

RESEARCH ARTICLE

## Effect of 35% sodium ascorbate combined with 0.4% surfactant on resin tag length in composite restorations following intracoronal bleaching

Rakhmalita Arlini\*, Tunjung Nugraheni\*\*✉, Ema Mulyawati\*\*

\*Conservative Dentistry Specialty Program, Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia

\*\*Departement of Conservative Dentistry, Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia

\*\*JI Denta No 1, Sekip Utara, Yogyakarta, Indonesia; ✉ correspondence: [rakhmalita@gmail.com](mailto:rakhmalita@gmail.com)

Submitted: 18<sup>th</sup> February 2024; Revised: 3<sup>rd</sup> June 2024; Accepted: 21<sup>st</sup> November 2024

### ABSTRACT

The application of 35% hydrogen peroxide in intracoronal bleaching generates free radicals that shorten resin tags and weaken the bond strength of composite resin restorations. Although 35% sodium ascorbate can neutralize free radical residues, its molecular instability limits its effectiveness. The addition of surfactants may enhance both the penetration ability and stability of sodium ascorbate. This study aimed to investigate the effect of adding 0.4% surfactant to 35% sodium ascorbate on the length of resin tags in composite resin restorations following intracoronal bleaching. Thirty mandibular premolars were prepared with standardized Class I cavities measuring 2.7 mm in diameter and 6 mm in depth. A 35% hydrogen peroxide gel was applied to the cavities for five consecutive days. After bleaching, the samples were randomly assigned to three groups of ten teeth each. The first group was stored in an incubator for seven days before undergoing composite resin restoration. The second group received an application of 35% sodium ascorbate, which was then rinsed off before immediate composite restoration. The third group received an application of 35% sodium ascorbate combined with 0.4% surfactant, followed by rinsing and immediate composite restoration. Histological preparations were made using hematoxylin-eosin staining and observed under a light microscope at 400× magnification. Resin tag lengths were measured using the Image Raster application. The one-way ANOVA test revealed a statistically significant difference among the groups ( $p = 0.000$ ). Post-hoc LSD analysis showed that resin tag lengths in the third group were significantly greater than those in both the first and second groups ( $p = 0.000$  for both comparisons). These results indicate that the combination of 35% sodium ascorbate with 0.4% surfactant significantly increases resin tag length and may enhance the bonding performance of composite restorations following intracoronal bleaching.

**Keywords:** hydrogen peroxide; resin tag; sodium ascorbate; surfactant

### INTRODUCTION

Bleaching is a dental treatment designed to improve tooth color by applying chemical agents to the teeth. It is categorized based on the status of the dental pulp, either vital or non-vital. Intracoronal bleaching is commonly indicated for discoloration in non-vital teeth that have undergone root canal treatment. Among the various techniques available, the walking bleach technique is frequently employed.<sup>1,2,3</sup> Intracoronal bleaching agents typically include 30–35% hydrogen peroxide, a colorless compound with a low molecular weight that readily penetrates both enamel and dentin.<sup>3,4</sup>

The bleaching process involves an oxidative reaction in which hydrogen peroxide produces

reactive oxygen species that break down chromogen molecules in the tooth structure. These reactive species interact with the double bonds of chromogens, fragmenting them into shorter molecular chains and resulting in a lighter tooth shade.<sup>3,5,6</sup>

Composite resin is a widely used material for permanent restoration after intracoronal bleaching.<sup>3</sup> Its adhesion to tooth structure is facilitated by micromechanical retention, which occurs through the formation of a hybrid layer and resin tags. The hybrid layer forms within the intertubular dentin and extends to the boundary of the dentinal tubules. Resin tags consist of bonding resin monomers that infiltrate the dentinal tubules and solidify during polymerization.<sup>7</sup>

However, the residual free radicals left behind after bleaching interfere with the polymerization process, particularly during the propagation phase.<sup>5</sup> This leads to early termination of the polymer chain, resulting in incomplete curing of the composite resin.<sup>8</sup> These residual radicals may remain trapped within the collagen matrix and dentinal tubules, inhibiting resin tag formation and compromising bond strength.<sup>9</sup> Short resin tags are associated with weaker micromechanical bonding. Studies indicate that resin tag lengths of 10–20 µm are necessary to achieve sufficient adhesion in composite resin restorations.<sup>10</sup>

Over time, residual free radicals diminish, improving bonding conditions. According to Hargreaves and colleagues, delaying the placement of composite resin for one to three weeks following intracoronal bleaching can mitigate the adverse effects of residual radicals. Resin tags are significantly longer in delayed restorations than in restorations placed immediately after bleaching.<sup>11</sup> However, such delays can be inconvenient for patients, as they require multiple visits and extended treatment time.

One approach to accelerating the elimination of residual free radicals following intracoronal bleaching is the application of antioxidant agents, particularly sodium ascorbate. Sodium ascorbate, the sodium salt of L-ascorbic acid, is biocompatible and capable of neutralizing free radicals remaining after bleaching treatment.<sup>9,12</sup> The application of 35% sodium ascorbate has been shown to increase resin tag length by approximately 35% compared to cases without its application, thereby enhancing the shear bond strength of composite resin restorations on teeth treated with 35% hydrogen peroxide.<sup>14</sup>

However, sodium ascorbate is inherently unstable due to its susceptibility to oxidation. To achieve optimal outcomes, it is essential to enhance its penetration into the tooth structure quickly, preserving its stability during application.<sup>15</sup> Surfactants are chemical agents that reduce surface tension and improve wetting, thereby facilitating faster penetration of sodium ascorbate molecules into enamel and dentin.<sup>16,17</sup>

Tween 80, a widely used and safe surfactant for both oral and topical pharmaceutical applications, has been found to bind effectively with sodium ascorbate, improving its penetration capabilities.<sup>18,19</sup> Among various surfactants, including sodium cholate and Span 80, Tween 80 demonstrates superior penetration due to its smaller molecular size.<sup>19</sup> The addition of 0.4% Tween 80 to 35% sodium ascorbate has been shown to enhance the penetration rate of sodium ascorbate by up to 35%, thereby optimizing its ability to bind free radical residues within dentinal tubules following intracoronal bleaching.

Moreover, incorporating 0.4% surfactant into the 35% sodium ascorbate solution reduces the contact angle, resulting in greater tensile bond strength of the composite resin compared to sodium ascorbate without surfactant.<sup>20</sup> Teeth treated with intracoronal bleaching followed by the application of 35% sodium ascorbate combined with 0.4% surfactant exhibit significantly higher shear strength than those treated without surfactant.<sup>21</sup> Based on these findings, this study aims to investigate the effect of adding 0.4% surfactant to 35% sodium ascorbate on the resin tag length in teeth that have undergone intracoronal bleaching.

## MATERIALS AND METHODS

This experimental study was conducted at the Integrated Research Laboratory of the Faculty of Dentistry, the Anatomical Pathology Laboratory of the Faculty of Medicine, and the Research and Integrated Testing Laboratory of Universitas Gadjah Mada, Yogyakarta. Ethical clearance was obtained from the Ethics Committee of the Faculty of Dentistry, Universitas Gadjah Mada, under certificate number 107/UNI/KEP/FKG-RSGM/EC/2023.

The study utilized 30 human mandibular premolars extracted for orthodontic purposes. Teeth were collected within a maximum of two months post-extraction and stored in 10% buffered formalin solution. Samples were randomly divided into three groups, each consisting of 10 teeth.

Inclusion criteria for sample selection included intact crowns, absence of caries and fractures, single straight root canals, fully developed apices, and no history of bleaching.

The preparation of 35% sodium ascorbate gel without surfactant was carried out based on the standard protocol of the Faculty of Pharmacy, Universitas Gadjah Mada. A total of 0.5 g of CMC-Na powder and 3.5 g of sodium ascorbate powder (Sigma-Aldrich, USA) were weighed using a digital scale. The CMC-Na gel was prepared by dissolving the powder in 10 ml of distilled water, warmed in a 60 °C water bath. The mixture was transferred to a glass beaker and homogenized using a magnetic hotplate stirrer with a glass rod. Once the gel cooled to room temperature and thickened, 3.5 g of sodium ascorbate powder was added to 4 ml of the CMC-Na gel and mixed thoroughly with a glass stirrer at room temperature. The resulting gel was transferred to a test tube, and additional CMC-Na gel was added to reach a final volume of 10 ml, followed by homogenization using a vortex mixer.

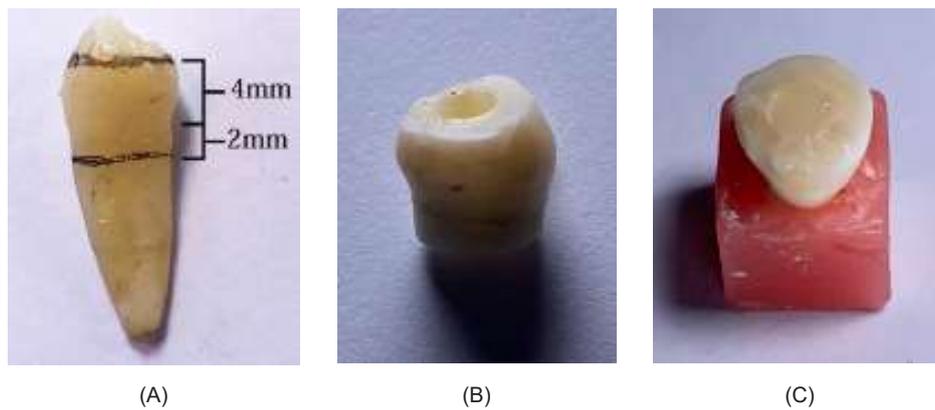
For the preparation of 35% sodium ascorbate gel with 0.4% surfactant, 10 ml of the previously prepared sodium ascorbate gel was combined with 40 µl of Tween® 80 (Sentra Chemical Indonesia) using a micropipette and mixed thoroughly with a vortex mixer. The final antioxidant gels were stored in dark glass bottles, sealed tightly, and refrigerated at 4 °C.

Measurements were made on each tooth, marking 2 mm in the apical direction and 4 mm in the coronal direction from the cemento-enamel junction (CEJ) using a digital caliper and pencil (Figure 1). The marked teeth were sectioned using a double-sided diamond disc bur. Standardized Class I cavities were prepared on all samples by creating occlusal access with a round diamond bur, followed by cavity enlargement using a wheel-shaped diamond bur to achieve a diameter of 2.7 mm and a depth of 6 mm (Figure 1). A 2 mm-thick layer of resin-modified glass ionomer cement (RMGIC) was applied to the cavity base and light-cured for 20 seconds using a light-curing unit to serve as a cervical barrier.

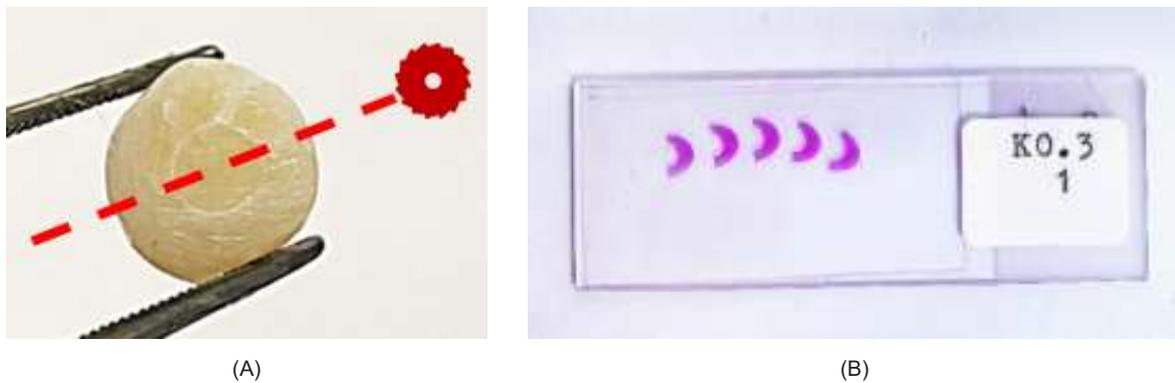
All samples were mounted in red wax blocks measuring 1 × 1 × 1 cm to ensure stability during treatment. Intracoronary bleaching was performed by applying 0.01 ml of 35% hydrogen peroxide gel (Opalescence Endo®, Ultradent, USA) to each cavity, followed by sealing with a temporary restorative material (Cavit G, 3M ESPE, USA). The samples were then placed in sealed tubes containing artificial saliva at pH 7 and incubated at 37 °C for five days.

All samples that had undergone intracoronary bleaching were rinsed with 15 ml of distilled water (aquadest). The specimens were randomly divided into three groups, each consisting of 10 teeth. In the first group, the temporary restoration was removed, and the samples were stored in an incubator at 37 °C for 7 days. Composite resin restoration (Filtek Z250 XT, 3M ESPE, USA) was performed after this 7-day delay. In the second group, 0.02 ml of 35% sodium ascorbate gel (without surfactant) was applied for 5 minutes, followed by rinsing with 15 ml of distilled water. This procedure was repeated twice, after which composite resin restoration was carried out immediately. In the third group, 0.02 ml of 35% sodium ascorbate gel containing 0.4% surfactant (Tween® 80) was applied for 5 minutes, followed by rinsing with 15 ml of distilled water. This application was also repeated twice, and the composite resin was applied immediately afterward (Figure 1).

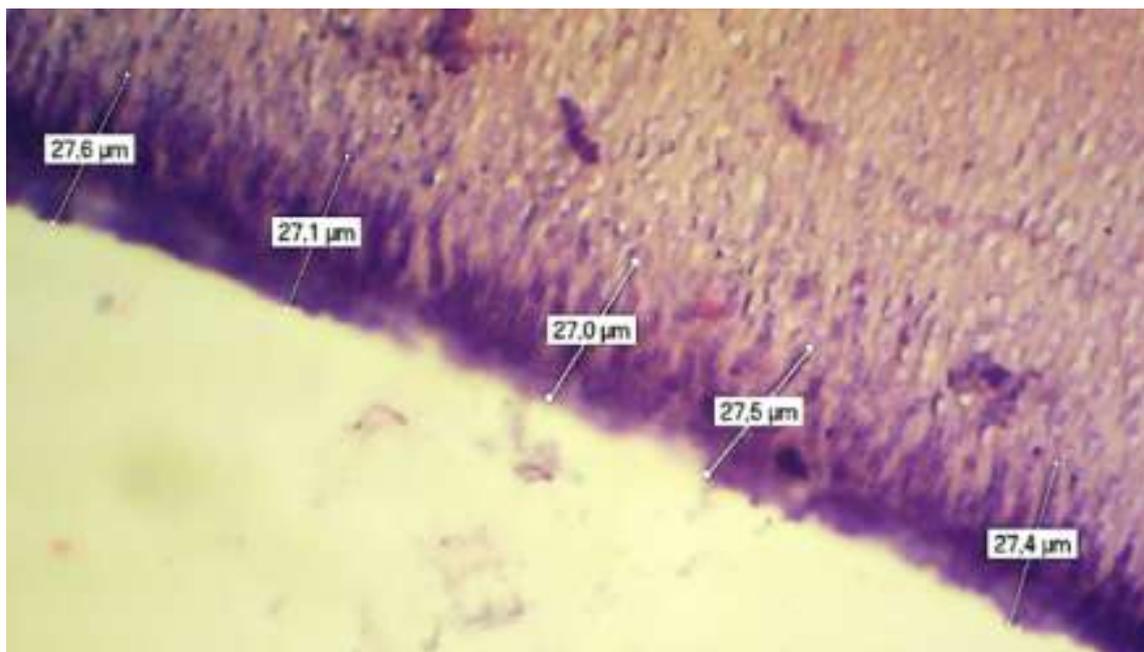
Following restoration, all samples were sectioned to a thickness of 3 mm and then cut buccolingually through the composite restoration (Figure 2). The buccal segments were processed for histological examination using hematoxylin-eosin (HE) staining, with sections cut at a thickness of 6 µm (Figure 2). Resin tag length was observed using a light microscope at 400× magnification. The dark-purple resin tags were measured from the adhesive interface to the tip of the tag within the dentinal tubules in micrometers (µm), using the Image Raster software (Figure 3). The lingual segments were analyzed using a Scanning Electron Microscope (SEM), with one sample selected from each treatment group.



**Figure 1.** (A) Samples marked and measured with a pencil. (B) Class I cavity preparation. (C) Samples after treatment, filled with composite resin.



**Figure 2.** (A) Direction of the buccolingual sectioning. (B) Histological preparations stained with hematoxylin-eosin.



**Figure 3.** Resin tag visualized under a light microscope at 400× magnification and measured using Image Raster.

**RESULTS**

The highest average resin tag length was observed in the group treated with 35% sodium ascorbate combined with 0.4% surfactant, measuring 24.72  $\mu$ m. The lowest average was recorded in the group with delayed restoration, which measured 20.14  $\mu$ m. Results from the Shapiro-Wilk test confirmed that the data were normally distributed ( $p > 0.05$ ), and the

Levene’s test yielded a value of 0.180, indicating homogeneity of variance ( $p > 0.05$ ).

One-way ANOVA analysis showed a statistically significant difference in mean resin tag length among the three groups ( $p < 0.05$ ;  $p = 0.000$ ), as presented in Table 2. Post hoc testing using the Least Significant Difference (LSD) method indicated a significant difference in mean resin tag length between the delayed

**Table 1.** Mean ( $\mu$ m) and standard deviation of resin tag length following intracoronal bleaching and treatment

Groups	n	Mean $\pm$ Standard deviation
Group 1 (7 days delayed)	10	20.14 $\pm$ 0.44
Group 2 (SA 35%)	10	20.55 + 0.77
Group 3 (SA 35% + Surfactant 0.4%)	10	24.72 + 0.73

**Table 2.** One-way ANOVA results showing differences in resin tag length among groups

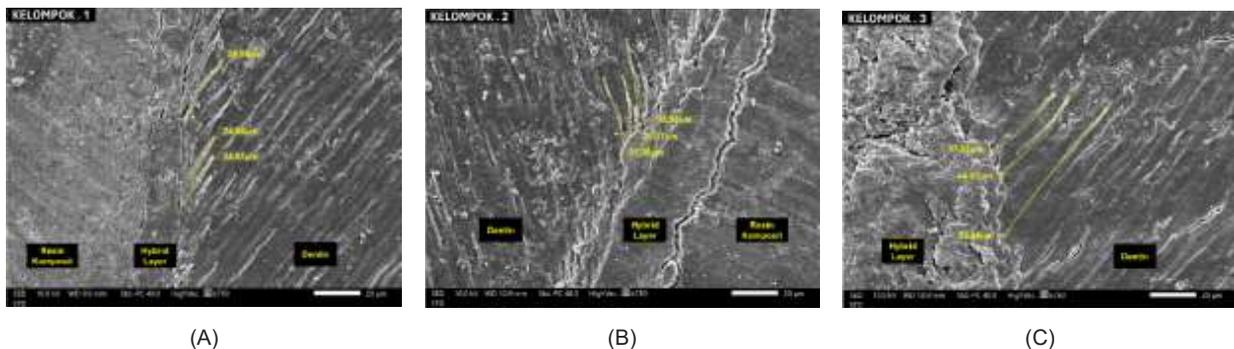
	Sum of Quare	DF	Mean Square	F	Sig.
Between Group	128.45	2	64.22	145.41	0.000*
Within Group	11.93	27	0.442		
Total	140.37	29			

\*: Sig  $p < 0.05$

**Table 3.** Post hoc LSD test results indicating pairwise comparisons of resin tag lengths between treatment groups

Groups	Sig.
7 days delayed – SA 35%	0.179
7 days delayed – SA 35% + Surfactant 0.4%	0.000*
SA 35% - SA 35% + Surfactant 0.4%	0.000*

\*: Sig  $p < 0.05$



**Figure 4.** SEM image at 750 $\times$  magnification showing the longest resin tag observed in Group 3, consistent with the findings from histological preparations stained with hematoxylin-eosin (HE) and examined under a light microscope

restoration group and the group treated with sodium ascorbate combined with surfactant ( $p = 0.000$ ). However, no significant difference was found between the delayed restoration group and the sodium ascorbate-only group, with a  $p$ -value of 0.179. These results are summarized in Tables 1 through 3.

Resin tag observations using a Scanning Electron Microscope (SEM) were conducted to describe and confirm the morphology and length of the resin tags. The SEM images revealed white-colored resin tags extending from the hybrid layer into the dentinal tubules. The shape and length of the resin tags observed via SEM corresponded closely with those seen in the histological preparations stained with HE under light microscopy. These observations are illustrated in Figure 4.

## DISCUSSION

The results demonstrated that Group 3, which received 35% sodium ascorbate combined with 0.4% surfactant, exhibited the longest average resin tag length. In contrast, Group 1, which underwent restoration after a 7-day delay, showed the shortest average length. The findings of the one-way ANOVA test indicated a significant effect of 35% sodium ascorbate combined with 0.4% surfactant on resin tag length in composite resin restorations following intracoronal bleaching.

The addition of a surfactant to sodium ascorbate reduces surface tension, enabling more rapid penetration of sodium ascorbate into the tooth structure. This reduction in surface tension is attributed to the interaction between the hydrophobic and hydrophilic groups of the surfactant and sodium ascorbate. The combination of 35% sodium ascorbate with 0.4% surfactant produces a lower contact angle compared to formulations with 0.2% surfactant.<sup>20</sup>

Surfactants also contribute to the increased stability of sodium ascorbate molecules. When bound to surfactants, sodium ascorbate is converted into dehydroascorbic acid, a more stable, less easily oxidized form. This reversible molecule can return to its original ascorbate form,

maintaining its antioxidant function and enhancing its capacity to scavenge free radicals.<sup>24,25</sup> The elimination of free radicals facilitates better penetration of adhesive resin monomers into the dentinal tubules, resulting in longer resin tags and stronger bonds between the composite resin and dentin. Therefore, intracoronal post-bleaching restorations treated with 35% sodium ascorbate in combination with 0.4% surfactant demonstrate higher shear bond strength compared to those treated without surfactant.<sup>22</sup>

The mean length of resin tags in the group treated with a combination of 35% sodium ascorbate and 0.4% surfactant was greater than that in the group with a 7-day delay or the group treated with 35% sodium ascorbate without surfactant. This result may be attributed to the enhanced ability of the sodium ascorbate–surfactant combination to eliminate free radicals more effectively than the delayed restoration approach. Free radicals generated during bleaching may persist in the dentinal tubules beyond 7 days, as they can become trapped and not fully dissipated. The application of 35% sodium ascorbate combined with 0.4% surfactant appears to facilitate deeper penetration into the dentinal tubules, enabling more effective neutralization of residual free radicals.

The elimination of these radicals promotes optimal polymerization of resin monomers from adhesive materials, resulting in longer resin tags. Longer resin tags are associated with increased bond strength between the composite resin and dentin. Application of the 35% sodium ascorbate–0.4% surfactant combination also demonstrated higher shear strength than restorations applied after a 7-day delay.<sup>20</sup>

Furthermore, the combination treatment proved more effective than 35% sodium ascorbate alone. Sodium ascorbate, while effective, penetrates the dentinal structure more slowly, requiring longer application times to bind free radical residues. Its slow penetration rate means that it often reacts prematurely with free radicals in the surrounding environment, diminishing its ability to reach radicals deeper in the dentin. To enhance

penetration and reduce premature oxidation, a carrier such as a surfactant is necessary.<sup>15,24</sup>

Surfactants are chemical agents that lower surface tension, enabling 35% sodium ascorbate to penetrate dentinal tubules more efficiently and remove free radicals more thoroughly.<sup>24</sup> They also help stabilize sodium ascorbate, increasing its efficacy as a radical scavenger.<sup>24</sup> Optimal free radical elimination facilitates resin monomer infiltration into dentinal tubules, yielding longer resin tags and thereby enhancing the bond strength of composite restorations.<sup>20</sup>

Application of 35% sodium ascorbate combined with 0.4% surfactant also resulted in higher tensile strength compared to formulations without surfactant.<sup>22</sup> In this study, the combination of 35% sodium ascorbate and 0.4% surfactant produced the most favorable results in terms of resin tag length and bond strength of composite restorations following intracoronal bleaching.

One limitation of this study is the potential for debris remaining after tooth preparation, which can obscure the surface of the sample and interfere with optimal SEM imaging. The etching process used to remove debris must be performed with caution to avoid damaging the resin tags. Further research is warranted to examine the effect of 35% sodium ascorbate combined with 0.4% surfactant on resin tag formation using SEM, particularly with a larger sample size to allow for more robust statistical analysis.

## CONCLUSION

Based on the study findings, it can be concluded that the application of 35% sodium ascorbate combined with 0.4% surfactant influences the length of resin tags in composite resin restorations on intracoronaally bleached teeth. The combination treatment produced longer resin tags than either 35% sodium ascorbate alone or the 7-day delayed restoration.

## CONFLICT OF INTREREST

The authors declare no conflict of interest related to this research.

## REFERENCES

1. Ingle JI, Rotstein I. Ingle's Endodontics 7. 50<sup>th</sup> ed. North Carolina: PMPH USA; 2019. 1203-1214
2. Salicha RP, Ismiyatin K, Sari PT, Widjadja OV, Sari PS. Internal bleaching of a non vital anterior tooth in patient with postural hypotension. *Dentika Dental*. 2020; 23(2): 45-50. doi: 10.32734/dentika.v23i2.4095
3. Torabinejad M, Fouad AF, Shabahang S. *Endodontics Principles and Practice*. 6<sup>th</sup> ed. USA: Elsevier; 2021. 368-381.
4. Kwon SR, Wertz PW. Review of the mechanism of tooth whitening. *Journal of Esthetic and Restorative Dentistry*. 2015; 27(5): 240–257. doi: 10.1111/jerd.12152
5. Hargreaves K, Berman LH. *Cohen's Pathways of The Pulp*. 11<sup>th</sup> ed. California: Elsevier; 2016. e100
6. Gopikrishna V. *Grossman's Endodontic Practice*. 14<sup>th</sup> ed. India: Wolters Kluwer; 2021. 480-488
7. Sakaguchi R, Ferrance J, John P. *Craig's Restorative Dental Materials*. 14<sup>th</sup> ed. Missouri: Elsevier. 2019. 136, 151
8. Garg N, Garg A. *Textbook of Endodontics*. 4th ed. India: Jaypee Brother Medical Publishers; 2019. 468-482
9. Ismail EH, Kilinc E, Hardigan PC, Rothrock JK, Thompson JY, Godoy CG. Effect of two-minute application of 35% sodium ascorbate on composite bond strength following bleaching. *The Journal of Contemporary Dental Practice*. 2017; 18(10): 874-880. doi: 10.5005/jp-journals-10024-2142
10. Shen C, Rawls HR, Esquivel JF. *Philips' Science of Dental Material*. 13<sup>th</sup> ed. USA: Elsevier Sounders; 2021. 259-260, 279-289.
11. Nofika R, Nugraheni T, Hardiyanto W. Pengaruh aplikasi natrium askorbat 10% dan 35% terhadap panjang resin tag pada gigi pasca bleaching intrakoronal dengan hidrogen peroksida 35%. *Jurnal Kedokteran Gigi*. 2018; 9(2): 280-286.
12. Ratih DN, Widyastuti, A. Effect of antioxidants on the shear bond strength of composite resin

- to enamel following extra-coronal bleaching. *J Clin Exp Dent*. 2019; 11(2): e126-32. doi: 10.4317/jced.55359
13. Nugraheni T, Nuryono, Sunarintyas S, Mulyawati E. Effect of 35% sodium ascorbate on calcium and phosphorus loss in dentin bleached by 35% hydrogen peroxide. *Majalah Kedokteran Gigi Indonesia*. 2021; 7(1): 10-16. doi: 10.22146/majkedgiind.46946
  14. Nugraheni T, Nuryono N, Sunarintyas S, Mulyawati E. Composite resin shear bond strength on bleached dentin increased by 35% sodium ascorbate application. *Dental Journal (Majalah Kedokteran Gigi)*. 2018; 50(4): 178-182. doi: 10.20473/j.djmk.v50.i4
  15. Yin X, Chen K, Cheng H, Shen X, Feng S, Song Y, Liang L. Chemical stability of ascorbic acid integrated into commercial products: a review on bioactivity and delivery technology. *MDPI antioxidants*. 2022; 11(53): 1-20. doi: 10.3390/antiox11010153
  16. Gupta N, Singh N. Effect of maleic acid, ethylenediaminetetr acid, mtad on smear layer removal and dentin microhardness. *Journal of Dentistry Indonesia*. 2018; 25(2): 91-98. doi: 10.14693/jdi.v25i2.1223
  17. Kesumawardhany B, Mita SR. Pengaruh penambahan tween 80 sebagai enhancer dalam sediaan transdermal. *Farmaka*. 2016; 14(2): 112-118. doi: 10.24198/jf.v14i2.9293
  18. Han Y, Mo S, Jiang L, Zhu Y. Effects of antioxidants on the microleakage of composite resin restorations after external tooth bleaching. *Eur J Dent*. 2014; 8(2): 147-153. doi: 10.4103/1305-7456.130581
  19. Wei L, Yu C, Lin H, Zhou X. Development of tacrolimus-loaded Transferosomes for deeper skin penetration enhancement and therapeutic effect improvement in vitro. *Asian J Pharma Sci*. 2013; 8(6): 336-345. doi: 10.1016/j.ajps.2013.09.005
  20. Yulianasari S, Santosa P, Nugraheni T. Effect of surfactant concentration in sodium ascorbate on contact angle and tensile bond strength after bleaching. *Majalah Kedokteran Gigi Indonesia*. 2022; 8(1): 59-69. doi: 10.22146/majkedgiind.62466
  21. Anindita. Pengaruh Surfaktan 0,4% dan 0,5% dalam Sodium Askorbat 35% Terhadap Sudut Kontak dan Kekuatan Geser Restorasi Resin Komposit pada Dentin Pasca Bleaching Intrakoronar dengan Hidrogen Peroksida 35%. Yogyakarta: Tesis Program Pendidikan Dokter Gigi Spesialis, Fakultas Kedokteran Gigi, Universitas Gadjah Mada. 2023.
  22. Sheraz MA, Khan MF, Ahmed S, Kazi SH, Ahmad I. Stability and stabilization of ascorbic acid a review. *Household and Personal Care Today*. 2015; 10(3): 22-25.
  23. Park JY, Kwon TY, Kim YK. Effective application duration of sodium ascorbate antioxidant in reducing microleakage of bonded composite restoration in intracoronally-bleached teeth. *Restorative Dentistry & Endodontics*. 2013; 38(1): 43-47. doi: 10.5395/rde.2013.38.1.43
  24. Cortes H, Parra HH, Chavez SAB, Audelo MLDP, Floran IHC, Jimenez FVB, Torres MG, Magana JJ, Gomez GL. Non-Ionic surfactants for stabilization of polymeric nanoparticles for biomedical uses. *Materials*. 2021; 14(3197): 1-39. doi: 10.3390/ma14123197.