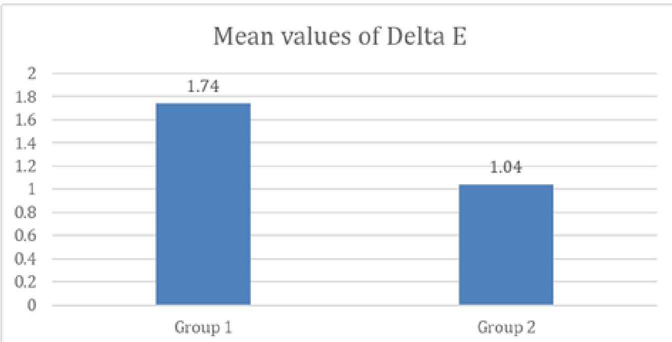

Figure 3: Mean Values of Delta E

Table 1 displays the mean color change (ΔE) values of the two CAD-CAM restorative materials assessed following the experimental process. The mean ΔE value of zirconia specimens (n = 10) was 1.0382 ± 0.5973, whereas the mean ΔE value of lithium disilicate specimens (n = 10) was 1.7421 ± 1.0719. The two groups' mean color change differed by 0.7039. The color stability of the two materials was compared using an independent t-test. The findings showed that there was no statistically significant difference (t = 1.814, df = 18, p=0.086).

The observed variation in color change between zirconia and lithium disilicate may be the result of chance, according to the 95% confidence interval for the mean difference, which varied from −0.1113 to 1.5191.

Overall, both materials showed clinically acceptable color stability, with no statistically significant difference between them, despite lithium disilicate showing relatively more color variation than zirconia.

Discussion

The color stability of CAD-CAM ceramics was assessed in this work after 6,000 coffee thermocycles. Lithium disilicate showed a greater mean color change (≈1.74) than zirconia (≈1.04) based on the computed ΔE values, suggesting material-dependent variations in optical stability [1,5].

When interpreted in relation to reported perceptibility thresholds (ΔE ≈1.3), color changes equal to or greater than this range may be visually detectable under controlled conditions[1]. The mean ΔE of zirconia (1.04) approximates this perceptibility limit, suggesting minimal but potentially detectable change. In contrast, the mean ΔE of lithium disilicate (1.74) exceeded perceptibility thresholds, indicating that discoloration may be clinically noticeable in certain scenarios [1,5].

However, when correlated with commonly cited clinical acceptability thresholds (ΔE ≈2.25), both materials demonstrated mean values within acceptable limits [1]. These results are in line with earlier studies that found quantifiable but typically acceptable color changes in CAD-CAM ceramics following staining media exposure[5,9]. The glass-ceramic microstructure of lithium disilicate may be responsible for the more noticeable color change[6]. When exposed to chromogenic fluids, especially under thermocyclic stress, the inclusion of a silica-based matrix may promote pigment adsorption or surface penetration [6,8]. The current results are corroborated by earlier research demonstrating that coffee thermocycling raises ΔE values in lithium disilicate ceramics [8].

Monolithic zirconia, on the other hand, had lower mean ΔE values; this could be due to its mostly polycrystalline structure and low glass content [4,9]. Translucency and color stability during age have been demonstrated to be influenced by material composition and crystalline dispersion [3,10]. In comparison to glass-ceramics, studies assessing zirconia exposed to staining liquids have also shown quantifiable but comparatively stable color behavior [5].

Thermocycling has been linked to changes in the mechanical and optical characteristics of CAD-CAM ceramics by simulating intraoral thermal stresses [14]. The ΔE values found in this investigation may be influenced by repeated thermal expansion and contraction, which could improve surface interaction with staining agents [6].

The observed color changes are statistically and visibly different, but their clinical significance needs to be carefully considered. The final color perception in vivo may be further affected by the overall thickness of the restoration and the shade of the resin cement, which could obscure or magnify ΔE discrepancies [15,16]. Furthermore, it has been demonstrated that stain accumulation and optical stability are influenced by surface properties and finishing techniques [8,13].

Within the limitations of this in-vitro study, monolithic zirconia demonstrated similar color stability to lithium disilicate following coffee thermocycling, even though both materials mostly stayed under clinically acceptable ΔE thresholds. These results are consistent with other comparative studies that found material-dependent differences in stainability across modern CAD-CAM ceramics [3,5,10].

The long-term therapeutic importance of these differences may be further clarified by future studies using dynamic oral simulation models and extended aging procedures.

Conclusion

Within the limitations of this in vitro study:

1. The mean ΔE values for both materials fell within clinically acceptable bounds ($\Delta E < 2.25$).
2. Lithium disilicate demonstrated greater ΔE values than monolithic zirconia after 6,000 coffee thermocycles, although the difference was not statistically significant ($p > 0.05$).

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