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ORIGINAL RESEARCH ARTICLE

The Effect of Different Polishing Procedures and Re-polishing on the Color Stability of Single-shade Composite Resin

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Abstract

Purpose: The aim of this study is to evaluate the effect of different polishing systems on the color stability of single-shade resin composite after coffee immersion, brushing cycles and re-polishing.
Materials and Methods: A total of 40 disc-shaped single-shade resin composite (Omnichroma, Tokuyama, Japan) specimens were prepared using a standard mold. One-step polisher (OneGloss, Shofu, USA), two-step polisher (Clearfil Twist Dia, Kuraray, Japan), multi-step polisher (OptiDisc, Kerr, USA) polishing systems were applied to each group (n=10) in accordance with the manufacturer's instructions. No polishing procedure was applied to the Control group. Representing 6-months and 1-year of clinical use, specimens were exposure in coffee solution (6-12 days) and subjected to brushing cycles (5000-10000 cycles). The specimens were then re-polished by applying the same polishing procedures as initially applied. Color measurements were repeated in all time periods and color change ($\Delta E00$) values were calculated with the CIEDE2000 formulation. Kruskal-Wallis analysis was used for between group comparison, and Mann-Whitney U test was used as a post-hoc test (α=0.05).
Results: At simulated 6-months and 1 year periods, the $\Delta E00$ values of the Control group and one-step polisher (OneGloss) group were statistically similar and significantly higher than the those of the other groups ($p<0.05$). There was no statistically significant difference between all groups in $\Delta E00$ values after re-polishing.
Conclusions: Two-step and multi-step polisher resulted in lower discoloration of single-shade resin composite compared to one-step polisher. Although re-polishing lowered the $\Delta E00$ values, no polishing system was able to cut down the color change of single-shade resin composite below the acceptable threshold.

Keywords: Brushing; Color; Coffee; Re-polishing; Single-shade Composite

Introduction

Innovative esthetic restorative materials are quickly developing to suit patients esthetic aspirations and adjust seamlessly with tooth shade. Within the scope of these developments, a new generation of smart chromatic single-shade resin composites has been introduced to the market, simplifying shade selection procedure without compromising shade matching potential of the composite restoration. One of these materials, Omnichroma (Tokuyama, Japan), was introduced to the market with the claim that it provides shade matching without added pigment and has become one of the most preferred single-shade resin composites by dentists.[1] In some studies, it has been reported that although single-shade resin composites initially exhibit good shade matching performance, they are subjected to more discoloration than resin composites with multi-shade systems.[2,3]

Resin composites must possess color stability and the capacity to resist surface stains to retain their visual appeal. Despite advances in resin composite manufacture, discoloration remains one of the major reasons for the replacement of resin composite restorations.[4] Discoloration of restorations can be caused by extrinsic staining agents or intrinsic discoloration. Intrinsic discoloration factors are mainly related to the composition of the resin composites, such as matrix, type, and amount of filler; photo-initiator system; and polymerization degree. Plaque accumulation, surface discoloration, and minor penetration of staining agents are examples of extrinsic factors that can cause discoloration in the superficial layers of resin composites.[5]

According to reports, coffee, tea, and other beverages commonly consumed as part of dietary habits cause staining and discoloration of resin composites. Several studies have reported that coffee is the beverage that has the most severe effect on the coloration of resin composites.[6–8] The coffee-induced discoloration is a result of both adsorption and absorption of coloring pigments. Coffee has the ability to release low-polarity yellow pigments that can penetrate the organic phase in resin composites and cause discoloration.[6] Considering that coffee is the most consumed beverage in the world and its consumption is increasing, it is important to understand its effect on the color stability of single-shade resin composite.

Brushing is recommended in the daily routine to partially or completely remove superficial stains caused by beverages and to maintain the color stability of dental resin composite restorations.[9,10] Another method commonly used to remove superficial surface discoloration in composite restorations is re-polishing. Re-polishing is a minimally invasive treatment alternative to improve the esthetics and longevity of resin composite restorations that have not been significantly damaged.[11] Polishing procedures are effective in both preventing and removing the discoloration of resin composites. Various methods and instruments are commercially available for finishing and polishing resin composite restorations. The effectiveness of aluminum oxide-coated abrasive discs is well known in the literature and is recommended as the gold standard.[12] However, the use of these discs is multi-step, and in recent years, one-step or two-step polishing procedures have become quite common in order to effectively reduce the time dentists spend at the chairside for polishing.

Spectrophotometers are considered the most reliable and reproducible measurement devices for determining the color changes of resin composites.[13] Spectrophotometers measure L*, a* and b* in the CIELAB color system and ΔE is calculated using the changes in the color parameters. The Commission Internationale de l'Eclairage (CIE) has developed the CIEDE2000 formula, which considers all variables equally to more accurately determine perceptible and acceptable color change. According to this formula, the 50:50% perceptibility threshold for color change is ΔE=0.8 and the 50:50% acceptability threshold is ΔE=1.8.[14]

Although the shade of resin composite restorations is initially compatible, color incompatibility may occur in the restorations under different external factors and oral conditions. To the authors' knowledge, although there are studies in the literature evaluating the color stability of single-shade resin composites after coffee immersion, the methods of these studies did not include brushing procedures.[15,16] The aim of this study was to evaluate the effect of different polishing procedures and re-polishing on the color stability of single-shade resin composite after coffee immersion and brushing cycles.

The null hypotheses to be tested in the present study were: H01) Regardless of time, there would be no difference in the effect of different polishing systems on the color stability of single-shade resin composite after simulated coffee solution immersion and brushing cycles. H02) Re-polishing procedure would not revert the color change, regardless of the polishing system used.

Material and Methods

In the present study, 3 different polishing systems, one-step polisher (OneGloss, Shofu Dental, USA), two-step polisher (Clearfil Twist Dia, Kuraray, Japan) and multi-step polisher (OptiDisc, Kerr, USA), were tested on a single-shade resin composite (Omnichroma, Tokuyama Dental, Japan) (Table 1). G*power program (G * Power 3.1 Software, Germany) was used to determine the specimen size. According to the results of the analysis a total number of 40 specimenss, at least 10 for each subgroup, was determined at 85% power and 0.05 significance level. Flow diagram of the study is shown in Figure 1.

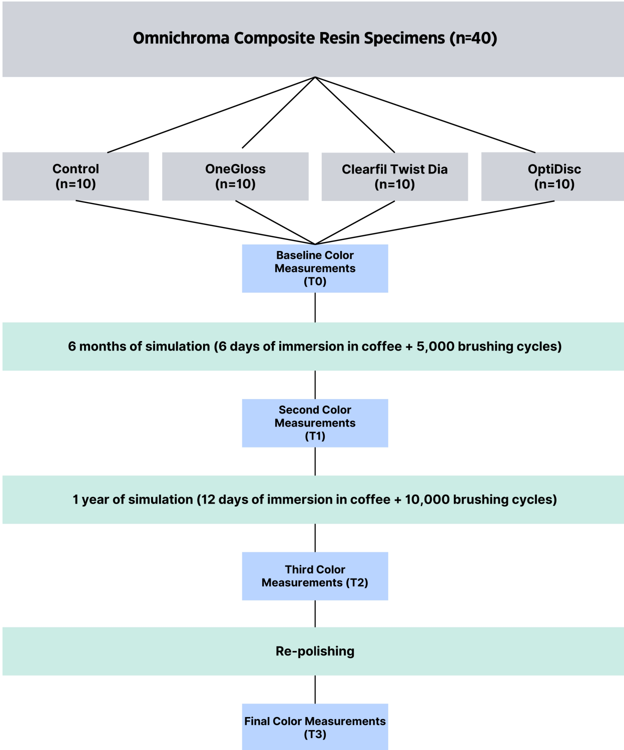

Figure 1. Flow diagram of the experimental design

Preparation of Specimens

A total of 40 disc-shaped single-shade resin composite specimens were prepared using a standard mold (10 mm diameter x 2 mm depth). After the resin composite was placed in the mold, a mylar strip and a 1-mm-thick glass slide were placed on the upper surface of the specimens. Light pressure was applied to ensure that the excess resin composite material overflows and to obtain a standard surface. The glass slide and mylar strip were removed, and the excess resin composite was removed with a metal spatula. After repositioning the mylar strip and glass slide, the specimens were photopolymerized with an LED light device (SmartLite Focus, Dentsply Sirona, USA) in contact with the glass slide for 10 s, after which the glass slide was removed and polymerized for an additional 10 s. After polymerization, the specimens were removed from the mold and stored in distilled water at 37°C in an incubator for 24 h.

Polishing Procedures

Resin composite specimens were randomly divided into 4 groups: Control, One-step polisher (OneGloss), two-step polisher (Clearfil Twist Dia), multi-step polisher (OptiDisc). Except for the control group, the specimens' top surfaces were roughened for 20 s at 250 rpm using 600-grit silicon carbide (SiC) paper in a polisher (Metaserv 250 Twin, Buehler, Germany) under a water stream to standardize the top surface. After each polishing step, the specimens were rinsed with water spray and air-dried. The rpm at which polishing materials were used was determined according to manufacturer instructions, all procedures were carried out in this study by the same operator to reduce variability.

- Control: No polishing procedure was applied.
- One-step polisher (OneGloss): Disc-shaped polishing rubber (IC REF 0183) was applied to the or 20 s at 10,000 rpm under water spray cooling.
- Two-step polisher (Clearfil Twist Dia): Pre-polishing spiral

(dark blue) and high gloss polishing (light blue) were applied for 20 s each at 8,000 rpm under water spray cooling.
- Multi-step polisher (OptiDisc): Polishing discs of 12.6 mm diameter, coarse, medium, fine and super fine, respectively, were applied at 10,000 rpm for 20 s each.

Staining and Brushing Procedures

The specimens were kept in the coffee solution in 1,5 ml Eppendorf tubes prepared for 6 and 12 days, exposure simulating 6 months and 1 year of clinical use. To prepare the coffee solution, soluble granulated coffee (Nescafe Gold, Nestle, France) was chosen. It was prepared using 1 g of coffee for every 100 ml. When the solution reached 37°C, each specimen was placed in separate Eppendorf tubes containing coffee solution and kept in an incubator at 37°C to mimic oral conditions, and the solution was renewed every day.

After staining procedures, 5,000 cycles simulating 6 months brushing, and 10,000 cycles simulating 1 year brushing[17?] were applied to the specimens in a circular motion, under a load of 250 g, with a movement diameter of 16 mm and a movement speed of 40 mm /s. During the brushing simulation, Sensodyne Promine Repair+ (GlaxoSmithKline, USA) toothpaste diluted 1/3 by volume was used with a Colgate Extra Clean toothbrush (Colgate-Palmolive Co., USA).

Re-polishing Procedures

Resin composite specimen groups were re-polished using the initial polishing systems and the same procedures after 6 and 12 days coffee exposure and 5,000 and 10,000 brushing cycles.

Color Measurements

The color values of the resin composite specimens were measured with a contact spectrophotometer (VITA Easyshade V, VITA Zahnfabrik, Germany) using the white calibration plate of the instrument before each measurement. To ensure precise measurements, the probe tip was positioned perpendicular and in direct contact with the surfaces of the specimens. The measurements were repeated three times at the center of the resin composite discs, and the mean L*a*b values were obtained. The color values of the specimens were measured at baseline (T0), after 6 days of coffee immersion followed by 5,000 brushing cycles (T1), after 12 days of coffee immersion followed by 10,000 brushing cycles (T2), and after re-polishing (T3). Using the CIEDE2000 formula, the color change value (ΔE) was calculated based on the mean L*a*b* values of the measurements (KL=KC=KH=1).

Statistical Analysis

Statistical analyses were performed with IBM SPSS Statistics (Version 26.0, IBM Corp., USA). The normality of the distribution of the data was analyzed by Kolmogorov Smirnov and Shapiro-Wilk tests. Kruskal-Wallis analysis was used for between-group comparison, and Mann-Whitney U test was used as a post-hoc test for significant differences. Wilcoxon Signed Rank test was applied for comparison of time periods. (α=0.05).

Results

Within the scope of the study, the color change values of resin composite polished with 3 different polishing systems were compared at simulated 6-months and 1 year coffee exposure, and after re-polishing. Comparisons between groups, mean color change values, and standard deviations are shown in the Table 2 and Table 3.

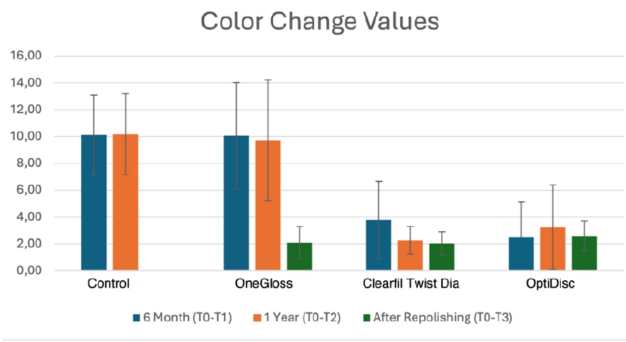

Figure 2. Bar chart of the mean color change value (ΔE00) of the groups at different time points and after re-polishing.

A statistically significant difference was found between the groups in the color change values after simulated 6-month coffee exposure and brushing ($p<0.05$). As a result of the post hoc test, the color change values of the Control and one-step polisher (OneGloss) groups were statistically similar ($p>0.05$), and significantly higher than the other polishing system groups. There was also no significant difference between two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups ($p>0.05$). The highest color change value was measured in the Control group and the lowest color change value was measured in the multi-step polisher (OptiDisc) group.

Similar to the 6-month exposure simulation results, a statistically significant difference was found between the groups in the color change values after aging, which exposure simulates the 1 year ($p<0.05$). 1 year time period color change values are statistically similar in the Control and one-step polisher (OneGloss) groups ($p>0.05$), and significantly higher than in other polishing system groups ($p<0.05$). No significant difference was found between the two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups ($p>0.05$). The highest color change value was measured in the Control group, and the lowest color change value was measured in the multi-step polisher (OptiDisc) group. Although there was a decrease in the color change values of the re-polished resin composites, there was no statistically significant difference between the polisher groups ($p>0.05$).

There was no statistically significant difference between the color change values in the comparison between the time periods in the Control, two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups ($p>0.05$). In the one-step polisher (OneGloss) group, there is no statistically significant difference between 6-months and 1-year exposure simulation color change values ($p>0.05$), but there is a statistically significant difference between 6 months exposure simulation and re-polishing and 1 year exposure simulation and re-polishing color change values ($p<0.05$). Resin composite specimens in the one-step polisher (OneGloss) group had significantly reduced color change values after re-polishing. The bar graph of the mean color change value of the groups is shown in Figure 2.

Discussion

Resin composite restorations should be able to esthetically mimic natural teeth regarding their optical properties such as color, gloss, and translucency and should retain these properties in the long term. However, even if the color matching of the restorations is initially acceptable with the teeth, they may change color over time due to exposure to different intrinsic and extrinsic staining agents. In the present study, the effect of different polishing systems on the color stability of single-shade resin composites was evaluated after immersion in coffee solution, brushing cycles, and re-polishing.

Table 1. Materials used in study

Materials	Composition	Type	Manufacturer	Lot Number
Omnichroma	UDMA, TEGDMA, Uniform-sized supra-nano-spherical filler (260 nm spherical SiO_2-ZrO_2), Composite filler (260 nm spherical SiO_2-ZrO_2), Filler loading 79% by wt (68% by vol)	Single-shade composite resin	Tokuyama Dental, Japan	567483
OneGloss	Highly concentrated aluminum oxide with silicone as binder	One-step polisher	Shofu Dental, USA	0719318
Clearfil Twist Dia	Diamond impregnated spiral	Two-step polisher	Kuraray Noritake Dental İnc., Japan	455213
OptiDisc	Polyethylene synthetic polymers aluminum oxide	Multi-step polisher	Kerr Corporation, USA	7120288

TEGDMA: Triethylene glycol dimethacrylate, UDMA: Urethane dimethacrylate

Table 2. Multiple comparisons of mean color difference (△E00) between different polishing systems after simulated coffee immersion and brushing, at different time points and after re-polishing.

		n	Median (Min-Max)[a]	Mean Rank	p
6 Month (T0-T1)	Control	10	10.9 (3.85-13.34)a	28.6	0.001
	One-step polisher(OneGloss)	10	12.02 (2.67-13.65)a	29.4	
	Two-step polisher(Clearfil Twist Dia)	10	2.33 (1.14-8.66)b	14.25	
	Multi-step polisher(OptiDisc)	10	1.26 (0.22-8.64)b	9.75	
1 Year (T0-T2)	Control	10	11.59 (5.60-13.05)a	29.3	0.001
	One-step polisher(OneGloss)	10	11.33 (1.41-13.57)a	28.8	
	Two-step polisher(Clearfil Twist Dia)	10	1.94 (1.18-4.21)b	12.3	
	Multi-step polisher(OptiDisc)	10	1.70 (0.52-9.62)b	11.6	
After Re-polishing (T0-T3)	Control	0	-		0.405
	One-step polisher(OneGloss)	10	1.50 (0.95-4.31)	13.5	
	Two-step polisher(Clearfil Twist Dia)	10	2.37 (0.64-2.96)	14.5	
	Multi-step polisher(OptiDisc)	10	2.61 (0.98-4.28)	18.5	

a,b exponential letters are used for comparison of groups at the same mean color change values. There is no difference between the groups with the same letter.

Table 3. Multiple comparisons of mean color difference (△E00) between different polishing systems after simulated coffee immersion and brushing, according to the different time points.

	6 Month (T0-T1) Median (Min-Max)	**1 Year (T0-T2) Median (Min-Max)**	**After Re-polishing(T0-T3) Median (Min-Max)**	**p**
Control	10.9 (3.85-13.34) a	11.59 (5.60-13.05) a	-	-
One-step polisher (OneGloss)	12.02 (2.67-13.65) a	11.33 (1.41-13.57) a	1.50 (0.95-4.31) b	0.013
Two-step polisher (Clearfil Twist Dia)	2.33 (1.14-8.66) a	1.94 (1.18-4.21) a	2.37(0.64-2.96) a	-
Multi-step polisher (OptiDisc)	1.26 (0.22-8.64) a	1.70 (0.52-9.62) a	2.61 (0.98-4.28) a	-

a,b exponential letters are used for comparison of groups at the same mean color change values. There is no difference between the vertical columns with the same letter.

The effect of different polishing systems on the color change of single-shade resin composite was found to be different after exposure simulations at 6 months and 1 year periods, so hypothesis H01 was rejected. Although re-polishing had no significant effect on color change in two-step polisher (Clearfil Twist Dia) and multi-step polisher (OptiDisc) groups, a significant change in color change was observed after re-polishing with one-step polisher (OneGloss). Therefore, hypothesis H02 was rejected.

Coffee consumption is widespread and increasingly becoming a part of dietary habits around the world. In the study of Guler et al.[18], it was stated that a cup of coffee is consumed in approximately 15 min, and the average daily coffee consumption per person is 3.2 cups. Based on these data, the present study immersed resin composite specimens in coffee solution for 6 days, simulating 6 months of clinical use, and for 12 days, simulating 1 year of clinical use. Also, it has been reported that tooth brushing, as part of oral hygiene, reduces staining by removing extrinsic pigments that stain restorative materials.[9,10] A study by Sexson et al.[19] found that a person performs an average of 15 cycles of brushing per brushing session. This finding means that a total of 10,000 cycles are completed over the course of a year while maintaining oral hygiene by brushing twice a day. Therefore, in addition to staining the resin composite samples, 5,000 cycles simulating 6 months of tooth brushing and 10,000 cycles simulating 1 year of tooth brushing were performed on the brushing simulation device. In the present study, no significant difference was found between the 6-months and 1-year coffee and brushing exposure simulation in all groups tested ($p>0.05$).

The formation of a resin-rich layer on the top surface of the resin composite as a result of polymerization under a mylar strip has an impact on the color stability of the resin composite. More discoloration has been reported in composite resins finished with mylar strips only as a result of the resin-rich layer compared to surfaces polished with a polishing system.[20,21] Although polishing results in a rougher surface compared to resin composites finished with mylar strips, it reduces the hydrophilicity of the restoration by reducing the amount of organic matrix on the surface.[22] This means that the coloring pigments are less absorbed. In the present study, the resin composite specimens in the control group did not receive any polishing procedures and were cured against a mylar strip. The Control group showed the highest color change at 6-months and 1-year of coffee and brushing exposure simulation. In addition, resin composite specimens polished with one-step polisher (OneGloss), exhibited a similar color change to the Control group ($p>0.05$).

It has been reported that the surface quality of resin composite is affected by finishing and polishing procedures, which may be associated with the early discoloration of resin composites.[23–25] In the present study, resin composite specimens polished with diamond abrasive two-step polisher (Clearfil Twist Dia) and aluminum oxide-coated abrasive disc multi-step polisher (OptiDisc) exhibited significantly less discoloration than one-step polisher (OneGloss). The one-step polisher (OneGloss) had the highest abrasive particle size (80 μm) among the materials compared in the study. The abrasive type, hardness, and distribution of the tested polishing systems varied significantly and may have had an effect on the color stability of the resin composite. In a similar previous study comparing the color change of Omnichroma polished with three-step (Enamel Plus Shiny), two-step (Super-Snap X-treme) and one-step (OneGloss) polishers and stained with coffee, it was reported that there was a difference between the polishing materials and that the group with the least color change was the three-step (Enamel Plus Shiny), and the group with the most color change was the one-step (OneGloss) polisher. However, unlike the present study, no brushing procedure was included in this study.[15]

Re-polishing can partially or completely remove discoloration or absorbed stains on the top surface of colored resin composite restorations.[8,26] In few studies examining the depth of discoloration, it was reported that restoration discoloration occurs in a superficial layer of less than 20 μm and that it is possible to remove this layer by re-polishing.[27,28] In a study examining the effect of re-polishing Omnichroma resin composite after immersion in coffee on color change, researchers reported that re-polishing with different polishing systems affected the results and that polishing systems containing diamond particles were more effective in stain removal than aluminum oxide particles and silicon-carbide abrasive particles.[29] In this study, the re-polishing procedure applied to remove stains after the coffee immersion and brushing cycles was significantly effective in reducing the color change values for specimens polished with the one-step polisher (OneGloss) group only. In addition, the color change values of the single-shade resin composite were above the acceptable $\Delta E=1.8$ in all periods and groups. The results of our research align with previous studies that have shown the efficacy of re-polishing resin composites after staining with different solutions in decreasing the ΔE values to some extent.[8,30–32]

In addition, the polishability and surface quality of resin composites are affected by various variables depending on the type of resin composite , such as filler particle size, filler load and type, resin amount, and particle shape.[33] The inorganic filler composition of the single-shade resin composite Omnichroma, utilized in this investigation, contains fillers consisting of silicon dioxide (SiO2) and zirconium dioxide (ZrO2) with a uniform supra-nano spherical particle size of 260 nm, and contains TEGDMA and UDMA monomers in the resin matrix composition. It has been reported that the TEGDMA monomer in the matrix structure of resins composites shows more color change than other monomers.[34,35] Several studies comparing the color changes of resin composites have concluded that Omnichroma, a single-shade resin composite, undergoes a more pronounced color change than other resin composites.[2,3,36] The color change values measured in the present study were higher than the acceptable $\Delta E=1.8$ at all time periods. Therefore, the monomer structure and inorganic components of Omnichroma may have affected color stability regardless of the polishing systems tested.

One of the limitations of the present study is that the color stability evaluation was performed under in vitro conditions. Although beverage consumption and brushing are simulated, variables such as chewing movements in the oral cavity, the temperature of food and beverages, and saliva will also be important for color stability. Furthermore, although all procedures were performed by a single operator, the absence of a pressure stabilization system may have affected the results. In addition, the polishing systems tested in the present study were tested on a single type of resin composite. In the future, the color stability of resin composite types and commercial brands with different monomer and resin matrix structures should be compared in long-term clinical studies.

Conclusion

Within the limitations of this current in vitro study, it was concluded that: The color change value of the single-shade resin composite was significantly higher in the group polished with a one-step polisher as a result of coffee exposure and brushing simulations. Although the two-step polisher and the multi-step polisher performed better than the one-step polisher, the measured color change was above the acceptable threshold. Although the color change values decreased quantitatively after re-polishing, this decrease was significant only in the group re-polished with one-step polisher.

Author Contributions

Methodology and Conceptualization : All Authors
Data Analysis and İnterpretation : S.O.

Writing - Original Draft : S.O.
Review and Editing : All Authors

Conflict of Interest

The authors do not have any financial interest in the companies whose materials are included in this article.

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