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The Effect of Silver Diamine Fluoride and Potassium Iodide on Colour Changes in Caries Process

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Abstract

Silver diamine fluoride (SDF) is a topical fluoride that is normally used to control and inhibit the progression of caries. It is also being used as a desensitising agent. However, the black staining appearance of the tooth structure due to SDF application created a major concern among the patient. This recent study was aimed to investigate the effect of potassium iodide (KI) in preventing staining of the tooth structure from SDF. A total number of 30 extracted premolar teeth were divided into three groups. Each group consist of 10 samples and the colour measurement was recorded using Vita Easyshade Advanced 4.0 (VITA Zahnfabrik GmbH, Bad Säckingen, and Germany) at three different stages (baseline, demineralization and remineralization). Colour differences of colour dimension L, a, b (ΔL, Δa, Δb) and colour changes (ΔE) between groups at different time and value were calculated. There were significant differences among the groups (p<0.05*).* SDF groups recorded the highest colour changes compared to other groups whereas teeth treated with KI showed minimal staining and ΔL were lighter compared to SDF group. The study showed that SDF which followed by KI treatment reduced the staining effect on the structure compared with the SDF treatment alone.

Keywords: Aesthetic; Fluoride; Potassium Iodide; Silver Diamine Fluoride

Abbreviations: SDF: Silver Diamine Fluoride; KI: Potassium Iodide; CIE: Commission International del'Eclairage for L*a*b colour system, T0: Colour at baseline, T1: Colour at demineralization, T2: Colour at remineralization; ICDAS: International Caries Detection and Assessment System; SPSS: Statistical Package for Social Sciences.

Introduction

Dental caries is an oral health disease which continues to become a worldwide problem [1-4]. It is a process that involves multiple factors such host or tooth microorganisms, substrate and time [5,6]. The frequency of sugar consumption has been found to be the main

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aetiological factor for dental caries in children of age under 5 [7]. Dental caries is considered a non-age-related disease that occurs to all humans including children and adults [8]. It is also a major public health globally with 2.3 billion people worldwide suffer from dental caries [9, 10]. In 2005, a study in the urban Philippines reported that dental caries prevalence of primary dentition was 71.7% [11]. A study also found that a higher prevalence among rural schoolchildren in the north east Malaysia which was at 93% [12]. Meanwhile, a study by Satvinder et al., has documented a lower prevalence of 44.6% of urban schoolchildren in Kuala Lumpur [13]. There was a survey in the United States revealed untreated caries among children and adults [1].

Dental caries begins with the dissolution of the tooth's mineral structure in a process called demineralization. Demineralization occurs due to the presence of carbohydrate substance surrounding the tooth structure, which later acts as a source for the bacterial activity [14]. These substrates will further be fermented by acidogenic bacteria such as *Streptococcus mutans*, *Streptococcus sobrinus* and *Lactobacillus acidophilus* [15,16,17] into lactic acids that causes lowering of the pH at the area. If left untreated, the pH will remain low and will cause more demineralization of the tooth structure which will end up creating a cavity formation.

The traditional method to arrest the progression of dental caries is by tooth preparation where drilling and cutting on the caries site of the tooth structure. This method of treatment is aimed to halt and remove the caries before restoring the cavity with adequate material such as resin composite and amalgam. Nowadays, clinician practicing a technique which is less invasive and to preserve more tooth structure. The technique is so called a non-invasive method [18]. This method aims to prevent caries progression and enhance the remineralization process. Hence, the diagnostic method to detect early caries lesion is crucial to reduce the need for drilling and filling. The most common method used among clinician is visual examination with current caries identification system named the International Caries Detection and Assessment System (ICDAS) which based on score 0 to 6 [19-22]. For instance, the early caries may be detected by the ICDAS score 1 that is for the first visual change in enamel, while ICDAS score 2 represents a distinct visual change in enamel [20,23]. Other advanced caries diagnostic methods include radiographs, optical caries monitor, fiber-optic transillumination, light/laser-induced fluorescence, electrical current and ultrasound caries detector, with their advantages and disadvantages features [24,25].

Several studies found that fluorides application can prevent early caries [3,4] and created more decay-resistant enamel [26]. Fluorides help in remineralization by forming fluorohydroxyapatite in the enamel or dentine. Fluorohydroxyapatite is the least soluble mineral. These fluorides also reported to inhibit enzymatic activity by transporting into the cell as hydrogen fluoride and dissociates into H+ and F- when the cell's cytoplasmic pH is more alkaline than the neutral medium [27] thus will directly inhibit bacterial activity.

Currently, silver diamine fluoride (SDF) has been used to prevent caries [20,21,28] and to inhibit cariogenic biofilm formation [29,23]. SDF is a colourless liquid that is reported to have an intense antibacterial effect. SDF is also used to treat pit and fissure caries, root caries, as well as to control progression of caries in patient with high caries risk, and to desensitize the tooth [30]. Shimizu and Kawagoe [31] described three possible mechanisms of action of the SDF caries prevention activity. First, the silver ions and inorganic compounds of SDF help in the dentinal tubules obliteration. Second, the reaction product between SDF and tooth mineral components such as Calcium fluoride (CaF2) and silver phosphate (Ag3Po4) are responsible for caries prevention and hardening dental caries, respectively. Third, SDF also inhibits collagenase activity, hence preventing collagen degradation.

The major drawback of SDF is where the black staining occurred on the tooth structure after the application. The effect of staining brings a major concern for those who are very particular with their aesthetic appearance [32]. Studies found that application of potassium iodide (KI) after SDF treatment reduced the staining effect which was created by SDF [33,34,35]. KI is widely used a nutritional supplement. Generally, the study aimed to look at the effect of KI on the staining of the SDF-treated demineralised tooth. Specifically, we aimed to evaluate the changes in colour dimension (L, a and b) and colour changes (ΔE) of the SDF-treated demineralised tooth, with or without the presence of KI.

Materials and Methods

Specimen preparation

This is an *in-vitro* experimental study conducted in Multidisciplinary Laboratory at School of Dental Sciences, Universiti Sains Malaysia. Sample size was calculated for all objectives. Only the highest sample size was taken as study sample. The highest sample was obtained using the single mean formula,

$$n = \left(z\frac{\sigma}{\Delta}\right)^2$$

Where n = sample size, z = statistic for a level of confidence (95%, z = 1.96), σ = standard deviation (σ = 8.3 [24], and Δ = 3.7, perceptibility threshold of colour changes (ΔE) which tooth colour was clinically visible to naked eye [36, 37]. The previous studies also showed the significant difference with a sample size of 10 [33, 34]. The minimum sample size required round up to 10 samples.

Thirty extracted human premolar teeth were collected [35,38]. The inclusion criteria were sound premolar teeth which were extracted for orthodontic treatment [39] from patients 16-30 years of age. The exclusion criteria were carious teeth, filled teeth or teeth that have any pathology [39]. The teeth were stored in distilled water prior to usage. Before testing, the premolars were removed from the solution and washed with water. Mesial and distal surfaces of the crown were selected and recorded for colour measurement during baseline, demineralization and remineralization stages.

Demineralization and remineralization procedures

All samples were treated in 37% phosphoric acid (Alpha-Etch37 ®, Lincolnwood, Illinois) [40] for 30 minutes after the baseline colour measurement. The samples were washed with copious water to remove all the acids on the surfaces. After being dried, the teeth produced white chalky appearance. The following details of study groups:

a) **Control:** demineralization solution and only treated with distilled water as the remineralization medium.
b) **SDF:** demineralization solution treated with 38% SDF (Fagamin, Tedequim SRL, and Argentine) and immersed in the 10 ml human saliva as the remineralization medium for 24 hours.
c) **SDF+KI:** demineralization solution and applied with 38% SDF (Fagamin, Tedequim SRL, Argentine). Saturated KI (Upsher-Smith, Maple Grove, MN) was applied immediately after SDF and immersed in the 10 ml human saliva as the remineralization medium for 24 hours.

Thermocycling and colour measurement

All groups were incubated in the incubator (Cultura, Ivoclar Vivadent, Swiss) under 37°C [41] for 24 hours after both demineralization and remineralization procedures. Then, samples were thermocycled for 1500 cycles (55 ± 5 ºC and 10 ± 5 ºC). Data on colour measurement for each sample were recorded using Vita Easyshade Advanced 4.0 (VITA Zahnfabrik GmbH, Bad Säckingen, and Germany) by measuring the lightness, chroma and hue. Colour assessments (n = 10 per group) were taken at three different time points: T0: baseline (after storage of the tooth samples in formaldehyde), T1: 30 minutes after demineralization procedure and T2: after remineralization and thermocycling (completed 1500 cycles after SDF application) as shown in Figure 1. The Vita Easyshade Advanced 4.0 (VITA Zahnfabrik GmbH, Bad Säckingen, Germany) measured the colour three dimensionally using the Commission International del'Eclairage (CIE) L*a*b colour system. L* represented the lightness or darkness of grays ranging from white (L: 100) and black (L: 0), a* represented from red to green and b* represented from yellow to blue (Figure 1). Colour measurement was repeated for three times and the average value was recorded. Colour changes (ΔE) were calculated using the following formula [33]:

$\Delta E_{(L^*, a^*, b^*)}$ T0-T1= $[(\Delta L^*_{T1\text{-}T0})^2 + (\Delta a^*_{T1\text{-}T0})^2 + (\Delta b^*_{T1\text{-}T0})^2]^{1/2}$
$\Delta E_{(L^*, a^*, b^*)}$ T0-T2= $[(\Delta L^*_{T2\text{-}T0})^2 + (\Delta a^*_{T2\text{-}T0})^2 + (\Delta b^*_{T2\text{-}T0})^2]^{1/2}$
$\Delta L^* = L^*_{T1} - L^*_{T0}$; $L^*_{T2} - L^*_{T0}$
$\Delta a^* = a^*_{T1} - a^*_{T0}$; $a^*_{T2} - a^*_{T0}$
$\Delta b^* = b^*_{T01} - L^*_{T0}$; $b^*_{T2} - b^*_{T0}$
T0 = Baseline, T1= after demineralization, T2 = after remineralization and thermocycling

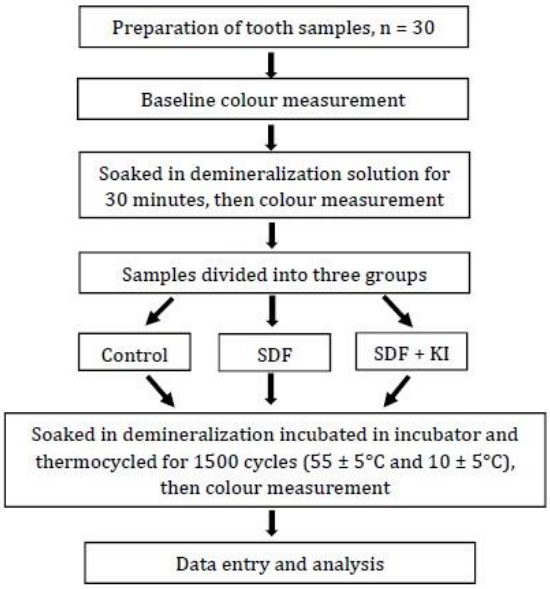

Figure 1: Flow chart of study design.

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 24.0 and Microsoft Excel were used to enter and analyse the collected data. Data normality was tested using One

Sample Kolmogorov-Smirnov test with $p > 0.05$. One-way ANOVA was conducted to evaluate value L*a*b* within groups. One-way ANOVA with Bonferroni post hoc comparison to detect the colour changes at different time. The level of significance was set at 0.05.

Ethical approval

Ethical clearance for this study was obtained from the Universiti Sains Malaysia Human Research Ethics and Committee (USM/JEPeM/18010027).

Results

Results of one-way ANOVA showed that the mean of colour dimension (L, a and b) between different time (T0, T1 and T2) was significantly different for all groups (Table 1). SDF group showed a significant decrease in L, a and b values at T1 to T2 with *p* value <0.000. There was no statistically significant between SDF and SDF + KI for colour changes (ΔE) from T0 to T2. However, ΔE of SDF group recorded higher compared to ΔE of SDF + KI group (Table 2).

Variables	Group	Mean (SD)			F statistic[a]	*p* value[a]	(df)
		T0	T1	T2			
L	Control	72.2 (1.8)	66.3 (4.3)	67.2 (4.2)	7.944	<0.002	2, 27
	SDF	77.8 (3.0)	68.8 (3.7)	42.6 (8.4)	3.778	<0.000	
	SDF + KI	83.5 (2.3)	76.2 (3.0)	53.2 (7.0)	10.692	<0.000	
a	Control	-0.7 (1.1)	-0.04 (1.2)	0.6 (0.98)	7.786	<0.036	
	SDF	-0.6 (0.7)	0.7 (0.99)	9.5 (1.7)	212.149	<0.000	
	SDF + KI	-1.2 (0.5)	-0.2 (0.8)	4.8 (1.3)	10.153	<0.000	
b	Control	22.9 (5.0)	22.8 (4.0)	30.2 (3.1)	118.796	<0.000	
	SDF	24.7 (4.9)	23.8 (4.0)	31.8 (4.2)	118.796	<0.001	
	SDF + KI	25.0 (2.6)	24.6 (3.1)	36.3 (3.1)	42.413	<0.000	

[a] One-way ANOVA test. Significance ($p < 0.05$). Mean scores are significantly different by post hoc test (Bonferroni procedure).

Table 1: Colour dimension of L, a and b values between groups at different interval time.

Variables	Group	Mean (SD)	F statistic[a] (df)	*p* value[a]
ΔE (T0-T1)	Control	7.02 (3.58) [b]	1.794 (2,27)	0.186
	SDF	9.87 (3.43)[b]		
	SDF + KI	7.89 (3.32)[b]		
ΔE (T0-T2)	Control	10.65 (3.72)	50.078 (2,27)	<0.000
	SDF	37.70 (8.95)[c]		
	SDF + KI	33.15 (5.63)[c]		

[a] One-way ANOVA test. Significance ($p < 0.05$).

[b c] Two pair of mean scores are not significantly different by post hoc test (Bonferroni procedure).

Table 2: Colour changes (ΔE) for T0-T1 and T0-T2 between study groups.

Discussion

SDF at a concentration of 38% was known for its ability to arrest caries and to treat hypersensitivity [38,42]. Oliveira *et al.,* suggested that SDF may act as an alternative option to glass ionomer cement to control carious progression [20,43]. Besides, there were no significantly differences between application glass ionomer cement and SDF [21,33] in the primary dentition of six-year-old schoolchildren and their first permanent molars. A study by Quock *et al.,* also agreed that SDF does not adversely affect the bond strength of resin composite to non-carious dentine [44]. However, the decayed tooth structure will darken as the caries lesions arrest after application of SDF. Because of this reason, SDF is mostly applied in the primary dentition before exfoliation. Saturated solution of KI has been suggested to be applied after SDF to reduce colour changes. From the finding, control group and SDF group produced more to the greener colour for value an at the baseline. Whereas, the value of b was more to the yellower colour. However, L value for SDF group is higher compared to the control group. For SDF and KI group, the results showed the highest L value with a greener and b yellower value compared with the other groups.

For the demineralization colour measurement, all groups recorded a decrease in L value. These results contradict with Tolcachir et al., [45] that recorded higher L value due to an increase in subsurface porosity which affected the absorption of the light. In this recent study, the higher L

value indicated higher demineralization in the enamel structure. This result corresponds with Kim et al., [46], which shown that the higher L value correlates with the clinical appearance of the teeth that appeared to be white after demineralization. Based on the findings of this study, it is concluded that topical application of silver or fluoride ions can increase the mineral density of demineralized enamel and dentine lesions during remineralization. The synergistic effect of silver and fluoride ions is relatively small [39].

The teeth surface does not immediately turn black after thin layer of SDF application. However, after 24 hours being incubated in saliva at 37°C, the black appearance can be seen on the etched teeth surface. No staining was found at sound teeth structure. This corresponds to the fact that SDF only stained demineralised teeth. The thermocycling process has further darkened the colour based on naked eyes observation. For SDF group, the L value has been decreased significantly as the etched surfaces turned black while a and b value increased. The drop in L value correlated with the black staining that appeared after SDF application. This finding was in accordance with previous study by Vinh Nguyen et al., [47], where the teeth with SDF regardless of the material used showed reduce in lightness value. As for the SDF + KI group, there was also a decrease in the L value but not as much as the SDF group. Vinh Nguyen et al., [47] also reported that the application of KI after SDF helps to reduce the intensity of darkness produced by SDF. The application of saturated KI helped to reduce the black staining by forming white-yellow precipitate that prevents a further decrease in L value. However, KI is questionable because it may weaken the bonding of final restoration while reducing the staining of SDF [35]. Nevertheless, it is essential to prevent and also arrest the caries progression. It has been improved that the lightness is increased with SDF. A study by Sayed *et al.,* has found that colour changes were significant with SDF [41] that supports the finding of the study. As for the colour changes, SDF group recorded the highest colour changes compared to SDF + KI group. Jeremy et al., has also stated the UCSF protocol for caries arrest using SDF followed by KI. Silver allergy is a contraindication. Whereas saturated solution of KI is contraindicated in pregnant woman and during breastfeeding due to concern of iodide [42].

Conclusion

SDF and KI treatment helps to reduce the staining effect done by SDF treatment alone. However, the effect of KI does not reduce the staining clearly instead, addition of KI on the teeth surface formed yellow precipitates.

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