ORIGINAL RESEARCH

Comparative Evaluation of Color Stability of Nanohybrid Direct and Indirect Resin-based Composites to Indian Spices: An *In Vitro* Study

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Abstract

Aim: This study aimed to evaluate the color stability of nanohybrid direct resin-based composites and indirect resin-based composites to Indian spices.

Materials and methods: Fifty samples of the nanohybrid resin-based composite (G-aenial) and the indirect resin-based composite (Adoro) were prepared using an acrylic template of dimension 8 mm × 3 mm. All the samples were polished with the Sof-Lex polishing kit. They were randomly divided into five groups and immersed in solutions of turmeric powder, tamarind extract, paprika powder, and saffron extract. Artificial saliva was used as the control group. Color values ($L^*a^*b^*$) were measured by a reflectance spectrophotometer using the Commission Internationale de l'Eclairage (CIE) $L^*a^*b^*$ system before and after 24 hours, 48 hours, 72 hours, and 1 month of immersion. Color differences ΔE^*ab were statistically analyzed by the two-way repeated measures ANOVA and the *post hoc* Tukey test using IBM SPSS v19.0.

Results: The results exhibited statistical significance between all five solutions and two groups at each time point considered ($p < 0.05$). From the mean, it is evident that in both indirect and direct composite groups, turmeric solution is having the highest mean when compared to other four solutions.

Conclusion: Indirect resin-based composites (Adoro) show less stainability when compared to direct resin-based composites (G-aenial). In both groups, turmeric showed maximum discoloration.

Clinical significance: Both the direct and indirect composites have a tendency to get stained with Indian spices. Indirect composites stain lesser to Indian spices when compared to direct composites. Thus, indirect composites are recommended for esthetic restorations.

Keywords: Color stability, Indirect resin composites, *In vitro* experimental study, Nanohybrid, Reflectance spectrophotometer, Resin composite, Spices, Turmeric.

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Introduction

Good color stability and color match is an important prerequisite for composite resin restorations.[1] However, the primary cause of failure that has been reported in the literature is unacceptable.[2] Color changes can be intrinsic and extrinsic, which are attributed to the type of resin, the type and size of fillers, as well as the type of food consumed.[3] The food causes discoloration of the resin composites due to the adsorption and absorption phenomena to their surface.[4] The discoloration depends on the pH and compatibility to the composite resin matrix.[5]

Advancements in nanotechnology have led to the development of nanocomposites. Nanohybrid composites contain milled glass fillers. They have discrete nanoparticles of size ranging from 40 to 50 nm as the dispersed phase. They exhibit good mechanical strength and surface finish when compared to the hybrid composites.[6]

Indirect resin composites (IRCs) are being used widely because of the enhanced mechanical properties due to additional polymerization of the monomer under intense light and heat in the laboratory unit. They are wear resistant, Esthetic, have less polymerization shrinkage, and hence less postoperative sensitivity. Being fabricated outside the oral cavity, they have clinical benefits such as better marginal integrity, proximal contacts, and contours. Second-generation IRCs are modified versions of first-generation IRCs that possess microhybrid fillers of diameter 0.04–1 µ with filler load twice that of first-generation IRCs.[7]

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Various researches have been done to assess the staining potential of tea, coffee, juices, and red wine on composite restorations.[8] Indian cuisine is abundant with flavors and colors, where natural colorants, as well as spices, are added. Relatively lesser studies are available in the literature assessing the effect of these colorants and spices on the composite resins. Among these studies, more focus had been on turmeric powder. Paprika and tamarind that are widely used in other Asian foods have also been evaluated recently.[9] Saffron is one of the most expensive spices but a widely used one in Indian foods for flavor and color.[10]

Thus, the current study was done to assess the color stability of nanohybrid resin-based direct composites and indirect resin composites to Indian spices such as turmeric, tamarind, paprika, and saffron.

Materials and Methods

Two types of resin composites (Fig. 1) of A3 shade used in the study were nanohybrid direct resin-based composites (G-aenial, GC, Asia) and indirect resin-based composites (Adoro, Ivoclar Vivadent, India). Table 1 shows the details of materials used. A total of 100 samples were used in this study, 50 samples in each group (group I and group II). Based on the mean and standard deviation of color variation for direct composites and indirect composites for immersion in distilled water from the previous study done by Arocha et al.,[8] the sample size for one immersion media was 10. There were five immersion media that means $5 \times 10 = 50$ per resin type. Fifty samples from each of the resin composites were prepared in an acrylic round template of 8×3 mm.

Sample Preparation (Group I)

Samples made from G-aenial, direct resin-based composite ($n = 50$) were placed into the template in two increments of 2 mm each using a Teflon-coated plastic instrument. After the placement of the second increment, Mylar strip-lined glass slide was placed over the material. It was then polymerized by the LED light-curing unit (Gulin Woodpecker, London, UK) with a wavelength 1,000 mW/cm^2 for 20 seconds on each side. The tip of the light-curing unit was placed on the glass slide. The thickness was approximately 2 mm. Hence, the distance between the light source and samples was standardized (Figs 2A and B).

Sample Preparation (Group II)

Samples were made from Adoro, indirect resin composite ($n = 50$). All the samples were prepared by following the same procedure of group I. After the initial sample preparation, it was placed in the indirect light-curing unit (Polymat, Indira Gandhi Institute of Dental Sciences, Puducherry) at 104°C for 30 minutes for further polymerization with both light and heat. This is known as the indirect fabrication method (Figs 3A and B).

Fig. 1: G-aenial (group I) and Adoro (group-II)

Sample Polishing

The samples were stored in distilled water at 37°C for finishing and polishing. One side of the Mylar surface was retained on the samples. A mark was made on that side for identification. The other side of the samples was ground with the 180-grit silicon carbide paper in running water. The surface was polished with a Sof-Lex polishing kit from coarse to fine disks. The finished sample is shown in Figure 4. After polishing, the samples were observed under a stereomicroscope for surface flaws or defects. Samples with defects were discarded. The polished samples of both groups were stored in distilled water for 24 hours at 37°C. The baseline color values were obtained using a spectrophotometer [Premier color scan, SS 5100A, Central Leather Research Institute (CLRI), Chennai, Tamil Nadu, India]. The samples were placed in the slot against the white background in a spectrophotometer. The baseline $L^*a^*b^*$ values were documented. The CIE $L^*a^*b^*$ system was chosen to measure the color of the samples because it is well suited for the determination of color differences.

Preparation of Spice Solution

One gram of pre-ground spice in 1,000 mL of boiling water was prepared to 0.1% of the solution. The 0.1% solution of turmeric, tamarind, paprika, and saffron was prepared with distilled water. The pH of the prepared solution was assessed with a pH meter. The samples in both groups were randomly divided into five groups ($n = 10$) and were immersed in 50 mL of the following solutions: subgroup 1: artificial saliva (control, $n = 10$), subgroup 2: 0.1% of the turmeric solution ($n = 10$), subgroup 3: 0.1% of the tamarind solution ($n = 10$), subgroup 4: 0.1% of the paprika solution ($n = 10$), subgroup5: 0.1% of the saffron solution ($n = 10$). Figure 2C exhibited the staining procedure of group I (G-aenial). Figure 3C exhibited the staining procedure of group II (Adoro).

All the solutions were maintained at 37°C and was agitated periodically to prevent sedimentation of the staining solutions. The solution was changed periodically everyday till 72 hours and every week for 1 month. All the samples were subjected to the spectrophotometric analysis (Fig. 5) after 24 hours, 48 hours, 72 hours, and 4 weeks of immersion.

The color differences were calculated as ΔE^* for every time interval using the formula, $\Delta E^* = [(L_1^* - L_0^*)^2 + (a_1^* - a_0^*)^2 + (b_1^* - b_0^*)^2]^{½}$, where ΔL^* is the change in luminosity, Δa^* is the change in the red-green parameter, and Δb^* is the change in the yellow-blue parameter.[8]

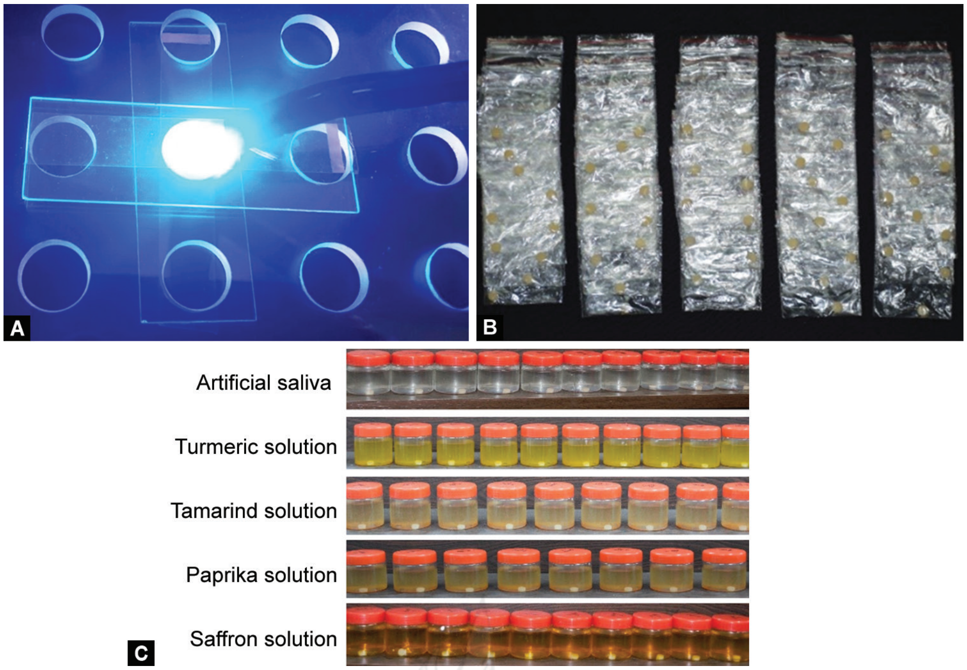
Statistical Analysis

The statistical technique applied in this study was the two-way repeated measures ANOVA by using the IBM SPSS 19.0 version and compared at 0.05 level of significance. Summary statistics like mean

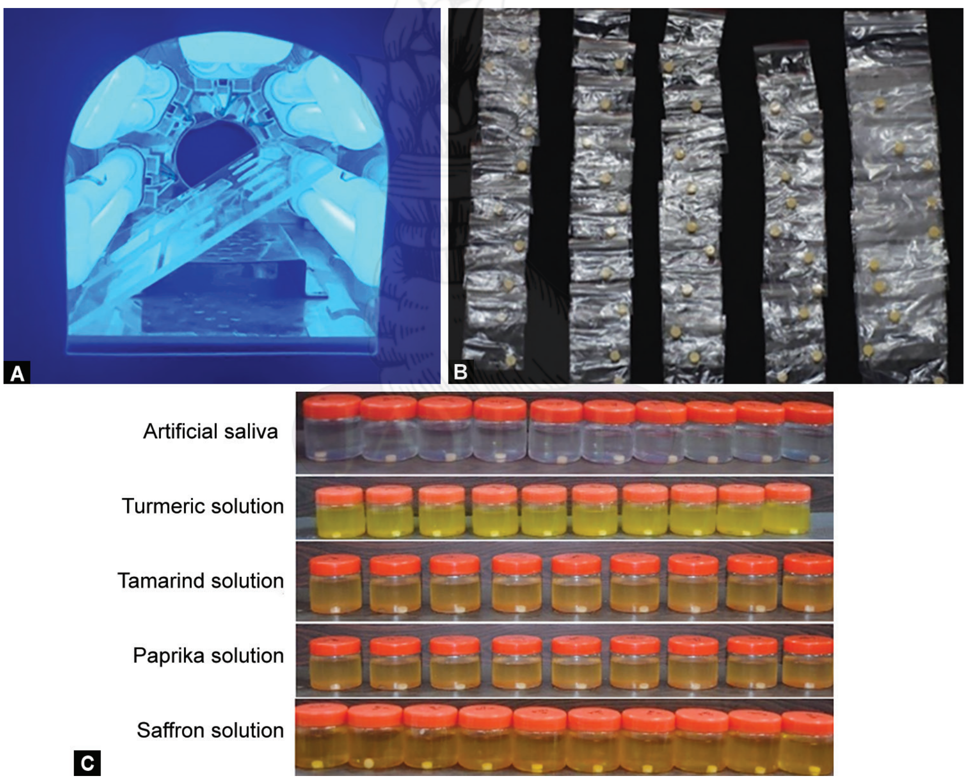
Table 1: Materials used in the study

Composite resin	*Technical specification*	*Resin matrix*	*Filler particle*	*Particle size*
Nanohybrid direct resin-based composite	G-aenial (GC, Asia) A3 shade	Bis-GMA	Prepolymerized fillers	40–50 nm
Indirect resin-based composite	Adoro (Ivoclar Vivadent) A3 shade	UDMA	Silica fluroalumino silicate	0.04–1 µm

Bis-GMA, bisphenol A glycidyl methacrylate; UDMA, urethane dimethacrylate



Figs 2A to C: (A) G-aenial sample preparation; (B) G-aenial samples (50); (C) G-aenial staining ($n = 10$)



Figs 3A to C: (A) Adoro sample preparation; (B) Adoro samples (50); (C) Adoro staining ($n = 10$)

and standard deviation were reported for all the five solutions across two groups at each time period. Further, the *post hoc* test, namely, the Tukey's test was applied.

Results

Table 2 shows the mean and standard deviation of Adoro and G-aenial after 24 hours, 48 hours, 72 hours, and 4 weeks of immersion. The mean ΔE^*ab value found with the turmeric solution was highest among all the solutions. These signify that there is statistical significance between all five solutions and two groups at each time point considered ($p < 0.05$). From the mean, it is evident that in both Adoro and G-aenial groups, turmeric is having the highest mean when compared to the other four solutions. These are depicted using line graphs in Figures 6 and 7.

The result of the present study shows that all the Indian spices used have the ability to stain both direct and indirect composites.

Fig. 4: Finished sample

Fig. 5: Spectrophotometric analysis

Table 2: Mean and standard deviation of Adoro and G-aenial

		Group			
		Adoro		*G-aenial*	
Duration	*Subgroup*	*Mean*	*Std. deviation*	*Mean*	*Std. deviation*
24 hours	Artificial saliva	0.823	0.486	1.465	2.002
	Paprika solution	1.835	0.596	4.134	1.630
	Saffron solution	3.568	3.885	2.866	1.450
	Tamarind solution	0.754	0.380	0.780	0.452
	Turmeric solution	13.696	1.844	17.620	4.035
48 hours	Artificial saliva	0.962	0.394	0.819	0.348
	Paprika solution	2.241	0.651	4.191	2.259
	Saffron solution	3.020	1.062	3.805	1.410
	Tamarind solution	1.190	1.453	0.878	0.428
	Turmeric solution	14.667	1.606	20.121	4.058
72 hours	Artificial saliva	0.843	0.514	0.789	0.374
	Paprika solution	1.777	0.513	5.179	2.650
	Saffron solution	4.007	1.926	9.141	1.900
	Tamarind solution	0.888	0.485	0.787	0.529
	Turmeric solution	14.978	2.153	20.894	4.031
1 month	Artificial saliva	0.867	0.413	1.030	0.443
	Paprika solution	1.507	0.792	3.974	2.260
	Saffron solution	7.423	1.935	13.563	1.392
	Tamarind solution	1.077	0.390	1.010	0.589
	Turmeric solution	15.818	3.784	20.558	5.487

Duration: F value = 16.366; p value = 0.000; group: F value = 5.487; p value = 0.000
Subgroup: F value = 259.013; p value = 0.000

Based on staining ability, the solutions were ordered from highest to lowest: turmeric > saffron > paprika > tamarind. In both groups, (groups I and II), turmeric showed the highest potential of discoloration. In this study, the indirect resin composite (Adoro) shows less stainability when compared to the direct resin composite (G-aenial), in all staining solutions.

Discussion

The present study assessed the ability of Indian spices to stain the nanohybrid direct composite and the indirect composite. External discoloration may be due to a variety of reasons like dental plaque deposition, stains from food colorants, dehydration, and oxidation of unreacted carbon double bonds.[8] The pigment absorption into the composite resins depends on the compatibility of the pigments with the resin matrix.

Polyphenols are abundant micronutrients present in diet especially in Indian spices. It causes staining on tooth. Polyphenols are a large class of chemical compounds found in plants, which has one or more phenol units. A phenol unit consists of six-membered aromatic hydrocarbon rings bonded directly to a hydroxyl group. Polyphenolic compounds are acidic compounds, which release hydrogen ions from the hydroxyl group. The ionic interactions resulted in staining of resin composites.[11]

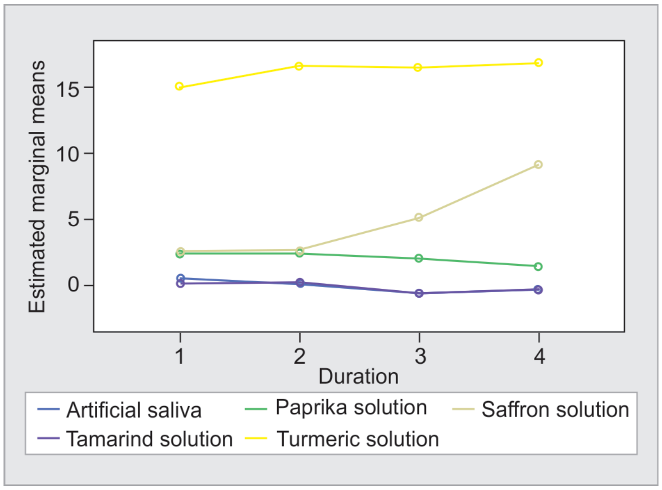


Fig. 6: Estimated marginal means of Adoro

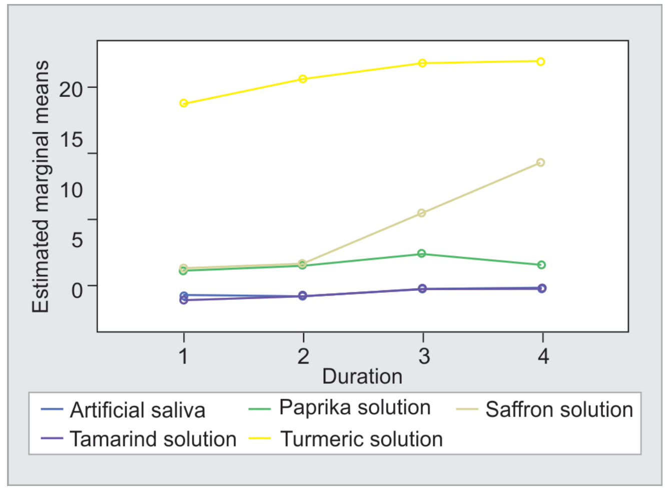


Fig. 7: Estimated marginal means of G-aenial

The direct resin-based composite, G-aenial, is a nanohybrid composite, which has a particle size of 40–50 nm. The main component is the methacrylate monomer. The matrix consists of prepolymerized fillers. Nanohybrid composites (G-aenial) contain milled glass fillers and discrete nanoparticles as the dispersed phase. They exhibit excellent surface finish and mechanical strength when compared to hybrid composites.[6] The indirect resin composite used in this current study is a microhybrid composite (Adoro). Urethane dimethacrylate (UDMA) is the main component in Adoro. It is a bis-GMA-free composite. The matrix involves silica-containing strontium and lanthanum. The other major component is silica fluoroaluminosilicate.[7]

Turmeric is an ancient spice, which is known as "golden spice of India." It is popularly known as Kitchen Queen. Curcumin gives yellow color to turmeric,[12] the major curcuminoid/polyphenolic compound that has a composition of –9%.[13] Turmeric contains high concentration of polyphenols, flavonoids, and ascorbic acid. The polyphenolic content in turmeric is 221.7 mg gallic acid equivalent (GAE).[14] The present study shows that higher amounts of polyphenols and pigments such as curcumin, desmethoxycurcumin, and bis-desmethoxycurcumin are responsible for the maximum stainability in turmeric.

Saffron is one of the most expensive and commonly used spices in Indian cuisine for color and taste. It has major bioactive compounds such as crocin, crocetin, picrocrocin, and safranal, which contribute the color. It is a hydrophilic carotenoid.[15] The other significant component present in saffron is flavonoids. The flavonoid fraction in saffron consists of five kaempferol derivatives. They are kaempferol-3-sophoroside, kaempferol-3-sophoroside-7-glucoside, kaempferol-3,7,40-triglucoside, kaempferol tetrahexoside, and kaempferol-3-dihexoside.[16] The polyphenol content in saffron is 16 mg/GAE, which is less when compared to turmeric.[17] The color stainability of saffron is due to the presence of polyphenols and the pigments such as crocin, crocetin, picrocrocin, and safranal. The study shows that saffron stains the resin-based composites next to turmeric.

Paprika is a ground spice. Three compounds (capsanthin, capsorubin, and β-carotene) cause red pigmentation in paprika. These pigments are insoluble in water, but it is oil-soluble. It is emulsified to make it water-soluble in food products.[11,18] Polyphenols are often responsible for the antioxidant capacity and stainability. The total polyphenols of analyzed paprika spices ranged from 14.67 mg/GAE.[19] The color stainability in paprika is because of the presence of polyphenols and the pigments such as capsanthin, capsorubin, and β-carotene. The present study shows that paprika stains less when compared to turmeric and saffron, owing to its less polyphenolic content.

Tamarind is widely used in Indian cuisine. The pigments responsible for the staining are leucoanthocyanidin and anthocyanidin. The polyphenolic content is less in tamarind when compared to turmeric, saffron, and paprika.[20] The polyphenolic content in tamarind is 3.9 mg/GAE.[21] The lesser color stainability in tamarind is due to the smaller polyphenolic content and the pigments such as leucoanthocyanidin and anthocyanidin. The result shows that tamarind stains less when compared to turmeric, saffron, and paprika. Artificial saliva is used as a control group to mimic the oral environment. The solvent used in this study is water. It is a common substance that has both liquid and solid forms.

If the curing is not sufficient in the direct composite, it causes yellow discoloration due to unconverted camphorquinone. The indirect composites have high conversion rate than direct composites. This may be the reason for less staining of indirect composites. Moreover, externally induced discoloration can be related to surface roughness, surface integrity, and the polishing technique.[16] Regardless of the solubility of pigments, it is the compatibility of the compounds with the organic resin matrix that determines whether the spices stain resin composites by adsorption and absorption.[9]

The limitation in this study during finishing and polishing procedures was that filler particles tend to debond from the resin matrix. It results in the formation of surface defects and voids on the surface. The surface defect depends on the size of the filler particle. Larger filler particles may result in larger surface defect and rougher surface. Thus, the study suggests that both the direct and indirect resin composites respond differently to staining by spices when either finished with Mylar matrix strips or polished with Sof-Lex disks. Other limitations of the current study include *in vitro* use of a spectrophotometer to assess the color differences of only two types of composite resin materials. The samples prepared for this study had flat surfaces. The presence of grooves and pits results in uneven polishing in clinical settings. Hence long-term *in vivo* studies are needed to assess the color stability of the composites. Another limitation of this study is the concentration of the spice solutions used. It varies according to the preference of the individual and the type of food. Hence, 0.1% concentration is only a general assessment. This study only verified the continuous staining for 1 month, which could be more than 1 month. The main drawback of continuous immersion in the staining solution is that it impedes the intermittent consumption pattern and other factors like oral hygiene and clearance of saliva. More investigations are needed, which include longer immersion period.

The result of the present study shows that all the spices used (turmeric, saffron, paprika, and tamarind) cause discoloration of resin composites. Turmeric causes maximum discoloration regardless of the composite type and finishing methods. Based on the staining capacity, the solutions were ordered from highest to lowest: turmeric > saffron > paprika > tamarind. In both groups (group I and II), turmeric showed the highest potential of discoloration. In this study, the indirect resin composite (Adoro) showed less stainability when compared to the direct resin composite (G-aenial). It may be due to additional polymerization of the monomer and the presence of UDMA as the resin matrix.

Conclusion

Within the limitations of the study findings, all the Indian spices used caused discoloration in both direct and indirect resin composites. In both the groups, turmeric showed the maximum discoloration. Indirect composites (Adoro) exhibited less stainability when compared to direct resin-based composites (G-aenial).

Clinical Significance

Both the direct and indirect composites have a tendency to get stained with Indian spices. Therefore, patients should be warned regarding the chances of discoloration due to these spices. Indirect composites stain lesser to Indian spices when compared to direct composites. Thus, indirect composites are recommended for esthetic restorations.

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