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Effects of COVID-19 Preoperative Mouthrinses and Different Beverages and on Surface Alteration of Polyetheretherketone (PEEK)

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Abstract

Objectives: to compare the color change and surface roughness of polyetheretherketones (PEEK) immersed in various beverages and mouthrinses for 7 days.

Methods: the specimens were divided into 6 groups, 10 pieces per group, and each group was immersed in different solutions as followed: coffee, cola, red wine, distilled water, 0.5% povidone iodine, and 1% hydrogen peroxide. A color change (ΔE*ab) was measured in each sample before and after 7 days of immersion in different solutions. At a significance level of 0.05, color change data were analyzed using one-way ANOVA and pairwise comparisons with the Games-Howell method, and surface roughness changes were analyzed using the Wilcoxon Sign-Rank test.

Results: immersion of PEEK in 0.5% povidone iodine caused the most color change, followed by red wine when continuously immersed for 7 days. However, immersion in different types of solutions did not affect the surface roughness of PEEK.

Conclusions: After 7 days of immersion, 0.5% povidone iodine and red wine caused color change in PEEK with no change in surface roughness.

Keywords: betadine gargle, COVID-19, discoloration, polyether ether ketone, stain

Introduction

Removable partial dentures (RPDs) have been widely used to replace natural teeth in patients who have lost some teeth. Metal-based RPDs are the most common type and mainly made of cobalt-chromium (CoCr) providing high strength and stiffness, conducting heat and cold for a more natural experience, and being resistant to corrosion.[1] However, it has esthetic limitation due to the gray-colored. Because of its characteristics such as heavy-weight, metallic taste, some patients may develop intolerance to metal. Currently, a new polymer material, polyether ether ketone (PEEK), has been introduced to replace metal in patients with a history of metal allergy. Patients could be more satisfied with this material because of its esthetically tooth-color and lighter weight compared to CoCr.[2-4]

PEEK is a high-performance thermoplastic polymer, consisting of an aromatic backbone molecular chain, interconnected by ketone and ether functional groups. PEEK used in prosthodontics can be divided into two types, pure PEEK and modified PEEK. Pure PEEK is unfilled polymer with 100% of PEEK. The color of pure PEEK or unfilled PEEK is light brown[5] with good biocompatibility, good mechanical properties, high-temperature resistance, and good chemical stability.[6] Modified PEEK is white in color and consisting of either 80% PEEK with 20% titanium dioxide filler or 80% PEEK with 20% nanoceramic filler, with particle sizes of 300-500 nm.[7] Discoloration of dental prostheses can be caused by intrinsic factors such as resin matrix type, percentage and filler size, distribution of incorporated fillers, composition and polymerization mode, chemical reactions within the restorative material, age, and restoration processing mode, or extrinsic factors such as staining from adherent or penetrated by food, beverage, and mouth rinse colorants such as caffeine, anthocyanidins, tannins, and nicotine in smoking.[8] Given the past situation with spreading of SARS-CoV-2, preoperative mouthwash has played an important role in reducing oral viral and bacterial infections and become a routine preoperative procedure. It is recommended to gently gargle for 30 seconds in the oral cavity and 30 seconds in the back of the throat with either one of these following solutions: 1-3% hydrogen peroxide, 0.2-0.5% povidone iodine, 0.12% chlorhexidine.[9] Hydrogen peroxide has of bleaching potential, while providone iodine presents with dark brown color. These two solutions could have effect on the color of dental prosthesis if the patient has to use in a long period of time or routinely use in dental operation.

Color and surface roughness are important factors for the esthetic appearance of removable dental prostheses and patient satisfaction especially in RPDs made of PEEK. Several studies have reported that food and daily consumed beverages could negatively affect these properties. Heimer *et al.,* examined the effect on color stability and stain removal action of different cleaning methods on PEEK material, remaining in different media for 7 days, and revealed that PEEK was the most color stable material compared to polymethyl methacrylate (PMMA) and composite resin,[10] in line with the study of Papathanasiou *et al.,* by immersing the material in red wine, coffee, cola, and distilled water for 30 days, PEEK was the most color stable material compared to polyamide acetal resin and PMMA.[6] In some cases, for example full mouth rehabilitation cases, patients require several dental visits to complete the whole treatment. Most of cases, patients have to receive pre-prosthetic treatment such as periodontal cleaning, caries management, endodontically treatment, and pre-prosthetic surgery prior to the full mouth rehabilitation treatment. Every dental visit, patients have to use preoperative mouth rinse prior to start the treatment. Therefore, they will be facing with mouthrinse for a long period of time. However, the study regarding effect of preoperative mouth rinse on PEEK materials has not yet been clarified and never been compared to the effect of other beverages especially in long-term usage. Therefore, the purpose of this study was to evaluate the effect of preoperative mouth rinse and various beverages on color stability and surface roughness of a newly introduced PEEK polymer.

Materials and Methods

Cylindrical PEEK blanks provided by the manufacturer (Smile PEEK®, Pressing Dental SRL, San Marino, Italy) were prepared in a disc form with a diameter of 12 mm and a thickness of 2 mm for total 60 pieces. All disc-shape specimens were stored in dry conditions until finishing and polishing were done by one investigator at 2 surfaces of the specimens so an overall total surfaces were 120 surfaces. After qualifying the dimensions using a digital caliper (Mitutoyo Vernier Calipers, Mitutoyo, Tokyo, Japan) specimens were ground with 600-grit, 800-

grit, and 1200-grit waterproof silicon carbide paper using a rotary grinding machine (Buehler Metaserve Universal, Buehler Ltd., Lake Bluff, Illinois, USA). After that, they were cleaned with distilled water in an ultrasonic cleaner (Easy 10 Ultrasonic Cleaner, Elma Schmidbauer GmbH, Singen, Germany) and dried with tissue papers.

Ten randomly selected specimens were immersed for 7 days at 37°C and 100% relative humidity in one of the following solutions (n=20 surfaces/solutions): Coca-Cola (Coke®, Coca-Cola (Thai) Trading Co., Ltd., Bangkok, Thailand), black coffee (Birdy Black®, Malee group, Nakhon Pathom, Thailand), red wine (Charles Strong Reserve Classic Bin 991®, Cumulus Estate Wines, New South Wales, Australia), 0.5% Povidone iodine (BETADINE® Gargle, Mundipharma Ltd., Bangkok, Thailand), 1% Hydrogen peroxide (Siribuncha, Siribuncha Ltd., Bangkok, Thailand) and distilled water (Table 1). This period of immersion may correspond to 34 to 67 months of clinical services, based on an average daily exposure of 5 to 10 minutes to coffee or wine.[11] The pH of the solutions was measured using a pH indicator (SevenCompact pH meter S220, Mettler-Toledo (S) Pte Ltd, Singapore). Immersing solutions were renewed every 24 hours. Color and surface roughness measurements were performed before and after immersion. Before any measurement, specimens were rinsed with distilled water in an ultrasonic cleaner and dried with soft tissue paper.

Color measurements were performed using a spectrophotometer (ColorQuest XE, Hunter Associates Laboratory Inc., Virginia, USA). A custom-made black foam holder was fabricated for each specimen to standardize specimen positioning against the spectrophotometer head. The CIE L*a*b* system was used for color assessment. The CIE L*a*b* system represents a three dimensional color space with components of lightness (L), red-green (a), and yellow-blue (b). The average of 3 consecutive measurements in the center of specimens was calculated to yield L*, a*, and b* of each specimen before and after immersion. The total color change (ΔE) obtained was calculated for each specimen using the following equation:

$$\Delta E = [(\Delta L^*)2 + (\Delta a^*)2 + (\Delta b^*)^2]^{1/2}$$

where ΔL*, Δa*, and Δb* are the differences of L*, a*, and b* before and after staining.

Surface roughness determinations were measured by a contact profilometer (Surfcorder SE2300, Kosaka Laboratory Ltd., Tokyo, Japan) The cutoff value for surface roughness was 0.8 mm and the traversing distance of the stylus was 5 mm. The radius of the tracing diamond tip was 5 µm, and the measuring force and speed were 4 mN and 0.5 m/s, respectively. Three random readings at the center of each specimen were performed and the average value was calculated at baseline and after immersion. The changes of surface roughness parameters (Ra) were obtained by the difference between final and baseline values. One-way ANOVA and Games-Howell post hoc tests were used to assess differences in color change parameters among solutions at baseline and after immersion. The Wilcoxon signed rank test was used to assess differences in surface roughness change parameters for each solution at baseline and after immersion. Statistical analyses were performed using IBM SPSS Statistics 22 software at a 0.05 level of significance.

Results

The one-way ANOVA revealed that staining solution significantly affected color change. Games-Howell pairwise comparisons revealed significant differences in a color change of PEEK among solutions after immersion for 7 days. The ΔE value of PEEK after immersion in distilled water, red wine, cola, coffee, 0.5% povidone iodine, and 1% hydrogen peroxide were 0.55, 1.53, 0.42, 0.52, 6.59, and 0.55 respectively. (Table 2) Immersion of PEEK in 0.5% povidone iodine resulted in the significantly highest discoloration of specimens ($p<0.05$), followed by red wine ($p<0.05$). Cola caused the lowest discoloration, however, the color change was not significantly different

Table 1: A list of immersion solutions used in this study and their respective pH

Solution	pH	Brand
Coffee	6.42	Birdy Black, Malee group, Nakhon Pathom, Thailand
Red wine	3.42	Charles Strong Reserve Classic Bin 991, Cumulus Estate Wines, Australia
Coca-Cola	2.49	Coke (Thai) Trading Co., Ltd., Thailand
Povidone-Iodine	3.09	BETADINE® Gargle, Mundipharma Ltd.,Thailand
Hydrogen peroxide	3.49	Siribuncha, Ltd.,Thailand

(p>0.05) when compared with distilled water, coffee, and 1% hydrogen peroxide. (Figure 1)

The Wilcoxon test (α =0.05) was used to test the surface roughness of PEEK after immersion in different solutions for 7 days, and the results showed that the change in surface roughness of all groups of PEEK was not significantly different (p>0.05) (Table 3).

Discussion

This study examined the effect of immersion of PEEK in six challenge solutions on the color change and surface roughness. The first null hypothesis (no differences in color change among different solutions) was rejected for changes in color parameters but the second null hypothesis (no differences in surface roughness among different solutions) was accepted for changes in surface roughness parameters. Immersion of PEEK in various solutions for 7 days significantly affected the color of PEEK, 0.5% povidone iodine exhibited the most color change, followed by red wine, while distilled water, cola, coffee, and 1% hydrogen peroxide showed no significant difference among them. On the other hand, there was no significant difference in surface roughness after immersion in different solutions for 7 days.

Color differences (ΔE) detected by human eyes are normally non-discernible below ΔE values of 1 and only change into an unacceptable color change when ΔE is more than 3.3.[12] In this study, red wine showed a mean value of ΔE*ab at 1.53, which was considered clinically acceptable. whereas 0.5% of povidone iodine possessed the mean ΔE*ab value at 6.59, which was considered clinically unacceptable. However, the data was obtained from a laboratory experiment and the results could be different in clinical circumstances. Staining mechanism of povidone-iodine in PEEK has not been clearly described. These stains, containing not only iodine, but a polymeric complexing agent, are difficult to remove by the usual laundering techniques and currently available detergent products. A study by McNeme *et al.,* reported that immersion of acrylic in iodine caused discoloration. The authors recommend choosing an iodine-free solution to reduce changes in the aesthetics of dentures.[13] In addition, artificial teeth (PMMA) had been immersed in 10% povidone iodine for 2 hours 30 minutes to 10 days. The ΔE*ab result was in the range of 0.042-0.893[14], which was different from the results of this study. Because the materials used in the study were different.

Table 2: Means and standard deviations of ΔE*ab values after 7-day immersion

Solutions	n	ΔE*ab (mean±sd)	Min	Max
Distilled water	20	0.55±0.23^{a}	0.14	1.01
Red wine	20	1.53±0.57^{b}	0.27	2.68
Coca-Cola	20	0.42±0.29^{a}	0.03	0.97
Coffee	20	0.52±0.27^{a}	0.16	1.06
0.5 % Povidone Iodine	20	6.59±1.11^{c}	4.62	8.15
1% Hydrogen peroxide	20	0.55±0.28^{a}	0.21	1.28

Similar superscript lowercase letters represent significant differences among staining solutions

Table 3: Means median and standard deviations of surface roughness after in different solutions

Solutions	Surface roughness Ra (μm)				Wilcoxon Signed Rank test
	Before		After		
	(mean±sd)	median	(mean±sd)	median	Sig. (<0.05)
Distilled water	0.10±0.01	0.1	0.11±0.01	0.1	0.059
Red wine	0.09±0.03	0.1	0.09±0.03	0.1	0.305
Coca-Cola	0.09±0.02	0.1	0.11±0.02	0.1	0.066
Coffee	0.09±0.03	0.1	0.10±0.02	0.1	0.234
0.5 % Povidone Iodine	0.09±0.03	0.1	0.10±0.03	0.1	0.129
1% Hydrogen peroxide	0.09±0.02	0.1	0.11±0.03	0.1	0.059

In red wine, the color change was greater than coffee. Unlike the study of Papathanasiou *et al.,* and Polychronakis *et al.,* their results showed that red wine exhibited less discolor than coffee. Red wine contains natural pigments (anthocyanidin or tannin) in high alcohol concentration and low pH, causing chemical deterioration of the surface of the polymers and increase surface roughness. Thus absorbing stains occurs.[15,16] However, it is noted that color changes in red wines have been influenced by a number of factors, including duration, grape composition, fermentation, and storage conditions.[17] Therefore, it cannot be generalized with all brands of red wine to behave on polymer surface in the same manner. In this study, specimens immersed in red wine showed no difference in surface roughness. Despite cola showed the lowest pH in all solutions, but it caused less staining than red wine.

This study examined the surface roughness of PEEK before and after immersion in various challenge solutions and the results showed no difference in roughness after immersed in all solutions. It was found that the surface roughness of PEEK specimens was below the critical value (0.2 µm). If the surface roughness was above this critical value, it may cause bacterial accumulation.[18] Papathanasiou *et al.,* immersed PEEK in coffee, red wine, and cola for 30 days. The results showed no significant change in surface roughness in all groups. It could be explained that PEEK, used as filler-free, can be polished to a good smooth finish. and no filler particle delamination occurs.[6] In addition, Since PEEK is an inert semi-crystalline polymer, it possessed the resistant to high temperatures, chemically stable, low water solubility and water absorption, low surface energy, and low surface roughness after polishing.[6,8,10] Due to these properties, PEEK has low adsorption and absorption of color stains and is supposed to resist to acidic solutions such as cola and red wine.

This is an *in vitro* study, the result could be different in clinical circumstances. There are more challenges inside the mouth, such as saliva, pH levels, temperature changes, parafunctional habits, food consumption behavior, cleaning which such factors may affect the staining. In addition, the samples were immersed at 37°C, which simulated the oral temperature. However, cola, red wine, and coffee are often consumed in cold or hot condition, which are different from oral temperature. Further *in vivo* studies are needed to determine the staining of PEEK in various solutions that cause staining. Also, the mechanism of iodine staining on PEEK should be further investigated.

Conclusions

Based on the results of the present *in vitro* study, the following conclusions were drawn:

1. povidone iodine (0.5%) caused the highest color changes of PEEK among different immersing solutions, followed by red wine.
2. PEEK surface roughness was not influenced by immersing solutions.

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Conflicts of Interest

The authors declare no conflict of interest.

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