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Effect of Whitening Mouthwash on Color Change of Discolored Bulk-Fill Composite Resins[#]

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Research Article

Acknowledgment
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History

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ABSTRACT

Objectives: The aim of this in-vitro study is to investigate discoloration of the composite resins with different characteristics which were colored by immersing in coffee, kept in mouthwashes with and without hydrogen peroxide.
Materials and Methods: In this study, 18 samples (6 mm x 2 mm) pre-heated bulk-fill (Viscalor Bulk -(VIS)), dual-cured (Fill Up!-(FUP)) bulk-fill and a microhybrid composite resin (G-aenial posterior-(GCP)) were prepared. After the samples were kept in distilled water for 24 hours, baseline colour measurements were performed with a spectrophotometer. ΔE001 color measurements were made of the samples immersed in coffee for 7 days. The samples were divided into two groups to be kept in mouthwashes with hydrogen peroxide (Crest 3D White) and without hydrogen peroxide (Listerine Advance White) (n=9). ΔE_{002} color measurements were applied after kept in whitening mouthwashes for 24 hours. Discoloration were calculated with the CIEDE2000 formula. Data were statistically analysed with One-way ANOVA and post hoc tukey tests.
Results: For samples immersed in coffee, while statistically highest ΔE values were obtained in GCP (7.30) group, there was no difference between VIS (3.30) and FUP (3.01). Statistically significant colour reduction was observed in VIS and FUP samples kept in both mouthwashes. GCP samples showed colour change above the clinically acceptable threshold (ΔE<2.25).
Conclusions: A decrease in discoloration for all materials was found as an effect of whitening mouthwashes. However, GCP showed clinically unacceptable discoloration after immersed in coffee or mouthwashes. Both whitening mouthwashes provided effective whitening for VIS and FUP groups.

Keywords: Bulk-Fill Composite, Color Stability, Dual-Cured Composites, Pre-Heating, Whitening Mouthwash.

Beyazlatıcı Ağız Gargaralarının Renklendirilmiş Bulk-Fill Kompozit Rezinlerin Renk Değişimine Etkisi[#]

Bilgi
#Bu çalışma 23-25 Kasım 2021 tarihleri arasında düzenlenen 'Sivas Cumhuriyet Üniversitesi 1. Uluslararası Diş Hekimliği Kongresi'nde sözlü bildiri olarak sunulmuştur.
**Sorumlu yazar*

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ÖZ

Amaç: Bu in-vitro çalışmanın amacı, kahveye daldırılarak renklendirilen farklı özelliklerdeki kompozit rezinlerin, hidrojen peroksit içeren ve içermeyen ağız gargaralarında bekletilmelerinin renk değişimine etkisini araştırmaktır.
Yöntem: Bu çalışmada önceden ısıtma özelliğine sahip (Viscalor Bulk (VOCO)-(VIS)) ve dual cured (Fill Up! (Coltene)-(FUP)) bulk-fill kompozit rezinleri ile bir mikrohibrit kompozit rezinden (G-aenial posterior (GC Corp.)-(GCP)) 6 mm çapında 2 mm kalınlığında 18'er adet örnek hazırlandı. Örnekler 24 saat distile su içerisinde bekletildikten sonra başlangıç renk ölçümleri bir spektrofotometre ile yapıldı. 7 gün boyunca kahvede bekletilen örneklerin ΔE_{001} renk ölçümleri yapıldı. Ardından örnekler, hidrojen peroksit içeren (Crest 3D White) ve hidrojen peroksit içermeyen (Listerine Advance White) ağız gargaralarında bekletilmek üzere iki gruba ayrıldı (n=9). 24 saat beyazlatıcı ağız gargarasında bekletildikten sonra ΔE_{002} renk ölçümleri yapıldı. Renk değişiklikleri CIEDE2000 formülü ile hesaplandı. Elde edilen veriler tek yönlü varyans analizi (One-way ANOVA) ve post hoc tukey testleri ile istatistiksel analiz edildi.
Bulgular: Kahvede bekletilen örneklerde GCP (7,30) grubunda istatistiksel olarak en yüksek ΔE değerleri elde edilirken (p<0,05), VIS (3,30) ve FUP (3,01) arasında fark yoktu. Her iki gargarada bekletilen VIS ve FUP örneklerinde istatistiksel olarak anlamlı renk azalması gözlendi. GCP örnekleri klinik olarak kabul edilebilir eşiğin (ΔE<3,3) üzerinde renk değişimi gösterdi.
Sonuçlar: Beyazlatıcı ağız gargarası içerisinde bekletilmesi sonucunda tüm materyallerin renklenmesinde bir düşüş bulunmuştur. Ancak GCP örnekleri hem kahvede hem gargaralar uygulandıktan sonra klinik olarak kabul edilemez düzeyde renk değişikliği göstermiştir. Her iki beyazlatıcı ağız gargarası VIS ve FUP grupları için etkin bir beyazlatma sağlamıştır.

Anahtar Kelimeler: Bulk-Fill Kompozit, Renk Stabilitesi, Dual-Cure Kompozit, Beyazlatıcı Ağız Gargarası.

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Introduction

Nowadays, composite resins are among the most preferred restorative materials due to their improving mechanical, physical and aesthetic properties. With the development of composite resins, one of the composite resins that have been introduced to the market recently and that have undergone changes in their content and polymerization properties is bulk-fill composite resins.[1] Bulk-fill composite resins, which are applied to a depth of 4-5 mm in one step, have been introduced to the market due to the formation of voids, interlayer oral liquid contamination and time-consuming layering technique, when composite resins are applied in layers with a maximum thickness of 2 mm.[2,3]

The use of bulk-fill composites simplifies the procedure for deep and wide restorations and saves clinical time. In addition, it is becoming a more acceptable alternative due to its polymerization properties and better control of stress from polymerization shrinkage.[4] One of the bulk-fill resins with different properties that have been introduced to the market recently is the composite resin designed with thermo-viscous technology. Preheating improves the composite resin's handling properties and reduces film thickness, increasing flow and providing better marginal adaptation.[5] Another contemporary bulk fill composite is the dual cure bulk fill composite for polymerization in deep cavity restoration.[6]

Bulk-fill composite resins are mostly preferred for the posterior region, but it is important to preserve the basic aesthetic properties of the restoration. Despite the improvement of their physical and mechanical properties, the inability of composite resins to maintain their color stability for a long time is one of the most important reasons for rebuilding of restoration.[7] External and internal discoloration can be seen in composite resin restorations.[8] Extrinsic coloration occurs due to insufficient polymerization, heat, UV irradiation, water absorption, or absorption of colorants from food and beverages. Intrinsic discoloration is associated with filler particles, resin matrix and photoinitiators.[9,10]

Rebuild of the stained restoration is a costly treatment option to correct the aesthetic problem. Re-polishing and whitening approaches can be considered as less costly alternative treatments. Researchers have reported that bleaching treatments influence the color change of colored composite restorations.[8]

Current whitening agents have been marketed in various contents. The most used active ingredient is hydrogen peroxide. Oxygen molecules that emerge because of the breakdown of hydrogen peroxide penetrate the teeth, break down the pigmented molecules, and the whitening process takes place.[11] Most research has been done on hydrogen peroxide whitening mouthwashes that have proven whitening ability.[12-14] However, it has been reported that hydrogen peroxide causes many complications.[12,15,16] Commercially available whitening mouthwashes contain low levels of hydrogen peroxide, as well as carbamide peroxide, sodium chloride or alternative bleaching agents.[17]

The aim of this in-vitro study is to investigate the effect of hydrogen peroxide-containing and non-hydrogen peroxide mouthwashes on the color change of composite resins with different properties, which are colored by stored in coffee. The tested hypotheses that: 1) there would be no difference in discoloration among bulk-fill and microhybrid composite resins after coffee immersion, 2) whitening mouthwashes would not provide an effective color change on colored composite resins, 3) there would be no differences in color change between the tested whitening mouthwashes.

Materials and Methods

In this study, preheated (Viscalor Bulk (VOCO)) and dual-cured (Fill Up! (Coltene)) bulk-fill composite resins and a microhybrid composite resin (G-aenial posterior (GC Corp.) were used. The materials used in the study and their contents are given in Table 1.

Eighteen samples of 6 mm diameter and 2 mm thickness were prepared from each of the 3 materials by locating the resin material in a silicone mold After the materials were placed in the molds, they were covered with a mylar strip and microscopic slides were placed on top and bottom surface of mold. In accordance with the following manufacturer recommendations, composite resins were performed and light curing was carried out:

- Viscalor Bulk which unidose composite campules was pre-heated using a CapsWarmer (VOCO, Germany) in T3 mode (up to 68◦C) for 3 min (T3-3 min). It was applied to the mold within 30 seconds. Light cured for 20 seconds at 1000 mW/cm^2 in standard mode (VALO; Ultradent Products, Inc) using an LED light device.
- Fill Up! was applied to the mold, then light cured for 10 seconds at 1000 mW/cm^2 in standard mode using an LED light device to accelerate the curing process by the manufacturing information. After 3 min, Fill-Up! was chemically cured and removed from the mold.

G-ænial POSTERIOR microhybrid composite was applied to the mold in 2 mm thick layers. Each layer was light-cured separately for 20 seconds at 1000 mW/cm^2 in standard mode using an LED light device.

Samples were stored in distilled water at 37°C for 24 hours. The first color measurements (T0) after full polymerization were made using a spectrophotometer (VITA Easyshade Compact; VITA Zahnfabrik) and L*, a*, b* values were recorded. Measurements were made by calibrating the device before each measurement and on a white background (L=53.5, a=3.2, b=12.8) in lighting conditions in D65 standards. All color measurements were made by a single operator.

Table 1. The composition and manufacturer of the materials tested in the study

Material	Manufacturer	Code	Type	Content	FL	Shade	BN
VisCalor bulk	Voco, Cuxhaven, Germany	VIS	Termoviscous bulk-fill composite	Matrix: Bis-GMA, aliphatic dimethacrylate Fillers: Glass ceramic fillers (average 1 μm) silicon dioxide nanoparticles (20-40 nm)	83 wt.%	A2	2101677
Fill-Up	Coltene/Whaledent Altstätten, Switzerland	FUP	Dual curing bulk-fill composite	TMPTMA, UDMA, Bis-GMA, TEGDMA, benzoyl peroxide, dibenzoyl peroxide Fillers: Glass, amorphous silica, zinc oxide (2 μm)	65 wt%	A2	J87573
G-ænial Posterior	GC Corporation Tokyo, Japan	GCP	Micro-hybrid composite	Monomers; Methacrylate monomers, UDMA, dimethacrylate comonomers Fillers; Prepolymerized fillers (silica, strontium and lanthanoid fluoride), fluoroaluminosilicate, fumed silica (16-17 μ)	77 wt%	A2	1806215

BN: Batch Number; FL: Filler load% wt; TM PTMA: Trimetholeolpropane trimethacrylate, UDMA: urethane dimethacrylate, Bis-GMA: bisphenol glycidyl methacrylate, TEGDMA: triethylene glycol dimethacrylate

Table 2. Details of tested whitening mouth rinses

WMR	Composition	Company
Crest 3D White	Water, glycerin, hydrogen peroxide, propylene glycol, sodium hexametaphosphate, poloxamer 407, sodium citrate, flavor, sodium saccharin, citric acid	Procter & Gamble, Cincinnati, OH, USA.
Listerine Advance White	Aqua, Alcohol, Sorbitol, Tetrapotassium Pyrophosphate, Pentasodium Triphosphate, Citric Acid, Poloxamer 407, Sodium Benzoate, Eucalyptol, Thymol, Menthol, Sodium Saccharin, Sodium Fluoride, Tetrasodium Pyrophosphate, Propylene Glycol, Sucralose, Aroma, Disodium Phosphate.	Johnson& Johnson, Pomezia, Italy

WMR: Whitening Mouth Rinse

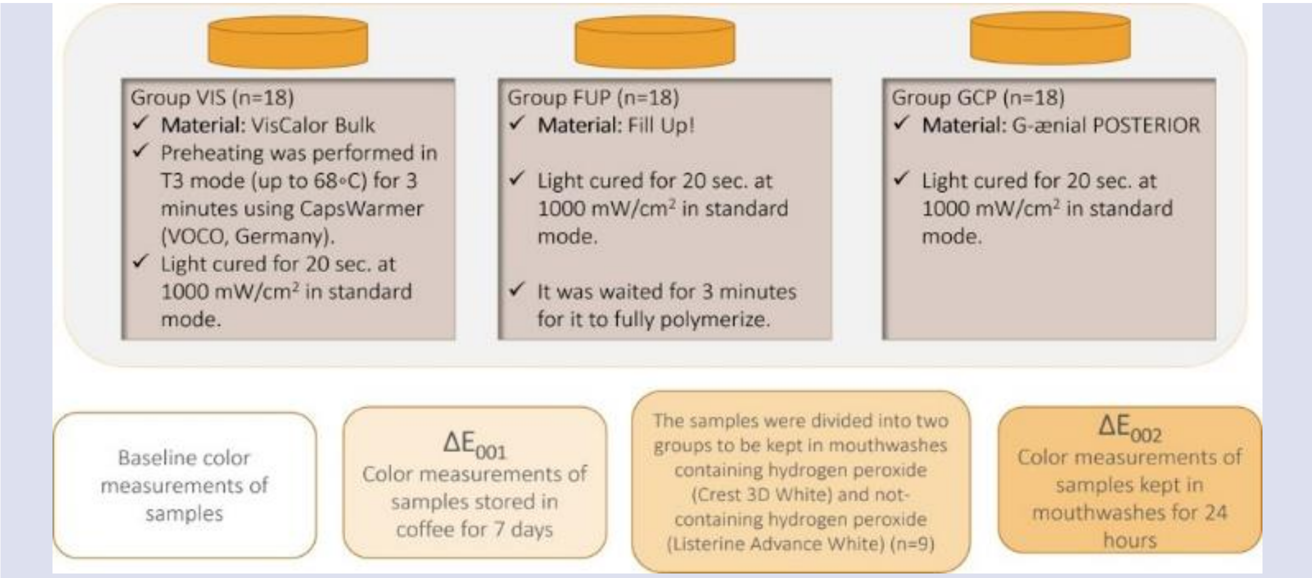

Figure 1. Study overview

Following the color measurement, the samples were kept in coffee (2 g sachet contents were dissolved in 200 mL boiled water that did not contain sugar or milk. (Nescafé Classic, Single Bags; Nestlé)) in closed containers for 1 week. Coffee was refreshed daily. After the coloring process, the second color measurements of the samples were made (T1).

Washed and dried samples were kept in 2 mouthwashes (Crest Crest 3D White, Procter & Gamble and Listerine Advance White, Johnson& Johnson) with different contents for 24 hours (n=9). The samples extracted from the solutions were washed under running water and dried before the third color measurement (T2). The flow chart of the study is shown in Figure-1.

Color changes were evaluated according to the formula CIEDE2000 (ΔE_{00}) between T1 and T0, between T2 and T0. The ΔL, ΔC, and ΔH in the formula describe the differences in lightness, chroma, and hue between two measurements. 'S' stands weight functions for chroma and hue. In this study, K_L, K_C and K_H were accepted as "1".[13]

$$\Delta E_{00}=\sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2+\left(\frac{\Delta C}{K_C S_C}\right)^2+\left(\frac{\Delta H}{K_H S_H}\right)^2+R_T\left(\frac{\Delta C}{K_C S_C}\right)\left(\frac{\Delta H}{K_H S_H}\right)}$$

Statistical analyzes of this study were performed using the SPSS 21.0 (SPSS Inc. Chicago, IL, USA) program. The normality of data was checked with the Shapiro-Wilk test, and then statistical analysis was completed using one-way analysis of variance (ANOVA) and post hoc tukey test. Statistically significant level of $p<0.05$ was accepted.

Results

ΔE_{001} values of the samples after immersion in coffee are given in Figure 2. Statistically, the highest color change was obtained in the GCP group (7.30) ($p<0.05$). There was no statistically significant difference in discoloration between VIS (3.30) and FUP (3.01) ($p>0.05$).

50:50% acceptability threshold value was reported to be DE00= 2.25 by Ghinea et al.[18] Accordingly, clinically acceptable color changes were not observed in all groups evaluated in coffee immersion.

Figure 2: The mean and standard deviations of ΔE001 (color measurements of stored in coffee) values.

Table 3. The mean and standard deviations of ΔE002 values

ΔE_{002}	Crest 3D White	Listerine Advance White	p
VIS	1.51±0.45a	1.07±0.57a	0.428
FUP	1.51±0.63a	1.19±0.20a	0.284
GCP	5.15±2.32b	4.63±1.55b	0.012
p	0.000	0.000	

The superscript lowercases indicate the statistical differences within lines. The effect of mouthwashes on the material does not difference significantly ($p<0.05$).

The color change values (ΔE_{002}) obtained after the groups were immersed in whitening mouthwashes are shown in Table 3. In immersed both mouthwashes, VIS and FUP bulk-fill composite resins showed higher color stability than GCP. Statistically significant color reduction was observed in VIS and FUP samples in both mouthwashes ($p<0.05$). When ΔE_{001} and ΔE_{002} values were examined, there were significant difference in whitening in VIS and FUP groups in both mouthwashes, but no statistically significant difference was observed in the GCP group. Only in GCP, clinically acceptable color change (ΔE_{00} >2.25) was not observed after immersed in Listerine (ΔE=4.63) and Crest (ΔE=5.15).

Discussion

In the study, bulk-fill composite resins colored by immersed in coffee showed significantly higher color stability than the microhybrid composite. Therefore, the first hypothesis was rejected.

In this study, the CIEDE2000 color system was used to determine the color differences. The studies stated that color differences are determined more accurately in this system.[19-21] CIEDE2000 (ΔE_{00}) provides a better harmony than CIELAB, as it better distinguishes slight color differences in terms of threshold values during the evaluation of color differences.[19] Also, the DE00 formula changes the a* coordinate of the CIELAB and can include these special coordinates for non-uniform interactions between hue and chroma that specifically affect low chroma color.[22] Composite resin materials can absorb water as well as other liquids and pigments. This results in coloring of the composite resins.[23] The human eye is limited in observing color differences. In this study, the ΔE threshold detectability and acceptability was evaluated as 2.25.[18] In the current study, clinically unacceptable discoloration was observed in all tested composite resins in coffee immersion (ΔE_{00} >2.25). The color stability of resin composite restorations is affected by several factors, including the resin matrix, filler size, and the photoinitiator system of the composites.[24] Due to the hydrophilic characteristic of the resin matrix, the resin monomers and the degree of water absorption of these monomers can affect color stability. Higher water absorption can cause the resin matrix to absorb not only water but also other coloring liquids that cause discoloration.[23] The Bis-GMA based resin matrix has higher water absorption and therefore less stain resistance than UDMA.[19] In addition, increasing the ratio of TEGDMA in the resin matrix caused an increase in the water uptake of Bis-GMA based resins.[19] However, in this study, lower color change was observed in FUP samples in spite of containing Bis-GMA and TEGDMA. This difference can be attributed to the fact that the FUP material contains different resin monomers (such as TMPTMA). In a study, FUP material showed lower color change than other composite resins containing Bis-GMA.[25]

The chemical formulations, ratios and degree of crosslinking of composite resin materials differ from each other. These compositions of the resins that compose the matrix, which vary according to the brands, can show great differences in their color behavior. As a result, due to the polar structure of the resin matrices, it can also allow the penetration of color-changing agents, causing discoloration.[23] In this study, effective color reduction was observed in all composite resins evaluated after bleaching in mouthwashes. However, the color reduction in VIS and FUP samples was statistically significant. Therefore, the second null hypothesis, which stated that whitening mouthwashes would not provide an effective color change on colored composite resins, was rejected. The increased susceptibility of GCP to staining compared to bulk fill composite resins could be attributed to the filler size. VIS contains silicon dioxide nanoparticles (20-40 nm) and glass ceramic fillers (1µ). The presence of these nanofillers provides improved resistance to color changes, improving the material's smoother surface formation, gloss and polishing ability.[26-28] FUP contains 2 µ glass, amorphous silica fillers, while GCP's average filler size (16-17 µ) is larger than the tested bulk-fill composites (Table 1). With increasing infill size, the material can be easily eroded by the effects of coloring agents, resulting in rougher surfaces that are prone to staining.[24] In the literature, it has been reported that composite resin specimens in soaking mouthwash for 12 hours is equivalent to gargling once a day for 2 minutes for a year.[29] To use mouthwash and antiseptics is recommended 2 times a day for 2 minutes in accordance with the manufacturer's instructions. Considering this situation, the samples were kept in solutions for 24 hours and it was aimed to provide an effect equivalent to the 1-year exposure of the solutions.

Whitening products, which can be used without the supervision of a physician, are easy to use and can be easily obtained from markets, pharmacies and the internet. These products, which are reported to be safe to use, show less whitening effect compared to professional whitening systems applied by the physician, due to their low concentration of whitening agent and short application time.[30] Whitening mouthwashes contain hydrogen peroxide, sodium hexametaphosphate, pyrophosphate, sodium citrate and various enzymes as a whitening agent. Hydrogen peroxide is a common bleaching agent used in both professional physician-applied whitening and self-applied products.[14,31] It is a very strong oxidizing agent and causes bleaching by breaking down long-chain organic pigment molecules into short-chain compounds. However, peroxide application in whitening mouthwashes is more difficult due to the short application time and safety restrictions. In general, whitening mouthwashes contain low concentrations of hydrogen peroxide.[12] Crest 3D White used in this study contains hydrogen peroxide.

There are studies evaluating the bleaching efficiency of hydrogen peroxide in the literature.[14,32,33] Researchers reported that 6% and 35% hydrogen peroxide application had a bleaching effect against coffee discoloration in enamel, dentin and composite resin samples.[32] In a study was reported that 10% concentration of hydrogen peroxide provides bleaching in composite resin samples that could be noticed with the naked eye.[33]

Increasing the percentage of hydrogen peroxide in whitening mouthwashes may result in more effective whitening. However, the use of these agents at home carries some risks due to their uncontrolled application. It easily penetrates the cell membrane, inducing broad-spectrum DNA lesions and transforms into hydroxyl radicals that can interact with DNA. In fact, oxygen reagents derived from H_2O_2 have been reported to be involved in DNA damage, which is considered a major mechanism of chemical carcinogenesis.[15]

In the present study, the efficacy of mouthwashes with and without hydrogen peroxide were evaluated. There was no difference between the whitening efficacy of mouthwashes in the evaluated materials. Therefore, the tested 3rd hypothesis was accepted. The low pH of hydrogen peroxide whitening mouthwashes and their potential risks have motivated manufacturers to develop hydrogen peroxide-free whitening mouthwashes due to their uncontrolled application.[12,15,34] These mouthwashes contain alternative whitening agents such as sodium hexametaphosphate, tetrasodium pyrophosphate, and phthalimido-peroxy-caproic acid.[15] It is thought that Listerine Advance White used in this study provides as effective whitening as mouthwashes containing hydrogen peroxide thanks to its Tetrasodium Pyrophosphate content. The results of this study are in accordance with previous studies. In a study, it was stated that the color change of the colored microhybrid composite resin of mouthwashes with and without hydrogen peroxide varies according to the mouthwash brand, not according to the hydrogen peroxide content.[13] Lee et al. investigated the color stability of composite resins of different mouthwashes and found no significant difference between different composites and different mouthwashes.[35]

In daily use, factors such as the washing effect of saliva, mouth water intake, food-beverage variety and their interactions may affect the color change after mouthwash. The effect of mouthwash in daily use should also be examined clinically, and the effect of these solutions on the color stability of composite restorations should always be considered.

Conclusion

Based on this study, the following conclusions could be found:

- The tested bulk-fill composite resins were more resistant to coloring beverage than the microhybrid composite resin.
- Both bleaching mouthwashes evaluated were an effective factor in color recovery on colored bulk-fill composite resins.
- Hydrogen peroxide in whitening mouthwashes did not create any significant difference in whitening composite resins.

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N/A

Conflicts of Interest Statement

The authors declare that they have no conflict of interest.

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