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Color Stability of CAD-CAM Laminate Veneer after Aging and Exposure to Food Spices

(Kestabilan Warna Venir Laminat CAD-CAM selepas Penuaan dan Pendedahan kepada Rempah Makanan)

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ABSTRACT

The color stability of CAD-CAM ceramic veneer restoration is a crucial factor for the long-term success of the restoration. However, the effect of food spices on CAD-CAM ceramic has not been evaluated. The purpose of this study was to evaluate the color stability of CAD-CAM laminate veneer materials after artificial aging and exposure to turmeric and paprika staining solutions. CAD-CAM ceramic slices (N=72; shade; A2; diameter 9 mm × 7 mm) were prepared using feldspathic ceramic (n=36) and zirconia-reinforced lithium disilicate (n=36). Each type of ceramic material is divided into two thicknesses, 0.5 mm (n=18) and 0.7 mm (n=18). The ceramic slices were cemented onto central incisors. The samples were subjected to accelerated aging for 1000 cycles. Samples were further divided into 3 subgroups (n=6): distilled water (control), turmeric, and paprika staining solutions, and soaked for 24 h. Spectrophotometric color measurement was recorded, and color difference (ΔE) was calculated after aging (ΔE1), and after 24 h of immersion in spices solutions (ΔE2). Two-way analysis of variance and Bonferroni's test were used for the statistical analysis (α=.05). ΔE1 means were not significantly influenced by ceramic materials (P=0.770) and thicknesses (P= 0.162). ΔE2 means were significantly affected by the interaction between thickness and staining solutions in both materials (P <0.05). Both ceramic veneers presented the highest color change after immersion in turmeric solution. Ceramic veneers show color changes after artificial aging. Turmeric shows a significant effect on the color of ceramic veneer after staining. Ceramic thickness influences the amount of color change after aging and staining.

Keywords: CAD/CAM ceramic veneer; color stability; food spices

ABSTRAK

Kestabilan warna pemulihan venir seramik CAD-CAM merupakan faktor penting untuk kejayaan jangka panjang pemulihan. Walau bagaimanapun, kesan rempah makanan pada seramik CAD-CAM belum dinilai. Tujuan kajian ini adalah untuk menilai kestabilan warna bahan venir lamina CAD-CAM selepas penuaan buatan dan pendedahan kepada larutan pewarna kunyit dan paprika. Kepingan seramik CAD-CAM (N=72; lorek; A2; diameter 9 mm × 7 mm) disediakan menggunakan seramik feldspathic (n=36) dan litium disilikat bertetulang zirkonia (n=36). Setiap jenis bahan seramik dibahagikan kepada dua ketebalan, 0.5 mm (n=18) dan 0.7 mm (n=18). Potongan seramik disimen pada gigi kacip tengah. Sampel telah tertakluk kepada penuaan dipercepatkan untuk 1000 kitaran. Sampel dibahagikan lagi kepada 3 subkumpulan (n=6): air suling (kawalan), larutan pewarna kunyit dan paprika dan direndam selama 24 jam. Pengukuran warna spektrofotometri telah direkodkan dan perbezaan warna (ΔE) dikira selepas penuaan (ΔE1) dan selepas 24 jam rendaman dalam larutan rempah (ΔE2). Analisis dua hala bagi varians dan ujian Bonferroni digunakan untuk analisis statistik (α=.05). ΔE1 bermakna tidak banyak dipengaruhi oleh bahan seramik (P=0.770) dan ketebalan (P= 0.162). Purata ΔE2 telah terjejas dengan ketara oleh interaksi antara ketebalan dan larutan pewarnaan dalam kedua-dua bahan (P <0.05). Kedua-dua venir seramik memberikan perubahan warna yang paling tinggi selepas rendaman dalam larutan kunyit. Venir seramik menunjukkan perubahan warna selepas penuaan buatan. Kunyit menunjukkan kesan ketara pada warna venir seramik selepas pewarnaan. Ketebalan seramik mempengaruhi jumlah perubahan warna selepas penuaan dan pewarnaan.

Kata kunci: Kestabilan warna; rempah-rempah makanan; venir seramik CAD/CAM

INTRODUCTION

The demand for esthetic restorations has increased following the evolution of computer-aided design and computer-aided manufacturing (CAD-CAM) and the continuous development of CAD-CAM ceramic restorative material (Cho et al. 2024; Farook et al. 2020; Naidu & Jaju 2022; Soygun et al. 2017). It has been reported that veneers fabricated using CAD-CAM technology provide restoration with superior translucency that requires minimal tooth preparation and shows high strength, in addition to their pleasant esthetic outcome (Kara 2022; Ye et al. 2023). However, the type of ceramic used (Bagis & Turgut 2013), ceramic thickness (Calgaro et al. 2014; Igiel et al. 2018; Morsy, Ghoneim & Afifi 2020; Tamam, Güngör & Nemli 2020), and daily food and drink consumption (Palla et al. 2018) can influence the color stability of ceramic material over time.

CAD-CAM restorations offer a high degree of translucency, especially when thinner laminate veneers ranging from 0.5 mm to 1.0 mm are used, hence allowing the scattering and dispersion of light and closely mimicking the natural tooth appearance (Turgut & Bagis 2011). However, in discolored tooth cases, the thickness of the laminate veneer plays an important role in masking the underlying tooth substrate color (Bagis & Turgut 2013; Morsy, Ghoneim & Afifi 2020). It is important to note that the influence of the different thicknesses of CAD-CAM restorative material following long-term discoloration is not well unknown (Bagis & Turgut 2013; Igiel et al. 2018; Kara 2022; Lee & Choi 2018; Morsy, Ghoneim & Afifi 2020; Turgut & Bagis 2011).

Clinical environments can be stimulated by exposing various dental materials to ultraviolet (UV) light, temperature, or humidity variations, particularly in *in-vitro* studies. Artificial accelerated aging can be done through thermocycling to assess its effects on the optical properties of the materials (Gale & Darvell 1999). An alteration in the color of luted dental ceramics due to aging was reported in many studies (Gale & Darvell 1999; Turgut & Bagis 2011). Generally, this can vary among different oral conditions and can be attributed to a change in the color of the ceramic itself and the underlying cement. Various intrinsic and extrinsic factors can lead to the discoloration of ceramic materials. Extrinsic factors including adsorption or absorption of food colorants from food or drink (de Oliveira et al. 2023; Lee & Choi 2018), plaque accumulation, and oral hygiene agents (Lee et al. 2020; Soygun et al. 2017) could lead to esthetic failure of the restorations; whereas intrinsic factors such as ceramic composition and glaze surface influence overall esthetics as well (Alp et al. 2018; Atay et al. 2009; Soygun et al. 2017). On the other hand, resin cement discoloration can be attributed to the degradation of unreacted polymers in the polymerization process (Almeida et al. 2015; Çömlekoğlu et al. 2016).

Turmeric and paprika are widely used especially in Asian cuisines to enhance the flavor and aroma of food (Yew, Berekally & Richards 2013). These spices may influence the color stability of ceramic veneer, as it has been reported that turmeric and paprika have the potential to stain resin composites (Chittem, Sajjan & Varma Kanumuri 2017; Stober, Gilde & Lenz 2001; Yew, Berekally & Richards 2013). Previous studies have evaluated the effect of extrinsic factors, including environmental exposure, on the color stability of ceramic materials. For instance, numerous beverages have been tested such as black tea, wine, coffee, orange juice, and cola (Alp et al. 2018; Atay et al. 2009; Palla et al. 2018). However, less is known about the effect of food spices on the color stability of CAD-CAM ceramic veneer.

The aim of this study was therefore to investigate the color stability of feldspathic and zirconia-reinforced lithium silicate CAD-CAM ceramic veneer after artificial aging and exposure to turmeric and paprika staining solutions. The null hypothesis is that thermocycling does not have a significant effect on the color stability of CAD-CAM laminate veneer; and that food spices do not have an effect on the color stability of different CAD-CAM ceramic materials and different laminate veneer thicknesses.

MATERIALS AND METHODS

Seventy-two maxillary central incisors extracted for periodontal reasons were used in this study after written informed consent. The teeth were thoroughly examined under a stereomicroscope at 10× magnification to confirm the absence of cracks, fractures, carious lesions, restorations, erosion, or abrasive defects. The labial surface of the teeth crown was prepared to provide a flat enamel surface using a semi-automatic grinding and polishing device (EcoMet/AutoMet 250) with #600 silicon carbide (SiC) papers (Buehler) under water cooling (24) at 250 rpm speed for 20 s. The teeth were then randomly divided into twelve groups (n=6).

A precision high-speed cutting saw (Isomet High-Speed Pro, Buehler) was used to slice the ceramic blocks at a speed of 350 rpm under water cooling. A total of seventy-two CAD-CAM ceramic slices were obtained from felspathic ceramic (Cerec Blocs, Dentsply Sirona) (n=36) and zirconia-reinforced lithium silicate (Celtra Duo, Dentsply Sirona) (n=36). The thicknesses of the slices were 0.5 mm±0.05 mm (n=18) and 0.7 mm±0.05 mm (n=18) for each ceramic type. Further cutting of the ceramic slices to the diameter of 9×7 mm was performed using a high-speed rotary handpiece and diamond bur.

The ceramic samples were then grinded using #220 followed by #500, and #1200 silicon carbide papers (SiC) for polishing using a semi-automatic grinding and polishing device under water cooling at a speed of 150 rpm for 20 s. The final ceramic thickness was verified using digital calipers (Absolute Digimatic Caliper, Mitutoyo Corporation, Aurora). The ceramics were then cleaned with distilled water before cementation.

Ceramic slices were etched using 9% buffered hydrofluoric acid (Ultradent, Inc) for 90 s, washed thoroughly with water for 10 s, and air-dried. Then, a layer of silane coupling agent (Ultradent, Inc.) was applied for 60 s and air-dried. Concurrently, the tooth surface was etched using 37% phosphoric acid (DiaEtch Europe B.V) for 30 s, washed with water, and air dried. Following that, a layer of bonding agent (Tetric N-Bond Ivoclar Vivadent) was applied to the prepared tooth surface and the solvent was evaporated for 20 s and photoactivated for 20 s. Calibra veneer light cure resin cement (Shade translucent, Dentsply Sirona) was used for cementation. A load of 10 N equivalent to 1 kg was applied for 20 s to standardize the thickness of the resin cement for all samples (Lee & Choi 2018; Turgut & Bagis 2011). After light-polymerization, the samples were stored in distilled water at 37 °C in an incubator for 24 h in light-protected containers. The baseline color measurement (T0) was conducted using a spectrophotometer (CM-5, Konica Minolta, Inc.).

The samples were thermocycled for 1000 cycles between 5 °C and 55 °C with 20 s dwell time and 10 s transfer interval with a thermocycling machine (ATDM T6PD UM, Malaysia) before immersion in staining solution. Color assessment (T1) after thermocycling was recorded. Two staining solutions were prepared by diluting 1 g of each grounded spice (turmeric and paprika) into a beaker and dissolved in 1000 mL of distilled water. The solutions were boiled for 5 min with consistent mixing for the complete dissolution of spices. The solutions were then filtered to remove any suspended sediment.

The samples were then soaked in distilled water (n=6) that served as a control group, 0.1% turmeric solution (n=6), and 0.1% paprika solution (n=6). Samples were fully immersed in the solutions for 24 h and stored in an incubator at a controlled temperature of 37 and a dark container. The test solutions were stirred once at 12 h to maintain the homogeneity of the solution. Samples were cleaned with distilled water and blot-dried using tissue papers before color assessment (T2).

The color parameters were calculated under D65 standard conditions according to the Commission International de I0Eclairage. The CIE L*a*b* color parameters, L* (lightness), a* (green-red), and b* (blue-yellow) were used in the ΔE formula for color difference calculation: where ΔL*, Δa*, and Δb* are variations of each parameter, respectively. The first color difference (ΔE) was calculated before and after thermocycling (ΔE1). The second color difference was calculated for the thermocycled samples and after 24 h of immersion in staining solutions(ΔE2).

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$ (CIE Technical Report 2004).

A two-way analysis of variance (ANOVA) was employed to compare the mean color changes. The significance value was set at $P = 0.05$. The multiple comparisons post hoc Bonferroni test was used to detect significant differences among the groups.

RESULTS

The mean and standard deviation values were not significantly affected by the interaction between both material types (P=0.770) and thickness (P=0.162) and thermocycling (Table 1). However, the 0.5 mm ceramic veneer showed a higher ΔE1 mean (3.987±2.228) of color changes than 0.7 mm (3.341±1.536). The feldspathic ceramic veneer had a higher ΔE1 mean (3.731±1.852) compared to zirconia-reinforced lithium silicate (3.597±2.024). A reduction in the thickness of the laminated veneer from 0.7 mm to 0.5 mm increased ΔE1.

Results showed that there was no significant difference in ΔE2 mean between different types of ceramic materials (P= 0.414). However, there was a significant difference between the types of staining solutions (P<0.001). Post-hoc Bonferroni's test confirmed that turmeric (15.827 ±7.500) had a significant color difference (P <0.001) in the feldspathic ceramic group (14.553 ±8.191), and higher color changes in zirconia-reinforced lithium silicate group (17.102 ±5.225) which were beyond clinically acceptably value (ΔE2>3.3) (Duane Douglas, Steinhauer & Wee 2007). There were no significant color changes for distilled water (P=1.00) and paprika (P=1.00) groups (Table 2).

The result showed significant (P<0.001) color changes in both thicknesses of feldspathic ceramic material after immersion in staining solution. Post-hoc Bonferroni's test showed that the highest mean for the 0.5 mm ceramic group (21.995 ±6.09) was followed by the 0.7 mm group (7.112 ±4.609) when turmeric staining solution was used. For the distilled water and paprika groups, the mean color changes for the 0.5 mm groups were (2.666 ±1.877, and 1.926 ±2.271), and for the 0.7 mm groups were (1.335 ±1.052, and 0.681± 0.314) respectively (Table 3).

Whereas in zirconia-reinforced lithium silicate ceramic veneer, post-hoc Bonferroni's test confirmed that turmeric (17.102 ±5.225) had a significant (P<0.001) color change when compared with distilled water (1.806 ±1.218) and paprika (1.576 ± 1.172) after 24 h immersion. The 0.7 mm group (20.793 ±3.004) had a higher ΔE2 mean compared with 0.5 mm (13.410±4.281) after immersion in turmeric solution. Where for paprika the 0.5 mm color changes were (0.901 ±0.554), and the 0.7 mm (2.250 ± 1.276), and for the water group the 0.5 mm was (0.968±0.516), and 0.7 mm (2.643 ± 1.146) (Table 4).

DISCUSSION

The results of this study showed that the color value of CAD-CAM laminate veneer material after thermocycling has not significantly changed. Therefore, the null hypothesis that thermocycling does not have a significant effect on the color stability of CAD-CAM laminate veneer

TABLE 1. Two-way ANOVA results for ΔE1 values

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	8.526	3	2.842	.757	.522	.032
Intercept	966.754	1	966.754	257.515	<.001	.791
Type	.324	1	.324	.086	.770	.001
Thickness	7.508	1	7.508	2.000	.162	.029
Type * Thickness	.694	1	.694	.185	.669	.003
Error	255.283	68	3.754			
Total	1230.563	72				
Corrected Total	263.809	71				

Cerec Bloc (0.5 & 0.7 mm), Celtra Duo (0.5 & 0.7 mm) after thermocycling

TABLE 2. Two-way ANOVA results for ΔE2 values (effect of staining on ceramic materials)

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	3248.413	5	649.683	31.867	<.001	.707
Intercept	2940.167	1	2940.167	144.215	<.001	.686
Type	13.781	1	13.781	.676	.414	.010
Staining	3208.778	2	104.389	78.695	<.001	.705
Type * Staining	25.854	2	12.927	.634	.534	.019
Error	1345.565	66	20.387			
Total	7534.145	72				
Corrected Total	4593.978	71				

Cerec Bloc, Celtra Duo CAD-CAM ceramic materials after immersion

TABLE 3. Two-way ANOVA results for ΔE2 values (effect of staining on Cerec blocs thickness)

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	2008.875	5	401.775	35.526	<.001	.856
Intercept	1275.680	1	1275.680	112.798	<.001	.790
Type	304.852	1	304.852	26.955	<.001	.347
Thickness	1334.364	2	667.182	58.993	<.001	.797
Type * Thickness	369.659	2	184.830	16.343		.521
Error	339.284	30	11.309			
Total	3623.839	36				
Corrected Total	2348.159	35				

Cerec Bloc (0.5 & 0.7 mm) after immersion

TABLE 4. Two-way ANOVA results for ΔE2 values (effect of staining on Celtra Duo ceramic thickness)

Source	Type III sum of squares	Df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	2077.679	5	415.536	80.760	<.001	.931
Intercept	1678.268	1	1678.268	326.176	<.001	.916
Type	108.299	1	108.299	21.048	<.001	.412
Thickness	1900.268	2	950.134	184.661	<.001	.925
Type * Thickness	69.113	2	34.557	6.716	.004	.309
Error	154.359	30	5.145			
Total	3910.306	36				
Corrected Total	2232.038	35				

Celtra Duo (0.5 & 0.7 mm) after immersion

was accepted. Turmeric had a significant effect on the color values of CAD-CAM laminate veneer materials and thickness. Therefore, the hypothesis 'food spices do not affect the color stability of different CAD-CAM laminate veneer material and different veneer thicknesses' was partially rejected.

The purpose of this *in vitro* study was to evaluate the effects of thermocycling and food spices on the color stability of two different CAD-CAM ceramic veneer materials that were prepared in two different thicknesses. The CAD-CAM materials tested were selected because of their clinical acceptance and their innovative composition. Several studies have evaluated the optical characteristics of CAD-CAM ceramic material (Alp et al. 2018; Gürdal et al. 2018; Morsy, Ghoneim & Afifi 2020; Palla et al. 2018; Su et al. 2021). However, the authors are unaware of earlier research studying the effects of food spices on the color stability of CAD-CAM ceramic material.

Thermocycling is a well-established in vitro procedure to simulate a natural intraoral environment (D'Amario et al. 2010; Gale & Darvell 1999; Schuckar & Geurtsen 1997; Wegner, Gerdes & Kern 2002). In this study, 1000 thermal cycles were used which correspond to two months of aging in a normal human oral cavity environment (Gale & Darvell 1999). In this study, thermocycling resulted in higher color values and this finding is consistent with other studies (Gurdal et al. 2018; Morsy, Ghoneim & Afifi 2020). However, the differences in color values after thermocycling were not significant (P=0.770), where the feldspathic ceramic presented with a higher color value (ΔE1 mean 3.7315) after thermocycling as compared to ZLS (ΔE1 mean 3.597). This finding can be explained by referring to the irregular microstructure nature of the feldspathic ceramic that contains dispersed crystalline minerals (feldspar, silica, alumina) of large grain size in a glass matrix (Belli et al. 2017; de Carvalho Ramos et al. 2016) in comparison to zirconia-reinforced lithium silicate ceramic that has more homogenous structure and finer rodlike crystal particles with an average size of approximately 0.5 mm (Zarone et al. 2021). This discovery has a significant impact on both clinical outcomes and patient satisfaction, as well as on the appropriate selection of ceramic veneer materials for restorative procedures.

Two types of ceramic veneers were used in this *in-vitro* study and immersed in three staining solutions (distilled water, turmeric, and paprika) for 24 h to simulate one month *in vivo* (Ardu et al. 2010). It has been suggested that an average person would spend approximately one hour per day having meals, thus the immersion time in the study simulates an equivalent period of dietary staining exposure for about one month (Yew, Berekally & Richards 2013). Turmeric and paprika food spices were used in this study as they are among the most popular Asian spices. The significant color change of tooth-colored restorative materials after immersion in turmeric solution was shown in previous studies (Chittem, Sajjan & Varma Kanumuri 2017; Yew, Berekally & Richards 2013). This can be attributed to the high staining ability of turmeric due to the presence of curcumin, the polyphenols that contribute to its deep orange color and cause teeth discoloration. Meanwhile paprika is a flavoring agent, and the most noticeable characteristics are its color and pungency. Paprika's red color is due to the carotenoid pigments present. Besides that, the presence of capsanthin, capsorubin, and b-carotene imparts a reddish color to paprika. As a result, the presence of these agents will lead to discoloration of both materials, especially after immersion in turmeric solution (Bravo 1998; Yew, Berekally & Richards 2013).

In this study, a significant color change was noted when the two different ceramic veneer thicknesses were used after immersion in staining solutions, the highest color changes were observed when turmeric was used for both feldspathic ceramic (14.553 ±9.315) and zirconia-reinforced lithium silicate ceramic (17.102 ±5.225). This indicates that the color changes among turmeric groups were higher than the clinically accepted level and it was visually detected (Duane Douglas, Steinhauer & Wee 2007). Color changes of ceramic veneer after immersion in distilled water and paprika were within the clinically acceptable range (ΔE2<3.3), this result is constant with another study (Yew, Berekally & Richards 2013) that tested the same staining solutions on the color stability of composite resin material.

The 0.5 mm thickness laminate veneer had more color change compared to the 0.7 mm thickness laminate veneer when subjected to thermocycling. For the feldspathic ceramic veneer group, the 0.5 mm thickness samples showed higher values of color changes. This result was like previous studies (Bagis & Turgut 2013; Igiel et al. 2018; Morsy, Ghoneim & Afifi 2020; Palla et al. 2018) and can be explained by the masking effect of the thicker ceramic slices that can hide the color change within the cement layer (Morsy, Ghoneim & Afifi 2020). There is an interaction between the thickness and optical properties of feldspathic ceramic veneer, in which the absorption coefficient and refractive index would determine the masking effect of the material (Igiel et al. 2018). An increase in the thickness of ceramic results in greater absorption of light which leads to less exposure to the underlying tooth structure (Igiel et al. 2018). This result proved that the masking effect of ceramic veneers is crucial especially when placed on discolored, stained, and endodontically treated teeth. However, zirconia-reinforced lithium silicate ceramic showed contrary surprising results after immersion in staining solutions, in which 0.7 mm stained more compared to 0.5 mm ceramic veneer. This can be explained by the increased nanoroughness of zirconia-reinforced lithium silicate samples because of the alteration in the size of the crystal size and dissolution of the glass particles after artificial aging was used (Porojan et al. 2020). However, the effect of the compatibility of spice solutions on the optical properties of zirconia-reinforced lithium silicate ceramic is another topic that should be investigated in further research.

During the ceramic preparation, both materials have been sliced and bonded to the teeth structure to simulate a clinical setting. Whereas a single surface of the restoration would be exposed to staining conditions while the other intaglio surface was cemented to the tooth structure. In clinical scenarios, only the margin of cemented ceramic veneers tends to be exposed to the oral environment and cause discoloration (Almeida et al. 2015). Previous findings showed that when ceramic slices were used as samples without cementing on natural teeth, both sides of the ceramic were subjected to aging and staining, which led to increased color changes (Alp et al. 2018; Gurdal et al. 2018; Lee at al. 2020). However, in the current study, the ceramic veneers were cemented to natural teeth to mimic the clinical condition.

The limitations of this *in-vitro* study include the limited number of ceramic veneer materials and shades used. The 0.1% concentration of spices solutions used in this study and the typical intake of spices of 60 min per day were based on assumptions as these factors are often associated with cuisine and individual preference (Yew, Berekally & Richards 2013). Further studies may consider immersion of ceramic veneer in spice solutions before thermocycling to evaluate the color change of fresh samples. Other external factors of discoloration of ceramic veneers were not considered such as saliva cleansing action, oral hygiene routine, smoking habit, and exposure to pH in the oral environment.

CONCLUSIONS

Within the limitations of this *in vitro* study, it can be concluded that Zirconia-reinforced lithium silicate exhibited better color stability after artificial accelerated aging even with reduced thickness of the ceramic. A reduction in the thickness of the ceramic will increase the color changes and turmeric caused greatest color changes among all groups compared to paprika spices. The results of this study emphasize the need to inform patients about the potential for discoloration of the veneer restoration over time, especially when consuming turmeric and paprika spices. There is also a need for careful consideration of CAD-CAM ceramic material and ceramic thickness when planning for laminate veneer restorations.

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