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The Effect of Heat-polymerizing Method on Color Stability of Acrylic and Composite Resin Denture Teeth

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Abstract

Objectives: The purpose of this study was to investigate the color stability of acrylic and composite denture teeth after heat-polymerization method.

Methods: Three different brands of acrylic denture teeth: Livera Alpha (LA), Yamahashi (YA) and Major Dent (MA) and 2 different brands of composite denture teeth: Yamahashi PX (YC) and Endura (EC) were tested. Ten maxillary central incisors from each group were pressed onto putty-type polyvinyl siloxane in order to measure color in the same area of denture teeth. Color, at cervical third and incisal third, was recorded by spectrophotometer in CIE L*a*b system. All specimens were undergone heat-polymerization of heat-curing acrylic resin. After flask cooling for 24 hours, the specimens were removed. The color measurement was performed at the same area of each specimen. Color differences (ΔE) was calculated. A ΔE of ≤3.3 was considered clinically acceptable. The data were evaluated by 3-way repeated-measures ANOVA and Tukey HSD test (α =0.05).

Results: The ΔE of LA, YA, EC, MA and YC at incisal third were 4.41±0.56, 2.45±0.60, 0.76±0.57, 0.75±0.24 and 0.63±0.24 respectively. At cervical third, the ΔE of LA, YA, EC, MA and YC were 4.59±1.26, 2.44±1.08, 0.59±0.36, 0.81±0.61 and 1.22±0.78 respectively. The highest ΔE values were found in LA. These values were significantly higher than those obtained from other brands (p<0.05) and beyond clinically acceptable level.

Conclusions: After heat-polymerization, the color of LA changed significantly at both incisal and cervical areas. On the other hand, color stability of YA, EC, MA and YC were clinically acceptable.

Keywords: acrylic denture teeth, color stability, composite denture teeth, heat-curing polymerization

Introduction

The matching color between natural teeth and artificial denture teeth plays an important role in esthetics of removable dental prosthesis and affects patient's quality of life.[1,2] Color stability is a crucial physical property in order to maintain color matching.[3] Both intrinsic and extrinsic factors can cause color change of denture teeth.[4] Intrinsic factors are the type and composition of material.[5] Extrinsic factors are physical and chemical conditions, such as thermal change and denture cleansing agent.[4-6]

Various types of denture teeth are available in the market which are acrylic resin, composite resin and porcelain. Among these 3 types, acrylic resin denture teeth are widely used due to excellent chemical bond to denture base.[7] Composite resin denture teeth are gaining their popularity because of their esthetics and improved physical properties.[8,9] Although porcelain denture teeth exhibit the highest wear resistance and color stability compared to other artificial teeth, they has poor chemical bond to denture base.[5]

There are many studies investigated the color stability of denture teeth immersed in various types of chemical agents.[1-3] Systematic review by Tieh *et al.*, concluded that the degree of discoloration of denture teeth after immersion was time-dependent and the largest extent was found in initial phase.[2] An *In vivo* study by Rosentritt *et al*., found that composite resin veneers significantly exhibited higher color changes compare to acrylic resin denture teeth.[8] However, the discolorations of both materials were clinically accepted.

In conventional denture fabrication, polymerization process of denture base is inevitable. There is only 1 study about the color stability of denture teeth after the polymerization process.[5] This study showed that among 10 different brands of acrylic resin denture teeth, Biotone IPN and SR Vivodent PE teeth presented the greatest change in color; Mondial 6, Biolux, and Trilux teeth presented the least change in color. However, all ΔE values are within acceptable clinical limits for all brands.

Due to the lack of the study about color stability of denture teeth after polymerization process of denture base. The purpose of this study was to investigate the effect of heat-polymerization method on color stability of denture artificial teeth. Three different brands of acrylic artificial teeth and 2 different brands of composite artificial teeth that were commonly used in Thailand were investigated in this study. The null hypothesis was that the color stability of acrylic and composite resin artificial teeth was not affected by heat-polymerization method.

Materials and Methods

Three different brands of acrylic resin denture teeth; Livera Alpha (LA), Yamahashi (YA) and Major Dent (MA), and 2 different brands of composite resin denture teeth; Yamahashi PX (YC) and Endura (EC), were included in this study (Table 1). Total of 50 maxillary central incisors (10 from each group) were evaluated. All specimens were subjected to heat-polymerization method. Color measurements were performed at 4 timepoints in order to investigate the effect of heat-polymerization method on color stability of denture artificial teeth.

Heat-polymerization method

All specimens were put in a brass flask used for denture fabrication without embedding in plaster. The flask was placed in a water bath (KaVo EWL 5518, KaVo Elektrotechnishes Werk GmbH, Warthausen, Germany). Then the specimens were subjected to heat-polymerization according to manufacturer's instruction for heat-curing acrylic resin: boiling temperature was divided into 2 cycles; 80°C for 4.5 hours then 95°C for 5.5 hours. After flask cooling for 24 hours, the specimens were removed, washed with distilled water, and dried with paper.

Color measurement

Prior to heat-polymerization process, each specimen was pressed onto putty-type polyvinyl siloxane in order to measure color change in the same areas of each artificial tooth. Color measurement was performed at the center of cervical third and incisal third of each specimen and recorded at 4 timepoints: before heat-polymerization as baseline (B), 1 day (D1), 15 days (D15) and 30 days (D30) after the polymerization process by spectrophotometer (UltraScan-Pro Hunterlab® Hunterlab, VA, USA) in Commission Internationale de l'E´clairage (CIE) system.[10,11]

Visual color test

To determine clinical significance, the visual color test was performed. Three female fifth-year dental students who had a theoretical knowledge of color were

randomly selected as operators. They have normal vision tested by Snellen's Eye Chart[12] and they don't have color vision anomalies tested by Ishihara's color charts.[13] Then they were asked to compare the color of 50 denture teeth to un-treated denture teeth of each group at day 1, day 15 and day 30 after heat polymerization. All comparisons were performed against a white background for 5 seconds under a 15 W cool white fluorescent strip lamp. They marked the score 0 or score1 for each denture tooth when the color was not changed or the color was changed respectively (maximum=10 for each brand).

Statistical analysis

The denture teeth color were measured by using the CIE L* a* b* system then calculates color differences (ΔE) by using the formula : $\Delta E = (\Delta L^2+\Delta a^2+\Delta b^2)^{½}$. Color differences (ΔE) was calculated. A ΔE of ≤3.3 was considered clinically acceptable.[14,15] The effect of type of denture teeth, position and time after the polymerization process on color stability (interactions among these factors) was analyzed by 3-way repeated-measures ANOVA and the Tukey HSD test (α =0.05).

Results

Table 2 showed the means and standard deviations of ΔE values of all brands both incisal and cervical areas at 1 day, 15 days and 30 days after the heat-polymerization process. The ΔE at day 1 of LA, YA, EC, MA and YC at incisal third were 4.41±0.56, 2.45±0.60, 0.76±0.57, 0.75±0.24 and 0.63±0.24 respectively. At cervical third, the ΔE of LA, YA, EC, MA and YC were 4.59±1.26, 2.44±1.08, 0.59±0.36, 0.81±0.61 and 1.22±0.78 respectively. The highest ΔE values of LA were obtained; these values were significantly higher than those obtained from other brands (p<0.05) and beyond clinical acceptable level, whereas the other brands were considered clinically acceptable (ΔE ≤ 3.3) for both incisal and cervical areas. Resulting from the visual color test by 3 observers, the mean values(SDs) of LA artificial teeth which had color changed after heat polymerization was 7.67±0.57, 7.33±0.57, 8.33±1.15 at day 1, day 15 and day 30 respectively. However, the other brands had the number of color-changed denture teeth less than 5 (Table 3).

Considering the time after the polymerization process (Day 1, Day 15 and Day 30), regardless of brands and position of denture teeth, there were not statistically different. The same tendency was noticed for each position of denture teeth (incisal and cervical areas) (Table 4). The interaction between the brand of denture teeth and the position of denture teeth was statistically significant (p<0.001) (Table 4) and the interaction among the brand of denture teeth, position and time after the polymerization process was also statistically significant (p=0.001).

Table 1: Denture teeth used in this study

Brand	Code	Shade	Materials	Manufacturers
Livera Alpha	LA	A3.5	acrylic resin	SHOFU INC., Japan
Yamahashi	YA	A3.5	acrylic resin	Yamahashi Dental MFG., Co., Japan
Major Dent	MA	2L	acrylic resin	Major Prodotti Dentari S.p.A., Italy
Yamahashi PX	YC	A3.5	composite resin	Yamahashi Dental MFG., Co., Japan
Endura	EC	A3.5	composite resin	SHOFU INC., Japan

Table 2: Mean values(SDs) of color differences (ΔE) in denture teeth

	Incisal area			Cervical area		
	Day 1	Day 15	Day 30	Day 1	Day 15	Day 30
Livera Alpha (LA)	4.41(0.56)^a	4.35(0.47)^a	4.40(0.64)^a	4.59(1.26)^a	4.37(1.06)^a	3.68(0.97)^a
Yamahashi (YA)	2.45(0.60)^b	3.26(0.56)^b	3.17(0.40)^b	2.44(1.08)^b	1.17(0.66)^b	1.62(0.76)^b
Major Dent (MA)	0.75(0.24)^b	0.54(0.43)^b	0.81(0.61)^b	0.81(0.60)^b	1.19(0.52)^b	1.20(0.78)^b
Yamahashi PX (YC)	0.63(0.24)^b	0.57(0.45)^b	0.82(0.46)^b	1.22(0.78)^b	1.57(0.75)^b	1.11(1.05)^b
Endura (EC)	0.76(0.57)^b	1.15(0.35)^b	1.40(1.29)^b	0.59(0.36)^b	1.13(0.65)^b	0.63(0.38)^b

Different lowercase letters within column denote group differences that are statistically significant (p<0.05).

Table 3: Mean values (SDs) of color change scores by 3 observers

Brand	Day 1	Day 15	Day 30
Livera (LA)	7.67(0.57)[a]	7.33(0.57)[a]	8.33(1.15)[a]
Yamahashi (YA)	4.33(0.57)[b]	3.67(1.15)[b]	3.67(0.57)[b]
Major Dent (MA)	2.00(1.00)[b]	1.00(1.00)[b]	1.33(0.57)[b]
Yamahashi PX (YC)	1.67(0.57)[b]	1.33(0.57)[b]	1.00(0.00)[b]
Endura (EC)	1.00(1.00)[b]	1.00(0.00)[b]	0.67(0.57)[b]

Different lowercase letters within column denote group differences that are statistically significant ($p<0.05$)

Table 4: Results of 3-way repeated-measures ANOVA

Source	df	SS	MS	F	*p*
Brands	4	524.560	131.140	261.588	<0.001*
Position	1	1.541	1.541	3.074	0.081
Time	2	0.233	0.116	0.232	0.793
Brands x Position	4	30.328	7.582	15.124	<0.001*
Brands x Time	8	5.677	0.710	1.416	0.190
Brands x Position x Time	8	13.035	1.629	3.250	0.001*

*$p<0.05$ denotes statistically significant difference

Discussion

In clinical situation, we occasionally encountered the problem that the color of denture teeth in finished denture mismatched with adjacent nature teeth. Therefore we would like to identify the cause of this problem. In this present study, we investigated the color stability of 3 brands of acrylic denture teeth and 2 brands of composite resin teeth after heat-polymerization method. The null hypothesis of this study was partially accepted as the color stability of acrylic resin denture teeth was affected by heat-polymerization method. However, there was no significant effect on color stability of composite resin denture teeth.

The previous study compared the effects on color stability of heat polymerization to those of microwave polymerization.[5] All 10 brands of acrylic resin teeth had ΔE less than 3.3 in both groups of polymerization, indicating that the color change would likely not be clinically perceptible. Nevertheless, not only the acrylic denture teeth tested in their study are not commonly available in Thailand, but also composite resin denture teeth are not yet investigated. Therefore, we would like to conduct similar investigation with the acrylic and composite resin denture teeth that are commonly used in Thailand.

The measurement of artificial teeth color in this research was measured by spectrophotometer and observers using visual color comparisons. Considering the results between the visual evaluation and spectrophotometer, LA were marked the highest scores in visual evaluation corresponding with the highest ΔE value which was measured by spectrophotometer. These results suggested that the color change in LA is clinically perceptible and unacceptable. The ΔE of other brands (YA, MA, YC, EC) was lower than 3.3 both incisal and cervical areas, so most observers could not detect the color difference between denture teeth and marked low color change scores for them (Table 3). However, the visual comparison could not detect the little amount of color change. In addition, it could lead bias from variables namely light conditions, experience, age, and fatigue of the human eyes.[16] Therefore, spectrophotometer was used instead of visual evaluation in order to eliminate subjective interpretation.[17,18]

To avoid errors from the operation of the spectrophotometers, the machine was calibrated before color measurement of each group. After that, we measured the color values of the control group and compared with the previous results. Apart from the operation of the spectrophotometer, the position of the specimen could influence

the measurement of color. To ensure the maintenance of each denture tooth in the same place during all measurements, a silicone rubber tool was created specifically for each brand.

Thickness and smoothness of the tooth surface may influence its color. The lightness of the resin increased as thickness decreased.[19] However, no thickness and smoothness was altered in this present study. Previous study demonstrated that the color stability of composite resin veneers and acrylic resin teeth was observed.[8] The authors observed that the additional reagents in acrylic resin teeth, dibenzoyl peroxide, which remained after polymerization may affect color stability. LA teeth may present more levels of dibenzoyl peroxide than the other brands. According to the study of Guler *et al.*, The acrylic resin was usually used different monomers in their liquids such as MMA (methyl methacrylate), HDMA (hexamethylene glycol dimethacrylate), HEMA (2-hydroxy ethyl methacrylate).[3] Hersek *et al.*, and Lazzetti *et al.*, concluded that hydrophilic materials presented a greater color change than hydrophobic materials.[20] Therefore, LA teeth may contain more HEMA, which has more hydrophilic than HDMA and MMA, than other acrylic teeth brands. For YC and EC teeth, the factors which can affect the change in color of resin composite are chemical differences among the resin components, both filler type and concentration and polymerization time during the processing of the heat-curing material.[8]

Several studies found that the higher chromatic or darker shades had larger color changes.[8,21,22] To eliminate this factor, shade A3.5 was selected in our study. For MA, shade 2L which was similar to shade A3.5 of the other brands was selected. In general, cervical area of denture teeth would have higher pigments or chroma than incisal area. Therefore, we measured the color changes at incisal third and cervical third in each individual denture teeth. The results showed that there was no significant difference between these areas.

In this present study, we investigated color stability at 1, 15, 30 days after heat polymerization. The results by spectrophotometer and observers showed no significant difference among different time periods. These results suggested that color changes caused by heat-polymerization method did not increase by time and was irreversible.

The limitation of this study was the sample size. The small sample size decreases the accuracy to represent the entire population. This study did not completely mimic all denture fabrication procedures as only teeth were submitted to a simulation of polymerization without utilizing the acrylic resin as a denture base. Thus, further studies should evaluate the impact of acrylic resin denture base on its color stability of acrylic resin along with the denture teeth.

Conclusions

Within the limitation of this study, the following conclusions could be drawn:

1. Livera Alpha acrylic resin denture teeth had the least color stability and was clinically unacceptable.
2. The ΔE values of Yamahashi and Major Dent acrylic resin denture teeth were beyond clinical acceptable level for both incisal and cervical areas. The same resulted was found in Yamahashi PX and Endura composite resin denture teeth.
3. Considering the position of artificial teeth (cervical area and incisal areas) and the time after the polymerization process, color change was not statistically different in each position and time.

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Conflicts of interest

The authors declare no conflicts of interest.

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