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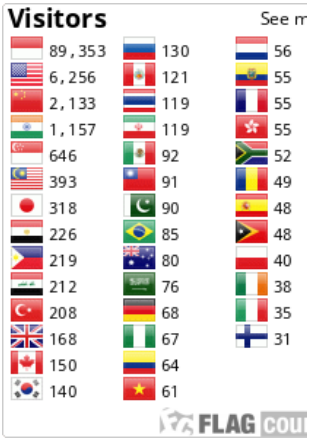

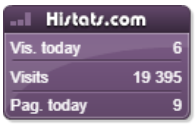

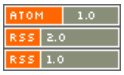

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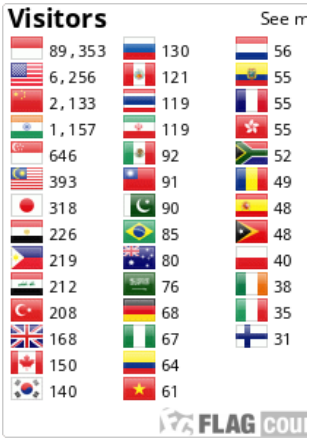

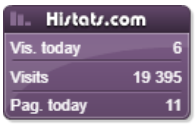

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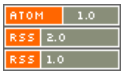

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Impact of Ready-to-Drink Beverages on the Color Stability of Acrylic Resin Teeth in Removable Partial Dentures: An In Vitro Study

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ABSTRACT

Background: Due to its many advantages, acrylic resin is the most widely used material for denture teeth in removable partial dentures. However, acrylic resin teeth are known to absorb colorants. As a substitute for natural teeth, these resin teeth are frequently exposed to foods and beverages consumed by patients. Popular ready-to-drink (RTD) beverages in Indonesia include coffee, orange juice, and carbonated drinks, each containing dyes that may affect the color stability of acrylic resin teeth. **Objective:** This study aims to assess the effect of various RTD beverages on the color stability of different acrylic resin denture teeth commonly used in Indonesia. **Materials and Methods:** The study sample consisted of 40 acrylic resin denture teeth samples, specifically maxillary central incisors, from the *Ortolux Top* and *New Ace* brands. The samples were immersed in distilled water, coffee (*Nescafe*), orange juice (*Minute Maid Pulpy Orange*), and carbonated soda (*Coca-Cola*) for five days in an incubator at 37°C. Color measurements were taken using a VITA Easyshade V spectrophotometer before and after immersion. Statistical analysis was performed using a one-way ANOVA test. **Results:** Coffee and Carbonated soda caused color changes in both brands of acrylic resin teeth, affecting the ΔE, ΔL, ΔC, and ΔH values, making the samples darker, more yellowish, and decreasing color saturation. However, orange juice only affected the ΔL and ΔC values of the *New Ace* brand, causing the samples to appear darker and less saturated. **Conclusion:** Some RTD beverages (coffee, orange juice, and carbonated drinks) can lead to discoloration of acrylic resin teeth, making them darker and less saturated.

Keywords: Acrylic resin teeth, ready-to-drink beverages, color stability

ABSTRAK

Latar belakang: Resin akrilik adalah bahan yang paling banyak digunakan untuk gigi tiruan pada gigi tiruan sebagian lepasan karena banyak keunggulannya. Namun, gigi tiruan resin akrilik diketahui dapat menyerap pewarna. Sebagai pengganti gigi asli, gigi tiruan ini sering terpapar oleh makanan dan minuman yang dikonsumsi oleh pasien. Minuman siap saji yang populer di Indonesia antara lain kopi, jus jeruk, dan minuman bersoda, yang masing-masing mengandung zat warna yang dapat mempengaruhi stabilitas warna gigi tiruan akrilik. **Tujuan:** Penelitian ini bertujuan untuk menilai pengaruh berbagai minuman RTD terhadap stabilitas warna gigi tiruan resin akrilik yang umum digunakan di Indonesia. **Bahan dan Metode:** Sampel penelitian terdiri dari 40 sampel gigi tiruan resin akrilik, khususnya gigi insisivus sentral rahang atas, dari merek *Ortolux Top* dan *New Ace*. Sampel direndam dalam air suling, kopi (Nescafe), jus jeruk (*Minute Maid Pulpy Orange*), dan soda berkarbonasi (Coca-Cola) selama lima hari dalam inkubator pada suhu 37°C. Pengukuran warna dilakukan dengan menggunakan spektrofotometer *VITA Easyshade V* sebelum dan sesudah perendaman. Analisis statistik dilakukan dengan menggunakan uji ANOVA satu arah. **Hasil:** Kopi dan Soda berkarbonasi menyebabkan perubahan warna pada kedua merek gigi resin akrilik, mempengaruhi nilai ΔE, ΔL, ΔC, dan ΔH, membuat sampel menjadi lebih gelap, lebih kekuningan, dan menurunkan saturasi warna. Namun, jus jeruk hanya mempengaruhi nilai ΔL dan ΔC pada merek *New Ace*, menyebabkan sampel tampak lebih gelap dan kurang jenuh. **Kesimpulan:** Beberapa minuman RTD (kopi, jus jeruk, dan minuman berkarbonasi) dapat menyebabkan perubahan warna pada gigi tiruan resin akrilik, membuatnya menjadi lebih gelap dan kurang jenuh.

Kata Kunci: gigi resin akrilik, minuman siap minum, stabilitas warna

1. Introduction

Dental health issues are prevalent in Indonesia, with the 2013 Riskesdas survey reporting 25.9% of the population facing dental and oral health problems—a figure that increased to 57.6% by 2018, accompanied by a DMF-T (Decayed, Missing, Filled Teeth) index score of 7.1. This index's "Missing" component is particularly high, with a rate of 2.5, underscoring the extent of tooth loss.[1, 2]. Untreated tooth loss over time can alter facial aesthetics.[3] To address this, removable partial dentures (RPDs) are a common treatment option designed to replace missing teeth and allow patients to remove and reattach them as needed.[4]

A critical component of RPDs is the artificial tooth, typically made from either acrylic resin or porcelain.[5] Acrylic resin teeth are preferred in removable dentures because they offer several benefits over porcelain.[5, 6] However, acrylic resin teeth tend to absorb colorants, making color stability an important factor.[7, 8] Discoloration can detract from the natural appearance of artificial teeth and may arise from external sources like coffee, tea, red wine, fruit juices, and carbonated drinks. The extent of discoloration also varies with the duration of exposure.[6, 8, 9] In Indonesia, the annual consumption of ready-to-drink (RTD) beverages is approximately 2.4 liters per person.[10] Popular RTD choices, such as coffee, orange juice, and carbonated drinks, contain pigments that may discolor acrylic resin.[11] Tannins in coffee can cause browning, while pigments in carbonated drinks and orange juice may be absorbed by resin.[8, 12]

Artificial teeth in dentures frequently come into contact with saliva, foods, and beverages.[6] Over time, acrylic resin teeth will likely change color due to ongoing absorption and adsorption of pigments from these substances. Extrinsic discoloration often results from continuous exposure to pigment-laden beverages, influenced by patient dietary habits.[8, 9] Based on this background, and the authors aimed to examine how different RTD beverages. Specifically, coffee, orange juice, and carbonated drinks affect the color stability of Indonesia's commonly used acrylic resin RPD teeth brands.

2. Material and Methods

This study employed a laboratory-based experimental design with a pre-test and post-test control group structure. A total of 40 samples were selected, comprising left and right upper central incisor acrylic resin teeth from two brands, Ortolux Top and New Ace, each with a shade of A3 (3M1D2). Each brand contributed 20 samples, which were divided into four groups based on immersion solutions: distilled water, canned Nescafe Original coffee (240 mL), Minute Maid Pulpy Orange juice (300 mL), and Coca-Cola (250 mL).

Before immersion, the initial color of each sample was measured using a spectrophotometer (Vita Easyshade V) , which was calibrated beforehand. The color was recorded by positioning the spectrophotometer's tip at the middle third of the labial surface of each tooth at a 90° angle.

Figure 1. Calibared Spectrophotometer

The pH of each beverage was carefully measured using a calibrated pH meter to assess its acidity, a critical factor influencing the potential discoloration of dental materials. For this purpose, 15 mL of each beverage—coffee, carbonated soda, and orange juice—was placed in separate clean containers to ensure accurate and uncontaminated readings. This step was essential to determine the chemical environment each dental sample would be exposed to during immersion. The pH measurements provided valuable context, as acidic beverages are known to interact with the surface properties of acrylic resin, potentially accelerating discoloration and degradation. By incorporating

pH analysis, the study offered a deeper understanding of how beverage acidity contributes to the color stability of dental prosthetic materials.

Figure 2. The pH of each beverage was also measured using a pH meter

Each acrylic resin sample was immersed in its respective beverage solution to simulate prolonged exposure under controlled conditions. The samples were stored in an incubator set at a constant temperature of 37°C, mimicking the average temperature of the oral cavity. The immersion period lasted for five days to allow sufficient interaction between the dental material and the beverage. To ensure the consistency and accuracy of the study, the immersion solutions were refreshed daily to prevent particle sedimentation or alterations in the beverage composition that could influence the results. This meticulous procedure was designed to replicate real-life conditions as closely as possible while maintaining the reliability of the findings, providing valuable insights into the long-term effects of these beverages on the color stability of acrylic resin dental elements.

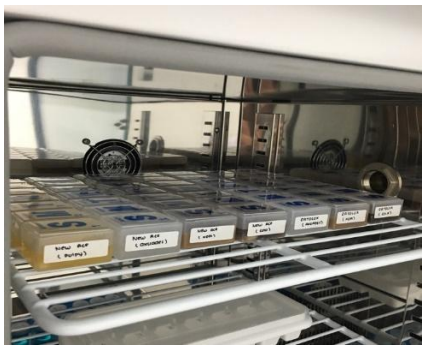

Figure 3. The sample was immersed in an incubator at a constant temperature of 37°C

After the five-day immersion period, each sample was carefully removed from its respective solution and dried thoroughly using a chip blower to eliminate any residual moisture that could interfere with the accuracy of the subsequent measurements. Once dried, the final color measurement was conducted using the VITA Easyshade V spectrophotometer, ensuring precise and consistent data collection. This final measurement captured any changes in the parameters of ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue), providing a detailed assessment of the impact of each beverage on the color stability of the acrylic resin teeth. The collected color data were then systematically analyzed and compared to the baseline measurements taken before immersion. This comparison allowed for the quantification of changes and provided insights into the extent and nature of discoloration caused by each beverage, contributing to a comprehensive understanding of how different RTD beverages affect the aesthetic properties of dental materials over time.

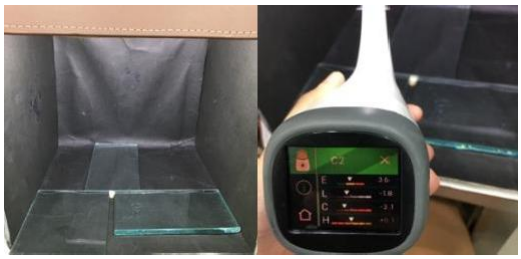

Figure 4. Color measurement using the spectrophotometer

The color measurement data obtained from the spectrophotometer were subjected to statistical analysis using IBM SPSS Statistics version 23 to determine the significance of the observed color changes. Initially, the normality of the data was assessed using the Shapiro-Wilk test, ensuring that the distribution of the data met the assumptions required for parametric testing. If the data were found to be normally distributed, a one-way Analysis of Variance (ANOVA) was performed to identify any significant differences in color changes across the different groups of beverages. When the ANOVA results indicated statistically significant differences, further post-hoc analysis was conducted using the Least Significant Difference (LSD) test to pinpoint which specific groups differed. This step-by-step statistical approach ensured a robust and detailed understanding of the impact of each beverage on the color stability of the acrylic resin samples. By employing these methods, the study provided reliable insights into the comparative effects of coffee, carbonated soda, and orange juice on dental prosthetic materials.

3. Results and Discussion

The study evaluated the color stability of acrylic resin teeth in removable partial dentures by measuring color changes using the VITA Easyshade V spectrophotometer, which provided precise data on four specific parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). These measurements comprehensively assessed the overall color changes, brightness or darkness, intensity, and tonal shifts caused by exposure to Ready-to-Drink (RTD) beverages. Before immersion, the pH levels of the beverages were measured to determine their acidity, a factor known to influence discoloration and surface changes in dental materials. The pH values recorded were 6.6 for coffee, indicating near-neutral acidity, 2.9 for carbonated soda, reflecting high acidity, and 4.0 for orange juice, representing moderate acidity. These pH differences were critical in understanding their potential impact on color changes. The immersion process was designed to simulate real-life exposure conditions, and the resulting data highlighted the extent and nature of discoloration caused by each beverage. This study provides valuable insights for dental practitioners and patients, emphasizing the importance of dietary choices in maintaining the aesthetic longevity of removable partial dentures.

Table 1. Normality Test Using the Shapiro-Wilk Test

Acrylic resin teeth brand	Beverages	*p*			
		ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest	.502*	.687*	.492*	.984*
	Coffee	.814*	.421*	.195*	.787*
	Carbonated Soda	.201*	.114*	.985*	.093*
	Orange juice	.501*	.135*	.314*	.884*
New Ace	Aquadest	.421*	.314*	.382*	.814*
	Coffee	.421*	.314*	.435*	.421*
	Carbonated Soda	.980*	.685*	.492*	.131*
	Orange juice	.814*	.101*	.077*	.314*

* $p > 0.05$

Table 1 presents the results of the Shapiro-Wilk normality test conducted for both brands of acrylic resin teeth, Ortolux Top and New Ace, across all measured color parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). The p-values for each parameter were greater than 0.05, indicating that the data met the assumption of normality. This confirms that the distribution of the color measurement data was statistically normal for all parameters and across both brands, allowing for parametric tests in subsequent analyses. The normality of the data provides a solid foundation for conducting a one-way ANOVA to investigate further differences in color

stability among the various beverage groups. This step was crucial in ensuring the validity and reliability of the statistical conclusions drawn from the study.

Table 2. Oneway-ANOVA test

Acrylic resin teeth brand	Beverages	*p*			
		ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest Coffee Carbonated Soda Orange juice	.000*	.000*	.000*	.000*
New Ace	Aquadest Coffee Carbonated Soda Orange juice	.000*	.000*	.000*	.000*

* $p > 0.05$

Table 2 provides the results of the one-way ANOVA performed to assess the effects of beverage immersion on the color stability of acrylic resin teeth from both brands, Ortolux Top and New Ace. The analysis revealed p-values below 0.05 for all measured parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). These statistically significant results led to the rejection of the null hypothesis, confirming that the immersion of samples in the three tested beverages—coffee, carbonated soda, and orange juice—over the five days caused notable changes in the color stability of the dental materials. The significant differences observed highlight the varying impact of each beverage on the aesthetic properties of the acrylic resin teeth. The findings underline the susceptibility of dental prosthetics to discoloration and changes in visual properties when exposed to acidic or pigment-rich beverages. This analysis serves as a key step in identifying the degree and type of discoloration caused by each beverage, providing valuable information for dental professionals and patients regarding the care and maintenance of removable partial dentures.

Table 3. The results of the LSD test

Acrylic resin teeth brand	Control group	Sample group	*p*			
			ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest	Coffee	.000*	.000*	.000*	.000*
		Carbonated Soda	.001*	.000*	.000*	.000*
		Orange juice	.438	.678	.934	.963
New Ace	Aquadest	Coffee	.000*	.000*	.040*	.000*
		Carbonated Soda	.000*	.000*	.019*	.000*
		Orange juice	.000*	.000*	.003*	.147*

* $p > 0.05$

Table 3 summarizes the results of the Least Significant Difference (LSD) test, which compared the control group (distilled water) with the treatment groups (Coffee, Carbonated soda, and Orange juice) for each acrylic resin brand, Ortolux Top and New Ace. For Ortolux Top, significant changes in color stability were observed in the ΔE, ΔL, and ΔC parameters when comparing the control group to the Coffee and Carbonated soda groups ($p < 0.05$). These findings indicate that these beverages substantially impacted the aesthetic properties of Ortolux Top resin teeth. In contrast, no significant differences were found between the control and Orange juice groups ($p > 0.05$), suggesting that Orange juice had minimal or no effect on the color stability of Ortolux Top samples.

For New Ace, all treatment groups—Coffee, Carbonated soda, and Orange juice—exhibited significant changes in color stability across most parameters ($p < 0.05$) compared to the control. This indicates that New Ace resin teeth are more susceptible to discoloration from all three tested beverages. However, for the ΔH (hue) parameter, no significant difference was observed between the control and Orange juice groups ($p > 0.05$), suggesting that Orange juice had a limited impact on the tonal shift of New Ace samples. These results highlight the varying susceptibility of different acrylic resin brands to discoloration caused by Ready-to-Drink (RTD) beverages and underscore the importance of material selection in dental prosthetics to minimize the effects of dietary habits on their aesthetic longevity.

This research analyzed data using SPSS software, focusing on four metrics: ΔE, ΔL (value), ΔC (chroma), and ΔH (hue). Statistical tests employing one-way ANOVA revealed that the color of

acrylic resin dental elements from Ortolux Top and New Ace changed after immersion in packaged beverages (Coffee, Carbonated soda, and orange juice) for 5 days. These color changes illustrate how different packaged beverages impact the color stability of the acrylic resin dental elements. Both the canned coffee (Nescafé) and carbonated beverage (Coca-Cola) caused noticeable color alterations in both brands of dental elements. These changes were reflected in the values of ΔE, ΔL, ΔC, and ΔH. Specifically, after soaking in coffee and Carbonated soda for 5 days, the ΔL value decreased, indicating that the samples became darker. Similarly, the ΔC value also dropped, suggesting a reduction in the sample's color concentration. The ΔH value was positive, indicating a shift in color toward a yellowish hue.

The discoloration observed in the samples soaked in coffee is attributed to tannin, a chromogenic substance in coffee that can lead to yellowish-brown discoloration of dental materials.[8] The tendency of acrylic resin to absorb color pigments contributes to the darkening and yellowing of the dental elements. Furthermore, the porosity of acrylic resin allows colorants to be absorbed through absorption and adsorption processes.[7] Color changes were also noted in both brands after immersion in Carbonated soda, which has a low pH 2.9. Acidic beverages can erode the surfaces of acrylic resin elements, facilitating pigment adherence and discoloration.[13] Additionally, Carbonated soda contains caramel coloring, which ranges from light yellow to dark brown, contributing to the yellowish discoloration of the acrylic resin dental element samples.[8]

These findings are consistent with earlier research by Mousavi et al. (2016) in Iran, which indicated that coffee's tannin content influences color changes in acrylic resin dental elements. Furthermore, beverages with low pH values can cause extrinsic discoloration in acrylic resin dental elements.[8] The study also found notable differences between the acrylic resin dental elements from the Ortolux Top and New Ace brands following immersion in Orange juice. For the Ortolux Top dental elements, no color change was observed after immersion, suggesting that Orange juice did not cause discoloration in this brand.

In contrast, the New Ace dental elements exhibited changes in ΔL and ΔC values after being soaked in Orange juice for 5 days. The ΔL value decreased, indicating a darker sample, while the ΔC value also dropped, reflecting a reduction in color concentration. This is likely due to the acidic pH of the beverage, which is classified as 4. The acidity affects the surface texture of the dental elements, allowing colorants to adhere more readily. This finding aligns with previous research by Guimaraes et al. (2015), which demonstrated that extrinsic discoloration in acrylic resin dental elements can occur from consuming artificially flavored lemon juice due to its high acidity.[14]

The observed differences between the two brands after immersion suggest that the Ortolux Top acrylic resin dental elements are more resilient to the acidic conditions of Orange juice. This resistance may stem from stronger polymer bonding in the Ortolux Top resin, making it less susceptible to abrasion. Another factor contributing to the lack of color change could be the insufficient duration of immersion for significant absorption of colorants. Previous studies have indicated that the length of time elements are exposed to colored beverages affects color changes. The more often dental elements are exposed to pigmented beverages, the more pronounced the color changes become.[7, 8] In previous research by Guimaraes et al., acrylic resin dental elements were immersed in artificial lemon juice for 14 days, while this study involved a shorter immersion period of just 5 days.[14]

4. Conclusion

This study demonstrated that packaged beverages, including coffee, carbonated soda, and orange juice, have varying effects on the color stability of acrylic resin dental elements from the Ortolux Top and New Ace brands. Coffee and carbonated soda were found to significantly affect the color stability of both brands, with noticeable changes in lightness (ΔL) and chroma (ΔC), indicating that the samples became darker and less vibrant after immersion. Orange juice, however, exhibited a selective impact, significantly affecting the color stability of New Ace but not Ortolux Top, highlighting the superior color stability of Ortolux Top resin elements when exposed to acidic and pigment-rich beverages.

The findings suggest that the acrylic resin materials' chemical composition and surface properties play a critical role in their resistance to discoloration. These differences emphasize the importance of selecting materials with better color stability, particularly for patients with dietary habits involving frequent consumption of acidic or heavily pigmented beverages. Additionally, the

study underscores the need for proper care and maintenance of dental prosthetics to mitigate the aesthetic impact of dietary exposure, contributing to the longevity and functionality of removable partial dentures.

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Authors Contribution

Contribution	Wirahadikusumah A	Anggarawati N
Concepts or ideas	√	√
Design		√
Definition of intellectual content	√	
Literature search		√
Experimental studies	√	
Data acquisition	√	√
Data analysis	√	
Statistical analysis	√	
Manuscript preparation	√	√
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Impact of Ready-to-Drink Beverages on the Color Stability of Acrylic Resin Teeth in Removable Partial Dentures: An In Vitro Study

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ABSTRACT

Background: Due to its many advantages, acrylic resin is the most widely used material for denture teeth in removable partial dentures. However, acrylic resin teeth are known to absorb colorants. As a substitute for natural teeth, these resin teeth are frequently exposed to foods and beverages consumed by patients. Popular ready-to-drink (RTD) beverages in Indonesia include coffee, orange juice, and carbonated drinks, each containing dyes that may affect the color stability of acrylic resin teeth. **Objective:** This study aims to assess the effect of various RTD beverages on the color stability of different acrylic resin denture teeth commonly used in Indonesia. **Materials and Methods:** The study sample consisted of 40 acrylic resin denture teeth samples, specifically maxillary central incisors, from the *Ortolux Top* and *New Ace* brands. The samples were immersed in distilled water, coffee (*Nescafe*), orange juice (*Minute Maid Pulpy Orange*), and carbonated soda (*Coca-Cola*) for five days in an incubator at 37°C. Color measurements were taken using a VITA Easyshade V spectrophotometer before and after immersion. Statistical analysis was performed using a one-way ANOVA test. **Results:** Coffee and Carbonated soda caused color changes in both brands of acrylic resin teeth, affecting the ΔE, ΔL, ΔC, and ΔH values, making the samples darker, more yellowish, and decreasing color saturation. However, orange juice only affected the ΔL and ΔC values of the *New Ace* brand, causing the samples to appear darker and less saturated. **Conclusion:** Some RTD beverages (coffee, orange juice, and carbonated drinks) can lead to discoloration of acrylic resin teeth, making them darker and less saturated.

Keywords: Acrylic resin teeth, ready-to-drink beverages, color stability

ABSTRAK

Latar belakang: Resin akrilik adalah bahan yang paling banyak digunakan untuk gigi tiruan pada gigi tiruan sebagian lepasan karena banyak keunggulannya. Namun, gigi tiruan resin akrilik diketahui dapat menyerap pewarna. Sebagai pengganti gigi asli, gigi tiruan ini sering terpapar oleh makanan dan minuman yang dikonsumsi oleh pasien. Minuman siap saji yang populer di Indonesia antara lain kopi, jus jeruk, dan minuman bersoda, yang masing-masing mengandung zat warna yang dapat mempengaruhi stabilitas warna gigi tiruan akrilik. **Tujuan:** Penelitian ini bertujuan untuk menilai pengaruh berbagai minuman RTD terhadap stabilitas warna gigi tiruan resin akrilik yang umum digunakan di Indonesia. **Bahan dan Metode:** Sampel penelitian terdiri dari 40 sampel gigi tiruan resin akrilik, khususnya gigi insisivus sentral rahang atas, dari merek *Ortolux Top* dan *New Ace*. Sampel direndam dalam air suling, kopi (Nescafe), jus jeruk (*Minute Maid Pulpy Orange*), dan soda berkarbonasi (Coca-Cola) selama lima hari dalam inkubator pada suhu 37°C. Pengukuran warna dilakukan dengan menggunakan spektrofotometer *VITA Easyshade V* sebelum dan sesudah perendaman. Analisis statistik dilakukan dengan menggunakan uji ANOVA satu arah. **Hasil:** Kopi dan Soda berkarbonasi menyebabkan perubahan warna pada kedua merek gigi resin akrilik, mempengaruhi nilai ΔE, ΔL, ΔC, dan ΔH, membuat sampel menjadi lebih gelap, lebih kekuningan, dan menurunkan saturasi warna. Namun, jus jeruk hanya mempengaruhi nilai ΔL dan ΔC pada merek *New Ace*, menyebabkan sampel tampak lebih gelap dan kurang jenuh. **Kesimpulan:** Beberapa minuman RTD (kopi, jus jeruk, dan minuman berkarbonasi) dapat menyebabkan perubahan warna pada gigi tiruan resin akrilik, membuatnya menjadi lebih gelap dan kurang jenuh.

Kata Kunci: gigi resin akrilik, minuman siap minum, stabilitas warna

1. Introduction

Dental health issues are prevalent in Indonesia, with the 2013 Riskesdas survey reporting 25.9% of the population facing dental and oral health problems—a figure that increased to 57.6% by 2018, accompanied by a DMF-T (Decayed, Missing, Filled Teeth) index score of 7.1. This index's "Missing" component is particularly high, with a rate of 2.5, underscoring the extent of tooth loss.[1, 2]. Untreated tooth loss over time can alter facial aesthetics.[3] To address this, removable partial dentures (RPDs) are a common treatment option designed to replace missing teeth and allow patients to remove and reattach them as needed.[4]

A critical component of RPDs is the artificial tooth, typically made from either acrylic resin or porcelain.[5] Acrylic resin teeth are preferred in removable dentures because they offer several benefits over porcelain.[5, 6] However, acrylic resin teeth tend to absorb colorants, making color stability an important factor.[7, 8] Discoloration can detract from the natural appearance of artificial teeth and may arise from external sources like coffee, tea, red wine, fruit juices, and carbonated drinks. The extent of discoloration also varies with the duration of exposure.[6, 8, 9] In Indonesia, the annual consumption of ready-to-drink (RTD) beverages is approximately 2.4 liters per person.[10] Popular RTD choices, such as coffee, orange juice, and carbonated drinks, contain pigments that may discolor acrylic resin.[11] Tannins in coffee can cause browning, while pigments in carbonated drinks and orange juice may be absorbed by resin.[8, 12]

Artificial teeth in dentures frequently come into contact with saliva, foods, and beverages.[6] Over time, acrylic resin teeth will likely change color due to ongoing absorption and adsorption of pigments from these substances. Extrinsic discoloration often results from continuous exposure to pigment-laden beverages, influenced by patient dietary habits.[8, 9] Based on this background, and the authors aimed to examine how different RTD beverages. Specifically, coffee, orange juice, and carbonated drinks affect the color stability of Indonesia's commonly used acrylic resin RPD teeth brands.

2. Material and Methods

This study employed a laboratory-based experimental design with a pre-test and post-test control group structure. A total of 40 samples were selected, comprising left and right upper central incisor acrylic resin teeth from two brands, Ortolux Top and New Ace, each with a shade of A3 (3M1D2). Each brand contributed 20 samples, which were divided into four groups based on immersion solutions: distilled water, canned Nescafe Original coffee (240 mL), Minute Maid Pulpy Orange juice (300 mL), and Coca-Cola (250 mL).

Before immersion, the initial color of each sample was measured using a spectrophotometer (Vita Easyshade V) , which was calibrated beforehand. The color was recorded by positioning the spectrophotometer's tip at the middle third of the labial surface of each tooth at a 90° angle.

Figure 1. Calibared Spectrophotometer

The pH of each beverage was carefully measured using a calibrated pH meter to assess its acidity, a critical factor influencing the potential discoloration of dental materials. For this purpose, 15 mL of each beverage—coffee, carbonated soda, and orange juice—was placed in separate clean containers to ensure accurate and uncontaminated readings. This step was essential to determine the chemical environment each dental sample would be exposed to during immersion. The pH measurements provided valuable context, as acidic beverages are known to interact with the surface properties of acrylic resin, potentially accelerating discoloration and degradation. By incorporating

pH analysis, the study offered a deeper understanding of how beverage acidity contributes to the color stability of dental prosthetic materials.

Figure 2. The pH of each beverage was also measured using a pH meter

Each acrylic resin sample was immersed in its respective beverage solution to simulate prolonged exposure under controlled conditions. The samples were stored in an incubator set at a constant temperature of 37°C, mimicking the average temperature of the oral cavity. The immersion period lasted for five days to allow sufficient interaction between the dental material and the beverage. To ensure the consistency and accuracy of the study, the immersion solutions were refreshed daily to prevent particle sedimentation or alterations in the beverage composition that could influence the results. This meticulous procedure was designed to replicate real-life conditions as closely as possible while maintaining the reliability of the findings, providing valuable insights into the long-term effects of these beverages on the color stability of acrylic resin dental elements.

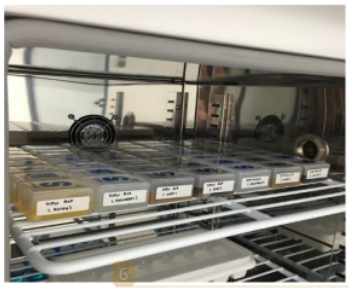

Figure 3. The sample was immersed in an incubator at a constant temperature of 37°C

After the five-day immersion period, each sample was carefully removed from its respective solution and dried thoroughly using a chip blower to eliminate any residual moisture that could interfere with the accuracy of the subsequent measurements. Once dried, the final color measurement was conducted using the VITA Easyshade V spectrophotometer, ensuring precise and consistent data collection. This final measurement captured any changes in the parameters of ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue), providing a detailed assessment of the impact of each beverage on the color stability of the acrylic resin teeth. The collected color data were then systematically analyzed and compared to the baseline measurements taken before immersion. This comparison allowed for the quantification of changes and provided insights into the extent and nature of discoloration caused by each beverage, contributing to a comprehensive understanding of how different RTD beverages affect the aesthetic properties of dental materials over time.

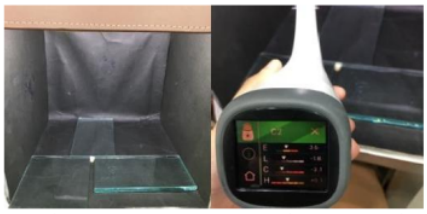

Figure 4. Color measurement using the spectrophotometer

The color measurement data obtained from the spectrophotometer were subjected to statistical analysis using IBM SPSS Statistics version 23 to determine the significance of the observed color changes. Initially, the normality of the data was assessed using the Shapiro-Wilk test, ensuring that the distribution of the data met the assumptions required for parametric testing. If the data were found to be normally distributed, a one-way Analysis of Variance (ANOVA) was performed to identify any significant differences in color changes across the different groups of beverages. When the ANOVA results indicated statistically significant differences, further post-hoc analysis was conducted using the Least Significant Difference (LSD) test to pinpoint which specific groups differed. This step-by-step statistical approach ensured a robust and detailed understanding of the impact of each beverage on the color stability of the acrylic resin samples. By employing these methods, the study provided reliable insights into the comparative effects of coffee, carbonated soda, and orange juice on dental prosthetic materials.

3. Results and Discussion

The study evaluated the color stability of acrylic resin teeth in removable partial dentures by measuring color changes using the VITA Easyshade V spectrophotometer, which provided precise data on four specific parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). These measurements comprehensively assessed the overall color changes, brightness or darkness, intensity, and tonal shifts caused by exposure to Ready-to-Drink (RTD) beverages. Before immersion, the pH levels of the beverages were measured to determine their acidity, a factor known to influence discoloration and surface changes in dental materials. The pH values recorded were 6.6 for coffee, indicating near-neutral acidity, 2.9 for carbonated soda, reflecting high acidity, and 4.0 for orange juice, representing moderate acidity. These pH differences were critical in understanding their potential impact on color changes. The immersion process was designed to simulate real-life exposure conditions, and the resulting data highlighted the extent and nature of discoloration caused by each beverage. This study provides valuable insights for dental practitioners and patients, emphasizing the importance of dietary choices in maintaining the aesthetic longevity of removable partial dentures.

Table 1. Normality Test Using the Shapiro-Wilk Test

Acrylic resin teeth brand	Beverages	*p*			
		ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest	.502*	.687*	.492*	.984*
	Coffee	.814*	.421*	.195*	.787*
	Carbonated Soda	.201*	.114*	.985*	.093*
	Orange juice	.501*	.135*	.314*	.884*
New Ace	Aquadest	.421*	.314*	.382*	.814*
	Coffee	.421*	.314*	.435*	.421*
	Carbonated Soda	.980*	.685*	.492*	.131*
	Orange juice	.814*	.101*	.077*	.314*

* $p > 0.05$

Table 1 presents the results of the Shapiro-Wilk normality test conducted for both brands of acrylic resin teeth, Ortolux Top and New Ace, across all measured color parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). The p-values for each parameter were greater than 0.05, indicating that the data met the assumption of normality. This confirms that the distribution of the color measurement data was statistically normal for all parameters and across both brands, allowing for parametric tests in subsequent analyses. The normality of the data provides a solid foundation for conducting a one-way ANOVA to investigate further differences in color

stability among the various beverage groups. This step was crucial in ensuring the validity and reliability of the statistical conclusions drawn from the study.

Table 2. Oneway-ANOVA test

Acrylic resin teeth brand	Beverages	*p*			
		ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest Coffee Carbonated Soda Orange juice	.000*	.000*	.000*	.000*
New Ace	Aquadest Coffee Carbonated Soda Orange juice	.000*	.000*	.000*	.000*

* $p > 0.05$

Table 2 provides the results of the one-way ANOVA performed to assess the effects of beverage immersion on the color stability of acrylic resin teeth from both brands, Ortolux Top and New Ace. The analysis revealed p-values below 0.05 for all measured parameters: ΔE (total color difference), ΔL (lightness), ΔC (chroma or saturation), and ΔH (hue). These statistically significant results led to the rejection of the null hypothesis, confirming that the immersion of samples in the three tested beverages—coffee, carbonated soda, and orange juice—over the five days caused notable changes in the color stability of the dental materials. The significant differences observed highlight the varying impact of each beverage on the aesthetic properties of the acrylic resin teeth. The findings underline the susceptibility of dental prosthetics to discoloration and changes in visual properties when exposed to acidic or pigment-rich beverages. This analysis serves as a key step in identifying the degree and type of discoloration caused by each beverage, providing valuable information for dental professionals and patients regarding the care and maintenance of removable partial dentures.

Table 3. The results of the LSD test

Acrylic resin teeth brand	Control group	Sample group	*p*			
			ΔE	ΔL	ΔC	ΔH
Ortolux Top	Aquadest	Coffee	.000*	.000*	.000*	.000*
		Carbonated Soda	.001*	.000*	.000*	.000*
		Orange juice	.438	.678	.934	.963
New Ace	Aquadest	Coffee	.000*	.000*	.040*	.000*
		Carbonated Soda	.000*	.000*	.019*	.000*
		Orange juice	.000*	.000*	.003*	.147*

* $p > 0.05$

Table 3 summarizes the results of the Least Significant Difference (LSD) test, which compared the control group (distilled water) with the treatment groups (Coffee, Carbonated soda, and Orange juice) for each acrylic resin brand, Ortolux Top and New Ace. For Ortolux Top, significant changes in color stability were observed in the ΔE, ΔL, and ΔC parameters when comparing the control group to the Coffee and Carbonated soda groups ($p < 0.05$). These findings indicate that these beverages substantially impacted the aesthetic properties of Ortolux Top resin teeth. In contrast, no significant differences were found between the control and Orange juice groups ($p > 0.05$), suggesting that Orange juice had minimal or no effect on the color stability of Ortolux Top samples.

For New Ace, all treatment groups—Coffee, Carbonated soda, and Orange juice—exhibited significant changes in color stability across most parameters ($p < 0.05$) compared to the control. This indicates that New Ace resin teeth are more susceptible to discoloration from all three tested beverages. However, for the ΔH (hue) parameter, no significant difference was observed between the control and Orange juice groups ($p > 0.05$), suggesting that Orange juice had a limited impact on the tonal shift of New Ace samples. These results highlight the varying susceptibility of different acrylic resin brands to discoloration caused by Ready-to-Drink (RTD) beverages and underscore the importance of material selection in dental prosthetics to minimize the effects of dietary habits on their aesthetic longevity.

This research analyzed data using SPSS software, focusing on four metrics: ΔE, ΔL (value), ΔC (chroma), and ΔH (hue). Statistical tests employing one-way ANOVA revealed that the color of

acrylic resin dental elements from Ortolux Top and New Ace changed after immersion in packaged beverages (Coffee, Carbonated soda, and orange juice) for 5 days. These color changes illustrate how different packaged beverages impact the color stability of the acrylic resin dental elements. Both the canned coffee (Nescafé) and carbonated beverage (Coca-Cola) caused noticeable color alterations in both brands of dental elements. These changes were reflected in the values of ΔE, ΔL, ΔC, and ΔH. Specifically, after soaking in coffee and Carbonated soda for 5 days, the ΔL value decreased, indicating that the samples became darker. Similarly, the ΔC value also dropped, suggesting a reduction in the sample's color concentration. The ΔH value was positive, indicating a shift in color toward a yellowish hue.

The discoloration observed in the samples soaked in coffee is attributed to tannin, a chromogenic substance in coffee that can lead to yellowish-brown discoloration of dental materials.[8] The tendency of acrylic resin to absorb color pigments contributes to the darkening and yellowing of the dental elements. Furthermore, the porosity of acrylic resin allows colorants to be absorbed through absorption and adsorption processes.[7] Color changes were also noted in both brands after immersion in Carbonated soda, which has a low pH 2.9. Acidic beverages can erode the surfaces of acrylic resin elements, facilitating pigment adherence and discoloration.[13] Additionally, Carbonated soda contains caramel coloring, which ranges from light yellow to dark brown, contributing to the yellowish discoloration of the acrylic resin dental element samples.[8]

These findings are consistent with earlier research by Mousavi et al. (2016) in Iran, which indicated that coffee's tannin content influences color changes in acrylic resin dental elements. Furthermore, beverages with low pH values can cause extrinsic discoloration in acrylic resin dental elements.[8] The study also found notable differences between the acrylic resin dental elements from the Ortolux Top and New Ace brands following immersion in Orange juice. For the Ortolux Top dental elements, no color change was observed after immersion, suggesting that Orange juice did not cause discoloration in this brand.

In contrast, the New Ace dental elements exhibited changes in ΔL and ΔC values after being soaked in Orange juice for 5 days. The ΔL value decreased, indicating a darker sample, while the ΔC value also dropped, reflecting a reduction in color concentration. This is likely due to the acidic pH of the beverage, which is classified as 4. The acidity affects the surface texture of the dental elements, allowing colorants to adhere more readily. This finding aligns with previous research by Guimaraes et al. (2015), which demonstrated that extrinsic discoloration in acrylic resin dental elements can occur from consuming artificially flavored lemon juice due to its high acidity.[14]

The observed differences between the two brands after immersion suggest that the Ortolux Top acrylic resin dental elements are more resilient to the acidic conditions of Orange juice. This resistance may stem from stronger polymer bonding in the Ortolux Top resin, making it less susceptible to abrasion. Another factor contributing to the lack of color change could be the insufficient duration of immersion for significant absorption of colorants. Previous studies have indicated that the length of time elements are exposed to colored beverages affects color changes. The more often dental elements are exposed to pigmented beverages, the more pronounced the color changes become.[7, 8] In previous research by Guimaraes et al., acrylic resin dental elements were immersed in artificial lemon juice for 14 days, while this study involved a shorter immersion period of just 5 days.[14]

4. Conclusion

This study demonstrated that packaged beverages, including coffee, carbonated soda, and orange juice, have varying effects on the color stability of acrylic resin dental elements from the Ortolux Top and New Ace brands. Coffee and carbonated soda were found to significantly affect the color stability of both brands, with noticeable changes in lightness (ΔL) and chroma (ΔC), indicating that the samples became darker and less vibrant after immersion. Orange juice, however, exhibited a selective impact, significantly affecting the color stability of New Ace but not Ortolux Top, highlighting the superior color stability of Ortolux Top resin elements when exposed to acidic and pigment-rich beverages.

The findings suggest that the acrylic resin materials' chemical composition and surface properties play a critical role in their resistance to discoloration. These differences emphasize the importance of selecting materials with better color stability, particularly for patients with dietary habits involving frequent consumption of acidic or heavily pigmented beverages. Additionally, the

study underscores the need for proper care and maintenance of dental prosthetics to mitigate the aesthetic impact of dietary exposure, contributing to the longevity and functionality of removable partial dentures.

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Authors Contribution

Contribution	Wirahadikusumah A	Anggarawati N
Concepts or ideas	√	√
Design		√
Definition of intellectual content	√	
Literature search		√
Experimental studies	√	
Data acquisition	√	√
Data analysis	√	
Statistical analysis	√	
Manuscript preparation	√	√
Manuscript editing	√	√
Manuscript review	√	√

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