Discoloration of Aesthetic Brackets caused by food dyes: Budu and Chili sauce

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Abstract

The purpose of this study is to investigate the effect of food dyes on the color stability of different types of aesthetic brackets.

Chili and budu sauces were selected to test their effect on color stability of aesthetic brackets (Polycrystalline, monocrystalline, zirconium and Polyurethane). Thus, 120 brackets were immersed in selected dyes for 72 hours. A spectrophotometer was used to assess color changes at 24, 48 and 72 hours. Color changes (ΔE) were calculated according to the CIE L*a*b system (Commission Internationale de l'Eclairage, 1976). ANOVA and Bonferroni Test of Multiple variances and t-test used for analyzing the data.

All aesthetic brackets showed high statistically significant difference to the tested chili and budu with p-value of 0.000, 0.0003 respectively. Mean of ΔE monocrystalline brackets showed least color changes to budu sauce (7.19) besides zirconium showed similar effect to chili sauce (13.29). Meanwhile, plastic brackets showed high ΔE value specifically with chili sauce (212, 68).

All tested food dyes had a strong effect on the color stability of aesthetic brackets specifically chili sauce. Zirconium and Monocrystalline bracket shown to be the best aesthetic brackets with high color stability, while plastic brackets are unacceptable.

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Introduction

Malaysian cuisine characterized by the presence of chili sauce and budu in plentifully of its meals. Budu is a dark-brown-to-black condiment. It is a domestic food that fermented, made and consumed mainly by a citizen of East Coast states of West Malaysia, particularly Kelantan and Terengganu; and the Southern district of Thailand. Budu is a form of fish sauce which prepared by fermenting fish with mixture (unprocessed 'budu') combined with tamarind, palm sugar, monosodium glutamate and flavoring compounds. Subsequently, the product is filtered, heat-treated and bottled [1].The fermentation process of (unprocessed 'budu') is done by *Stolephorus* spp., *Sardinella* spp. or *Decapterus macrosoma* with the availability of high salt concentration in covered earthen containers under the sun for 6 to 12 months (Klomkalo et al 2006). The fish sauce has other names such as 'patis' (Philippines), 'ngapi' (Burma), 'nam-pla' (Thailand), 'nuoc-mam' (Cambodia and Vietnam), 'ishiru' or 'shottsuru' (Japan) while it is called 'bakasang' in Indonesia [2].

Chili sauce is somewhat similar in appearance and popularity usage to tomato catsup. The main difference between chili sauce and tomato catsup is that chili sauce consists of least a portion of the tomato seeds and consists of small bits of the chopped vegetable for the flavoring ingredients. The main ingredients for chili sauce are red tomato, sweetener agent which is sugar (sucrose), spices, salts, acids (vinegar) and there are other ingredients such as onion (oftet dehydrated onion flakes), bell peppers (Red or green diced dehydrated peppers), celery, and sweet pickle relish, which

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contributes to the taste of the chili sauce made its form which decides the consistency and most of the chewiness of the finished chili sauce. The proportions and types of the ingredients vary extensively between manufacturers. Therefore, there are a variety of flavors can be expected in chili sauces[3].

In the new era of people's aesthetic interest, fixed orthodontic appliances appearance grows crucial throughout orthodontic treatment. Manufacturers have made many endeavors to fulfill the demands of markets, which includes manufacturing smaller metal brackets, lingual, invisible brackets, conventional or self-ligating brackets, or tooth-colored brackets [4,5].There are multiple new aesthetic brackets that meet demands the ideal requirement of orthodontic brackets that include plastic, ceramic and zirconium.

The current types of plastic brackets use different polymers such as polyoxymethylene and composite for producing of plastic brackets that include either fiberglass reinforcement or reinforced with special fillers[6]. The low modulus of the polymer of the appliances and a peel-off effect similar to that found for metal brackets make it easier and safer to debond [7].

Aesthetic ceramic brackets were first introduced in the 1980s that are mainly made from aluminum oxide. Ceramic Brackets have convent color stability and strength. However possessing excessive bond strength leads to enamel damage during removal as well as bracket breakage because of its brittleness[8]. They are available in two forms according to the manufacturing process polycrystalline or monocrystalline [9, 10]

The manufacturing process classified into translucent (Monocrystalline brackets) and non-translucent ceramic brackets (polycrystalline brackets) [11]. Monocrystalline brackets are translucent because of its structure made of a single crystal which allows passage of light while Polycrystalline brackets are not translucent because there are no boundaries between crystals and defilement in its structure that produced during the manufacturing process, which hindering passage of light [4].

One of the issues of the aesthetic brackets is their discolouration succeeding to short time wear in the oral cavity even in patients with excellent oral hygiene. Aesthetic brackets can be stained due to exogenous and endogenous factors. The reason for endogenous discolouration can be found in the ultraviolet (UV) irradiation and thermal energy. UV light can induce physicochemical reactions in the polymer, causing irreversible color changes of the brackets [12.]

Exogenous influences are beverages or foods that are capable of staining that not excluding colored mouth rinses. The degree of discolouration caused by various substances is affected majorly by the polymeric structure and surface roughness of the brackets. Many previous studies were done and it stated that type of immersion solution and the exposure time influences the degree of color changes [13].

The literature contains numerous studies on the color stability of tooth-coloured brackets with a different type of food or beverages. However, there are no studies on the color changes of aesthetic brackets in consumption with budu or chili sauce. Hereafter, this study objective is to investigate the color stability of different aesthetic brackets in relation to chili sauce and budu like drinks over different intervals of exposure time.

Materials and methods

The study sample consisted of 120 aesthetic Orthodontic brackets. There are four types of aesthetic brackets from different manufacturers that are plastic brackets (*SilkonPlus*), monocrystalline alumina (*Radiance)*, ceramic (polycrystalline alumina (Virage), and zirconium brackets (*Pure™,Ortho Technology*®)). The Brackets were divided into control and experimental groups. The control group subdivides into four subgroups on which each group contains 10 brackets of each type of aesthetic brackets and then were immersed into 15ml in distilled water for 72 hours.

The experimental groups that subdivided into two subgroups: chili sauce group and budu group. Then each group subdivided into 4 groups depending on the types of the aesthetic bracket in which each group immersed into chili sauce and the other one immersed in budu. Each subgroup of different types of the aesthetic brackets have 10 brackets and immersed in 15 ml chili sauce and budu for 72 hours.

Colorimetric Measurements

The entire groups of the different types of aesthetic brackets were color tested by using

spectrophotometer which is color measuring apparatus in a time interval of 24, 48 and 72 hours. In this study the, color measurements were carried out using the Minolta spectrophotometer CM-C3500 (Minolta Co. Ltd, Tokyo, Japan) with a pinhole diaphragm diameter of 3-mm according to the CIE *L*a*b** system (Commission Internationale de l'Eclairage, 1976). A color graph consist of *L**, *a**, and *b** coordinates can be produced by means of mathematical transformations. The *L** parameter corresponds to the degree of lightness and darkness and the* and *b** values to the chroma, where +*a** are red, –*a** is green, +*b** is yellow, and –*b** is blue (Eldiwany *et al.*, 1995). Colour changes (Δ *E* *) were then calculated with the formula $\Delta E^* = [(L_1^*-L_2^*)^2+(a_1^*-a_2^*)^2+(b_1^*-b_2^*)^2]$. It reported that a color change (*E**) of 3.3 is visually perceptible [14] . Therefore, in this investigation, color changes of value more than *E** 3.3 were considered to be clinically unacceptable.

Statistical analysis:

Statistical significance was selected at 95% confidence interval and data were analyzed using SPSS software version 17.0 software.

Test of homogeneity of variance was used and followed by single classification criterion Analysis of Variance (ANOVA) and Bonferroni Test of Multiple Comparison of means to determine the difference of color variation statistically between different types of brackets and between chili sauce and budu. Paired t-test was used to determine color changes of brackets to the different time interval.

Results

The results explained according to the type of solution, duration immersion, and type of aesthetic brackets.

In general, chili sauce and budu caused high color discolouration of all aesthetic brackets in ΔE mean in relation to immersion time as shown in Table 1 and Figure 1.

Plastic brackets showed high discolouration to both tested food dyes; higher in chili sauce (139.64), (212,68) after 24 and 72 hours respectively while in budu (36.5) after 24 hours and it increased to (83.698) after 72 hours of immersion.

Regarding duration of immersion, chili sauce showed to cause greater color changes after 24 hours for all types of brackets which higher color changes by budu. 48 hours mark shows similar color changes caused by chili and budu.

		Chili	Budu
Plastic Brackets	24 hours	139.643	36.543
	72 hours	212.68	83.698
Monocrystalline Brackets	24 hour	19.320	8.988
	72 hours	20.651	11.531
Polycrystalline Brackets	24 hours	10.899	10.355
	72 hours	14.354	21.365
Zirconium Brackets	24 hours	12.136	24.441
	72 hours	18.033	15.810

Table 1. ΔE for all brackets after immersion in food dyes at different intervals (Experimental group).

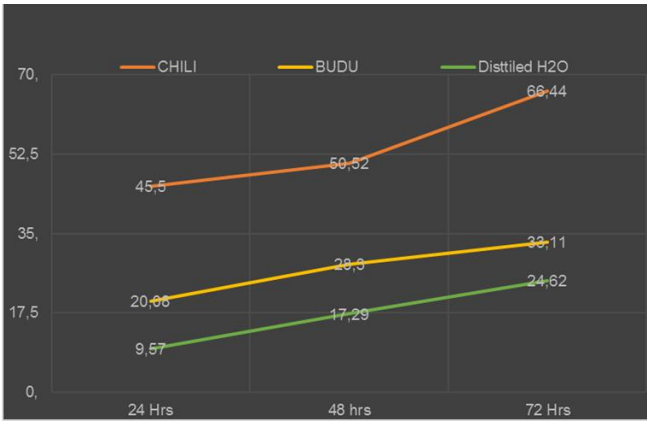

Figure 1. Comparison of ΔE of aesthetic brackets in control and experimental groups at 24, 48 and 72 hours.

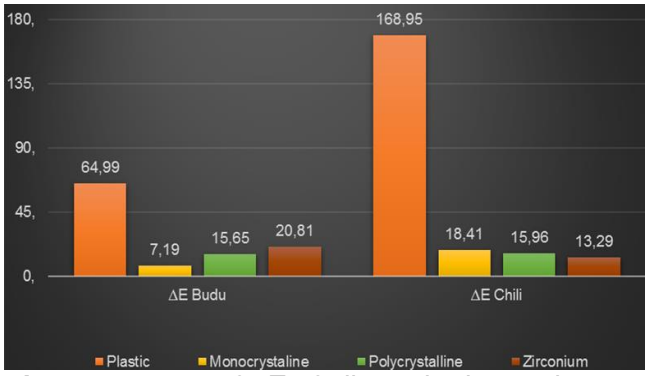

Figure 2. Mean of ΔE of all Aesthetic Brackets to Budu (p=0.003) and chili (p=0.000).

After 72 hours, all aesthetic brackets showed the high statistically significant difference to the tested food dyes. In this study, chili and

budu were presented with a *p-value* of 0.000, 0.0003 respectively (Figure 2).

According to the type of the brackets, monocrystalline brackets show the least color changes to budu in 24, 48 and 72 hours. Meanwhile, polycrystalline brackets were the high color stability changes when exposed to chili sauce in 24 hours and 72 hours duration but zirconium brackets recorded the lowest color changes in 48 hours to chili sauce exposure (Table 2 and Table 3).

(I) Type of aesthetic bracket	(J) Type of aesthetic bracket	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Plastic	Monocrystalline	150.54*	16.09	.000	94.58	206.50
	Polycrystalline	152.99*	16.09	.000	97.03	208.95
	Zirconium	155.66*	16.09	.000	99.70	211.62
Monocrystalline	Plastic	-1.50*	16.09	.000	-206.50	-94.57
	Polycrystalline	2.45	16.09	1.000	-53.51	58.41
	Zirconium	5.12	16.09	1.000	-50.84	61.08
Polycrystalline	Plastic	-1.53*	16.09	.000	-208.95	-97.02
	Monocrystalline	-2.45	16.09	1.000	-58.41	53.51
	Zirconium	2.67	16.09	1.000	-53.29	58.63
Zirconium	Plastic	-1.56*	16.09	.000	-211.62	-99.70
	Monocrystalline	-5.12	16.09	1.000	-61.08	50.84
	Polycrystalline	-2.679	16.09	1.000	-58.63	53.30

Table 2. Bonferroni Test between brackets after immersion in Chili sauce.

(I) Type of aesthetic bracket	(J) Type of aesthetic bracket	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Plastic	Monocrystalline	57.81*	10.86	.004	20.03	95.58
	Polycrystalline	49.34*	10.86	.011	11.57	87.12
	Zirconium	44.18*	10.86	.022	6.40	81.95
Monocrystalline	Plastic	-57.81*	10.86	.004	-95.58	-20.03
	Polycrystalline	-8.46	10.86	1.000	-46.24	29.32
	Zirconium	-13.62	10.86	1.000	-51.40	24.15
Polycrystalline	Plastic	-49.34*	10.86	.011	-87.12	-11.57
	Monocrystalline	8.46	10.86	1.000	-29.31	46.24
	Zirconium	-5.16	10.86	1.000	-42.93	32.62
Zirconium	Plastic	-44.19*	10.86	.022	-81.96	-6.40
	Monocrystalline	13.626	10.86	1.000	-24.15	51.40
	Polycrystalline	5.16	10.86	1.000	-32.62	42.94

Table 3. Bonferroni Test between brackets after immersion in Budu.
*. The mean difference is significant at the 0.05 level.

According to the type of aesthetic brackets and color stability of food dyes, ΔE mean of monocrystalline brackets showed least color changes to budu sauce (7.19), zirconium brackets showed least color changes to the chili sauce (13.29). Meanwhile, plastic brackets showed high discolouration for both test food dyes which is higher for chili sauce (139.64) and (212, 68) after 24, 72 hours respectively. While relation to budu (36.5) after 24 hours increase to (83.698) after 72 hours of immersion. A total of ΔE chili sauce caused higher color discolouration of all aesthetic brackets with 72 hours (66.44), while with budu ΔE was (33.11) as seen in Figure 1.

Discussion

The color changes can be detected visually. The observation of color changes and discolouration is very obvious and clear but is very subjective as human eyes have limited detection of tiny alteration in color difference is limited[15]. Therefore, colorimetric measurement is essential to assess color changes and difference among tested samples ΔE is used to evaluate the correlation of discolouration in dental material like composite resin or prosthesis. From previous studies, ΔE greater than 2.0 is easily noticed visually while ΔE values range from 1.0 to 2.0 cannot be detected visually by the human eye [16, 17 & 18]. It suggested that ΔE value should range from 3.3[19] - 3.7[20] can be observed clinically. Therefore, these values can be used as a reference evaluate color changes and of tooth colored material used in orthodontics like aesthetic brackets and elastics[21].

From previous studies, ΔE threshold greater than 2.0 is easily noticed visually. It was suggested that ΔE range 3.3 - 3.7 can be observed clinically [22, 23].

The recent study shows the plastic brackets had significant color changes to chili sauce and budu and it is least color stability between all compared brackets with ΔE values of 139.643, 154.5142, 212.68 in 24, 48 and 72 hours respectively. Previous studies showed plastic brackets that composed from composite or modern polymers undergo color changes due to oxidation of unreacted double bonds in polymer matrix and development of degenerated products from polymer oxidation or water dispersion. These chemical reactions lead to changes in optical properties of the plastic brackets which is accounted for visual perception of its color changes [24].

Microscope appearance of Monocrystalline brackets shows homogenous sizes of aluminum oxide particles that consist limited spaces between the parties, making its uptake to water and stain minimized. In the recent study results, it shows good color stability in which ΔE is 20.651 after 72 hours immersion in child sauce and ΔE is 11.531 after 72 hours

immersion in budu.

Polycrystalline bracket microscopically composed of different sizes of aluminum oxide particles and binder that lead to presence of a lot of spaces and pores in addition to the propagating lines between particles that results from machining interferences that escalate stain uptake and lead to colour changes when compared to monocrystalline brackets which is showed in the value of ΔE of 21.365 when immersed budu solution after 72 hours. However, polycrystalline shows less color changes when immersed in chili sauce as ΔE values is 10.899, 15.2549 and 14.354 in 24, 48 and 72 hours respectively.

The zirconium bracket showed the comparable color stability to both types of ceramic brackets, showing no dramatic variation between the ΔE values of chili sauce 18.033 and budu 15.810 after 72 hours immersion duration. The color stability of zirconium brackets might be explained due to its crystalline formation of dioxide of zirconium in monoclinic form [25]

The previous study concluded that color stability is affected by the type of immersion solution and exposure time and discolouration increased in all brackets after 24 hours to black tea, coffee and red wine with ΔE* > 3.7 [26,27,28] .

This is in agreement with our finding in relation tested food dyes chili sauce and budu recent finding on chili sauce and bud in the recent study. These findings coincide with other studies as the staining and color alteration is due to cumulative effect of colorant in the solution[14,18]

The study showed chili sauce color changes is significant for plastic brackets in compare with budu while there are minor differences in color changes when compare chili sauce and budu effect on other brackets.

Conclusions

Despite the limits in-vitro study and not representing the actual oral environment of the patient, it provides information on the color stability of aesthetic brackets in response to exogenous factors and valuable suggestions for best selection of aesthetic brackets for both clinicians and patients during orthodontic treatment plan.

The food dyes tested in this study like chili and Budu had a strong effect on the color stability of investigated aesthetic brackets. Then again, Zirconium and Monocrystalline bracket showed the best color stability.

In order to select suitable aesthetic brackets for orthodontic treatment is multifactorial based on the cost, patients' concerns and chemical and physical properties of the brackets. In spite of the high-cost ceramic brackets (monocrystalline or polycrystalline) but the study shows reasonable, resistant to discoloration, as well zirconium brackets showed the similar result of color stability to chili sauce and budu.

Despite latest advances in newly developed plastic brackets and its low cost still showed clinically unacceptable color stability in the long term.

The effect of Discoloration effect chili sauce and budu on the aesthetic brackets still not fully understood as the type of colorant and its mechanism in relation to brackets microscopic features and need furthermore studies to investigate this correlation.

Declaration of Interest

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