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Assessment of aging effects on porcelain repair systems discoloration

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Abstract

Introduction: The selection of porcelain is based on high biocompatibility, endurance, superficial texture and aesthetics. Nevertheless, the innate fracture charateritics of porcelain is the main cause of the intra oral fractures. Electing a suitable porcelain restorative system in terms of stability of color is important. For this reason, this study aimed to examine the color changes of common porcelain repair materials.

Methods: Using a silicon mold, 30 pieces of feldspathic porcelain in A3 color, 10mm of diameter and 2 mm of thickness were prepared. The samples were randomly distributed into three groups:
Group 1: Porcelain-Silane-Bonding-Composite
Group 2: Porcelain-Silane-Bonding-Panavia F 2.0-Bonding-Silane-Porcelain
Group 3: Porcelain-Silane-Bonding-Choice 2 -Bonding-Silane-Porcelain
The aging process was accomplished with thermocyling (3000 cycles, 5/55 degree), incubation in 37° and 100° humidity. Thereafter, discoloration was assessed In CIE system via designation of color transforming matrix in MATLAB environment.

Results: The average quantitative amount of discoloration at day 0, 90 and 180 were 76.8±0.57, 79.15±0.52, 80.13±0.6 for Choice, 78.03±0.9, 79.42±0.82, 80.17±0.51 for Panavia, and 78.41±1.53, 79.59±0.77, 81.03±0.63 for Composite, respectively. The color changes by the time were significant for the all three groups (p<001).Calculating day 0-180 color changes, mean color differences for Choice, Panavia and Composite groups were 3.33±0.83 , 2.13±1.23, and 2.61±1.6, respectively. The color changes did not differ in the studied groups (p<0.133).

Conclusions: Post-aging color changes were significant, although all samples had color changes less than 3.5. Considering the clinical significance of color changes of more than 3.5, these results were acceptable and all three restorative materials could reliably be applied in the daily clinical use.

Keywords: Porcelain, Color changes, Digital photographer, CIE LAB color system

بررسی آزمایشگاهی تاثیر Aging برتغییررنگ سیستم های ترمیم پرسلن

چکیده

مقدمه: انتخاب پرسلن به عنوان یک رستوریشن بر اساس سازگاری زیستی عالی، استحکام، فرم سطحی و زیبایی آن می باشد. با این وجود، خاصیت ذاتی شکنندگی آن، عامل اصلی شکست این رستوریشن ها در داخل دهان است. برای ترمیم شکستگی پرسلن روش های مختلفی پیشنهاد شده است. انتخاب یک روش ترمیم پرسلن با خصوصیات مناسب از لحاظ ثبات رنگ حایز اهمیت است. لذا بر آن شدیم تغییرات رنگ مواد رایج ترمیم پرسلن را مورد بررسی قرار دهیم.

مواد و روش ها: در این مطالعه ی آزمایشگاهی با استفاده از مولد سیلیکونی ۳۰ قطعه پرسلن فلدسپاتیک (Ceramco 3) رنگ A3 و به قطر ۱۰ میلیمتر و به ضخامت ۲ میلیمتر آماده گردید. سپس نمونه ها به طور تصادفی به سه گروه ده تایی بصورت زیر تقسیم می شدند:

۱- پرسلن-سایلن-عامل باندینگ-کامپوزیت مستقیم ۲- پرسلن-سایلن-عامل باندینگ-سمان دوال کیور(panavia F2) -عامل باندینگ-سایلن-پرسلن ۳- پرسلن-سایلن-عامل باندینگ-سمان لایت کیور (Choice 2)-عامل باندینگ-سایلن-پرسلن شرایط Aging نمونه ها شامل ۳۰۰۰ دور ترموسایکلینگ (5˚55 c˚) و قرار گیری داخل انکوباتور در دمای ۳۷ درجه و رطوبت ۱۰۰٪ بود. از نمونه ها در روز صفر و بعد از ۹۰ و ۱۸۰ روز Aging فتوگراف به وسیله دوربین دیجیتال تهیه شد. سپس درجه تغییر رنگ عکس ها بر اساس سیستم رنگ CIE Lab طراحی ماتریکس تبدیل رنگ در محیط نرم افزار MATLAB محاسبه شد.

یافته ها: میزان E (در سیستم رنگ (Commission International d 'Eclairage (CIE Lab) میانگین گروه ها در زمان های صفر، ۹۰ و ۱۸۰ روز در گروه Choice به ترتیب ۷۶/۸±۰/۵۷، ۷۹/۱۵±۰/۵۲ و ۸۰/۱۳±۰/۶ بود. این مقادیر برای Panavia به ترتیب ۷۸/۰۳±۰/۹، ۷۹/۴۲±۰/۸۲ و۸۰/۱۷±۰/۵۱ بوده و برای گروه Composite به ترتیب ۷۸/۴۱±۱/۵۳، ۷۹/۵۹±۰/۷۷ و ۸۱/۰۳±۰/۶۳ بدست آمد.

این تغییرات رنگ در طی زمان در هر سه گروهChoice $F(2,18) = 79.7$ $p< 0.001$، Panavia ($F(2,11.03) = 18.36$,$p<0.001$)، Composite ($F(2,18) = 18.37$,$p<0.001$) معنی دار بود ($p<0.001$). محاسبه ی مقدار تغییرات رنگ در بازه ۰ تا ۱۸۰ روز میانگین تغییرات رنگ در گروه سمان لایت کیور۳/۳۳±۰/۸۳، در گروه سمان دوال کیور ۲/۱۳±۱/۲۳ و در گروه کامپوزیت ۲/۶۱±۱/۶ بدست آمد. تغییرات رنگ بین گروه ها در طول زمان مطالعه از لحاظ آماری متفاوت نبودند.($F(2,16.98) = 2.18$ $p= 0.133$).

نتیجه گیری: تغییرات رنگ بعد از Aging معنی دار می باشد گرچه از لحاظ بالینی با توجه به $E\Delta<3.5$ تغییرات رنگ، قابل قبول بوده و هر سه ماده بکار رفته بصورت قابل اطمینانی در کلینیک قابل استفاده روزمره می باشند.

واژگان کلیدی: پرسلن، سمان رزینی، تغییررنگ، دوربین دیجیتال، سیستم رنگ CIE Lab

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Introduction

Color has always enchanted human being. It is represented in early cave paintings, art of porcelains, and textile fabrics. A color is perceived via reflection or transillumination of whole white spectrum or part of it (1, 2). The human visual system can distinguish three color parameters. These three color parameters are chroma, hue and value (3). Hue is the attribute that most readily distinguishes one color from other colors, for example reds, greens and blues.

Value or brightness indicates the lightness or darkness of a hue (4, 5). Sometimes value is defined by the degree of grayness, but value is a quality, not a quantity and this definition is wrong (2). Value is the most important characteristic during color selection and is independent of hue and chroma. Chroma is the degree of saturation, intensity and strength of a hue (2).

There are various spaces to measure color changes; like CIE LAB and Munsell Color can be described according to the Munsell color space in terms of hue, value and chroma by means of human visual system. The observed color will be compared with a large color collection in "color tab" (2). Color change is calculated via Nickerson formula ($I=(c/5)\ (2\Delta H)+6\Delta V+3\Delta C$) in Munsell space. In this system, color changes equivalent to 5 can be seen by the human eye (6).

CIE LAB color space has got three values, L*, a* and b*. The L* value is the measure of the lightness and it is similar to "value" in Munsell color space(5). a* and b* describe "chroma" which are the measure of redness (+a*), greenness (-a*), yellowness (+b*) or blueness
(-b*) (7). The differences between two colors can be determined from a color difference formula ($\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$). ΔL, Δa and Δb are the differences between L*, a* and b* parameters of the two colors. ΔE >3.5 is considered perceptible clinically (2). In general, tooth color can be quantified via these methods: visual measurement with Shade Guide, spectrophotometry, colorimetry and computerized analysis of digitized images (4).

Shade guide or visual color determination is the most frequently applied method in dental clinics and laboratories. This method is inaccurate, because of variable viewer interpretation and environmental and lighting influences at the same color assessment. Spectrophotometer measures the wavelength of the light reflected by species in the range of visible light and compares that with standard wavelength of colors. Colorimeter is a photoelectric instrument and is able to detect color differences between two species. This device is not capable to determine the exact value of color axis of a specimen. In digital analysis methods, digitized images are given to the computer, then the color will be evaluated using CIE lab or L & RGB systems (6).

Recent advancements in digital photography have resulted in the vast use of digital cameras for color evaluation of teeth. Using these cameras, we are able to record digital data from an object and view that on the computer screen and even transmit them via internet (8). Increasing demand for elegant and natural-looking restorations has developed new systems of ceramics. Choosing porcelain as a restoration in different forms is based on excellent biocompatibility and strength which gives it highly desirable aesthetic properties. However, metallic core of this restoration has affected the aesthetic properties in it that has caused discolorations or decrease in light transmission. These limitations have boosted the development of all-ceramic restorations which do not need metallic cores (9).

However, the brittle nature of dental porcelain is the main cause of failure of these restorations. There are various methods with which porcelain can be repaired. It varies from a simple composite repair to constructing a new prosthesis. Common porcelain repair methods using composite resin or facing with porcelain pieces use silane coupling agents. During the repair process with porcelain pieces, lutting agents can be used in forms of light cure or dual cure. Dual-Cure components are usually utilized in ceramic restorations with large facial thickness (more than 2mm) or highly opaque veneers. The problems in the degree of conversion and color instability due to chemical decomposition of amines have limited their usage.

Therefore, choosing a porcelain repair system with proper color stability is so important (2, 6, 7). The color of the repaired part can change because of its exposure to the oral cavity.

This color change might be due to intrinsic factors such color changes in the porcelain material, changes in resin matrix and matrix-filler interface or extrinsic factors like deposition of pigmented material from external sources, aging and temperature changes(10-12). The renewal process of fractured porcelain is both costly and time consuming. This study was conducted to evaluate the color changes of three porcelain repair systems using different materials and cement polymerization methods in repairing porcelain fractures.

Methods

In this in-vitro study, porcelain feldspathic samples (Ceramco 3, Densply, Germany) were used. Using a silicone mold, 30 porcelain feldspathic pieces in A3 shade, 10 mm of diameter and 2mm of thickness on a condense vibrator were prepared. Porcelain surface was abraded by air stream with 50µm aluminium oxide particles. The samples were randomly distributed into three groups.

In all the groups, porcelain surface was etched using 9.5% hydrofluoric acid (Porcelain Etchant, Bisco, USA) in 90 seconds, then washed with distilled water, soaked piece of cotton and one drop of 96% alchohol and dried with air spray. In the first group, after using silane, bonding agent (Clearfil SE Bond, Kurary, Japan) was used and thinned with a light air spray and then cured for 20 seconds. Finally, using an A3 direct composite (Clearfil AP-X, Kurary, Japan) and a silicone mold with 8 mm diameter and 2 mm thickness of restoration was built. A glasslam was put on it and the sample was cured with light cure device (Coltolux 75, Colten, 800mw/cm^2) for 40 seconds up and down.

In groups 2 and 3, disk shaped feldspathic porcelain restoration with 8mm diameter and 2mm thickness was prepared with the same method. In group 2, dual cure cement (Panavia F2) was used following the instructions. It means that after etching the porcelain, equal amounts of bonding (Clearfil SE bond) and silane (Porcelain bond activator, Kuraray, Japan) were mixed, poured on the porcelain surface and thinned with air spray. After dual cure cement (Panavia F2), light cement shade was prepared following the instructions and the second piece was put with a light pressure and light-cured for 40 seconds from up and down. In group 3, after etching, the porcelain was covered with silane (Bis-Silan™, Bisco. USA) and was thinned after 30 seconds with air spray.

The surface of the porcelain was poured with a thin layer of HEMA free porcelain bonding resin. The adequate amounts of translucent light-cure cement (Choice 2) were used and the second piece was positioned with a light pressure and light-cured for 40 second up and down, similar to group 2. Before the aging process, the samples were inserted in a light box (Iran, Yazd) under D56 light which emitted from both sides with 45 angle. Photographs were taken from the samples with a gray background from a 15cm distance using a 12 Mega pixel Canon camera (SXG, Tokyo, Japan). After taking primary photographs, the aging process of the samples was accomplished under 3000 cycles thermocycling (5˚/55˚c) and then, they were inserted in an incubator in distilled water at 37˚c and 100% humidity. After 90 and 180 days, the photographs were taken from the samples with similar conditions. The camera was positioned on a fixed tripod and the distance from the samples, light source and the background were identical during the experiments.

The photographs were saved on the computer and using MATLAB software, the color of the samples were determined. Then, the laboratory properties of the surface of the samples were measured according to the CIE system and ΔE (color differences) was determined using $\Delta E=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{½}$ formula.

At first, to assess the constancy of the photography ability of the camera, pilot samples were chosen, 5 photos of each were taken and compared. The color changes between the primary and experimental samples from0 to 90 go days were measured according to the CIE1976 color change formula. Data was statistically analyzed using repeated measures ANOVA, Paired t-test and one way ANOVA with SPSS 17 software ($p<0.05$).

Results

The results have shown the repeatability of the method of measurement of color changes by digital camera for pilot samples and are represented in table 1. In the analysis of the pilot data, Intra class Correlation (ICC) was 0.71 and this confirms the reliability of the camera and the method used in this study. It should be emphasized that ΔE<3.5 is accepted clinically and the human eye cannot detect color changes beneath that (1).

Table 1. Table of the E values of the pilot samples using digital camera to evaluate repeatability

E	Image 1	Image 2	Image 3	Image 4	Image 5
Pilot1	82.68	82.24	80.97	81.64	81.56
Pilot2	83	82.11	81.46	81.79	82.46
Pilot3	82.25	82.46	81.11	81.66	81.88
Pilot4	83.75	81.56	80.29	81.37	82.10
Pilot5	82.45	82.30	81.67	80.93	81.55

In Choice2 cement group, changes in all time span, 0 to 90 days (p=0.001), 90 to 180 days (p=0.001) and 0 to 180 days (p=0.006) were statistically significant.

However, in Panavia cement group in a 90 to 180 day period, the color changes were not significant (p=0.167). Also in Composite group, in a period of 0 to 90 days, there were no significant color changes (p=0.133). In a 0 to 180 day period, ΔE in the Choice group was 3.33±0.88, in the Panavia F2.0 group was 3.13±1.23 and in Clearfil composite group was 2.61±1.63. The differences between the groups are not significant (p=0.133 and F(2,16.98)=2.18) (figure1).

Changes in L and a parameters in all groups in the period of 0 to 180 days were significant, but in Panavia group, a parameter did not have any significant change (p=0.084) (table 2). The mean of the changes in a and L parameters in all three groups did not differ significantly [(p=1 and F(2)=2.50) and (p=0.18 and F(2)=0.18)]. But there was a significant difference in b parameter between the groups (p=0.004 and F(2)=6.97). Comparing L, a and b changes in all groups, only b parameter between composite and Panavia showed a significant difference (table 3).

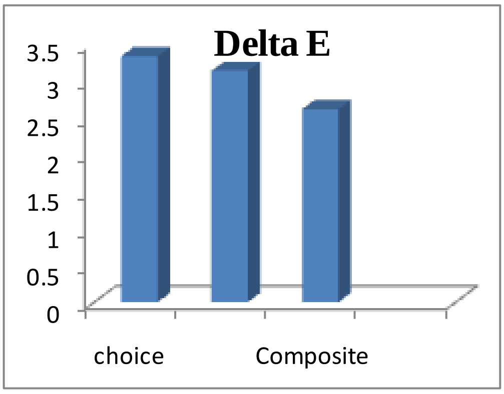

Figure 1. Comparison of the color ΔE in a 0 to 180 day using CIE system

Table 2. Changes in L*, a* and b* parameters in a 0 to 180 day period

Group	L value		Significance level	A		Significance level	B		Significance level
	Day 0	180		Day 0	180		Day 0	180	
Choice 2	76.80	80.2	t(a)=-11.69 p=0.001	2.18	2.37	t(a)=-3.88 p=0.004	13.91	13.4	t(a)=5.47 p=0.001
Panavia F2.0	78.06	80.17	t(a)=-5.56 p=0.001	2.32	2.49	t(a)=1.9 p=0.084	13.70	13.23	t(a)=2.30 p=0.001
Composite clearfil	78.41	81.03	t(a)=-5.05 p=0.001	3.30	3.44	t(a)=2.53 p=0.032	16.76	14.98	t(a)=5 p=0.001

Table 3. Comparison of changes in L, a and b parameters in the period of 0 to 180 days between groups

Groups	b changes P value	a changes P value	L changes P value
Choice2-panavia	0.357	1.00	0.14
Choice2-composite	0.109	1.00	0.565
Composite-panavia	0.019	1.00	1.00

Discussion

In the present study, the mean E changes (ΔE) in all groups were statistically significant (p<0.05), but these changes and discolorations were clinically acceptable (ΔE<3.5).

The discoloration of porcelain repair systems like Clearfil Composite, porcelain segment with Choice light cure cement and porcelain segment with Panavia F 2.0 dual cure cement, 90 and 180 days after the aging process was assessed using digital camera. The mean color changes were significant in all the study groups (p<0.05), but these changes were clinically acceptable, due to limitation of the human eye (ΔE<3.5). In Choice and Panavia cement groups, most changes were seen in a of 0 to 90 day period, but in the composite group, it was seen in a period of 90 to 180 days after aging process. Also, in this study, most changes were observed around L parameter, and b parameter was decreased in all groups.

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In the present study, a digital camera was used to assess the color of the samples. Working with this device was simple, cheap and time saving. The photographs were taken from the samples under the same conditions before and after the aging process. To evaluate the reliability of the method and the digital camera, 5 pilot samples were selected and 5 photos of each were taken under the same conditions.

During data analysis, Cronbach'salpha value was obtained (0.71), that confirmed the reliability and repeatability of the digital camera in the assessment of color of the dental material. Finally, color evaluation was performed using MATLAB software. Cal et al (4), Jarad et al (8), Tung et al (13) and Schropp (14) studies confirmed the use of digital camera to assess discoloration on the condition of proper utilization and regulation of distance and angles. However Cal et al (15). In 2006 in a study which compared a digital camera and spectrophotometer, found that the "L" parameter of camera images did not have a statistically significant correlation with spectrophotometer data, but the "a" and "b" parameters of both instruments showed statistically significant correlation. Also Caglar et al. in a project assessing the reliability of digital camera in determining colors, found that the L* and b* values obtained from digital camera showed a significant correlation with colorimetry data, but this did not hold true in a* value (16). The L*, a* and b* values of digital camera images can be obtained from various softwares like the photoshop and MATLAB (4, 15, 17). Guan et al. compared color evaluation by digital camera and spectrophotometer and used MATLAB software to measure tooth color in L* a* b* system. They have found that the application of digital camera in the assessment of discoloration is reliable (17).

The main advantage of using MATLAB software instead of photoshop is that, in photoshop by using Eyedropper Tool, the arithmetic mean of the selected points will be calculated, but by using MATLAB, programming and calculation of the whole surface is possible.

The present study revealed that although color change was statistically significant, but it was less than 3.5 and was clinically negligible. These results were similar to the previous studies which were to assess the accelerated aging effect using spectrophotometer and found clinically acceptable significant discoloration in cements ($\Delta E<3.5$)(18-20). In our study, most changes were observed in L parameter and b parameter was decreased in all groups. Heydecke et al (11). found similar data in 2001.

The interesting point of the present study was that Panavia F2.0 dual cure cement had a better color stability than choice 2 light cure cement, although these changes could not be seen by the human eye ($\Delta E<3.5$). It is expected that due to the presence of Amine accelerating agents in this cement, discoloration will be more. The presence of two types of light activator in Panavia F2.0 and probable high rate of polymerization may explain this contradiction. Also, the existence of Methacryloyloxydecyl Dihydrogen Phosphate (MDP) in resin matrix of cement may be another cause of that. With due attention to Zhangs research, it seems that the difference in type of curing (dual or self) is not the main reason of the difference in color changes (21), manufacturer and used dental material should be noted. Panavia F2.0 dual cure cement and Choice 2 Light cure cement were not from the same company and this was one of our study limitations. Comparing a light cure and dual cure cement from same the company with different techniques of polymerization like Soft or High intensity is the subject of the future studies to better identify the effect of method of polymerization on color stability.

The other limitation was the absence of spectrophotometer in the study to compare with the results obtained from the camera .It is suggested that this study should be conducted in clinics and for a longer time span. Also, composite samples were not polished and this might increase surface roughness and discoloration which could affect our results.

Conclusion

Referring to the results of this study, the color stability of Panavia, Choice and Clearfil resin composite cements is clinically acceptable. As renewal of porcelain crowns are costly, these materials can be routinely employed to repair chipped or fractured porcelains.

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