PMI SCIENCE
PHILIP MORRIS INTERNATIONAL

ORIGINAL PAPERS

bit.ly/PMI-Teeth1a

bit.ly/PMI-Teeth1b

dental restoration · dentin · enamel · heated tobacco · smoking · tooth discoloration

Effects of cigarette smoke and heated tobacco aerosol on color stability of teeth

- Cigarette smoke (CS) was found to cause visible discoloration and color mismatch between dental hard tissues (enamel and dentin) and composite resin restorations.
- Aerosol from the Tobacco Heating System (THS) 2.2 was found to cause no visible discoloration of dental hard tissues and no color mismatch between dental hard tissues and composite resin restorations.

Changes in color of enamel, dentin, and composite resin restorations after *in vitro* exposure for three weeks to cigarette smoke (CS) and aerosol from the Tobacco Heating System (THS) 2.2.
Color mismatch between hard tissues and composite resin restorations was observed in the CS group but not in the THS aerosol group.

CS is responsible for a multitude of health risks and is recognized as an important risk factor for tooth discoloration, a major concern in clinical dentistry. The aerosol produced by THS, which heats tobacco rather than burning it, has a different chemical composition to CS, with most harmful and potentially harmful constituents reduced by an average of 95%.

The objective of the study was to investigate the effects of THS aerosol on the color stability of enamel, dentin, and composite resin restorations in comparison to the effects of CS.

The objective of the study was to investigate the effects of aerosol from the THS 2.2 on the color stability of enamel, dentin, and composite resin restorations in comparison with CS. Dentin and enamel are the primary hard tissues found in human teeth, while composite resin is the most commonly used material by general dental practitioners in esthetic dental restorations.

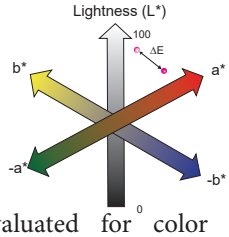
TOOTH COLLECTION AND PREPARATION

Tooth collection was conducted in accordance with the guidelines of the Eastman Institute for Oral Health, University of Rochester. Human premolars that had been extracted for orthodontic reasons were collected fresh from oral surgery clinics and sterilized with ethylene oxide. To allow initial color match with selected composite resin restorative materials, teeth with approximately an A2 shade were selected, and those with discoloration and enamel defects were excluded. A cavity was prepared on each tooth and restored with a universal composite resin (A2 shade). In total, 22 teeth were prepared and restored.

To explore the potential effect of aging on composite resin restorations, half of the restored teeth were subjected to thermocycling to simulate aging for six months in the oral environment before the beginning of the exposures. The remaining teeth were not subjected to thermocycling and served as fresh composite resin restorations for comparison.

BASELINE ASSESSMENTS

The color of enamel, dentin, and composite resin restorations was assessed in the Commission Internationale de l'Éclairage L*a*b* (CIE Lab) color space:



- L*: lightness
- a*: color in red and green coordinates
- b*: color in yellow and blue coordinates.

Composite resin restorations were evaluated for color matching, marginal discoloration, marginal integrity, and surface texture.

EXPOSURE METHODOLOGY

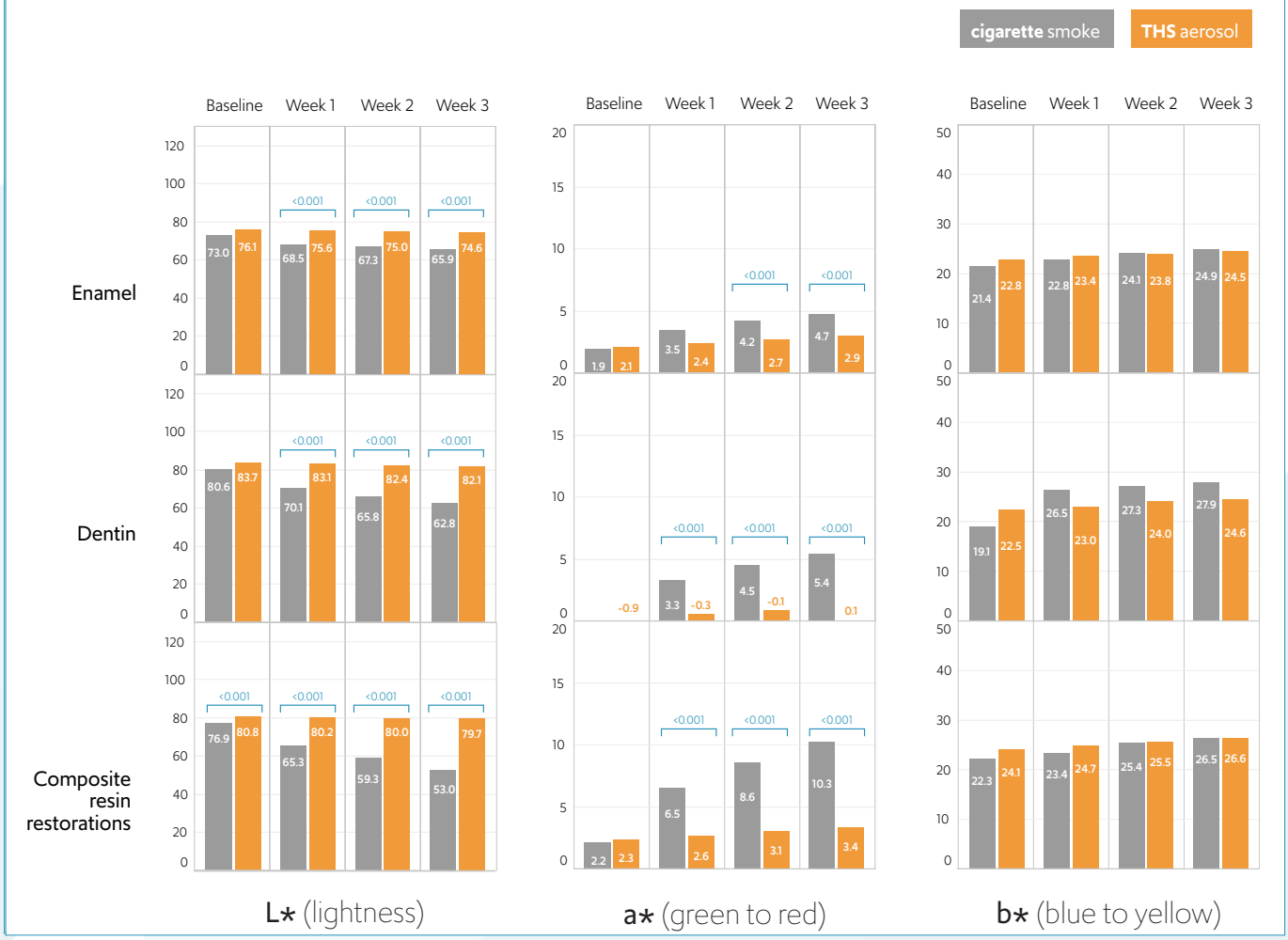
Teeth were divided randomly into two groups of 11 each. The first group was exposed to CS from a 3R4F cigarette (the industry-standard reference cigarette). The second group was exposed to THS aerosol. The experiments were conducted using the Vitrocell™ 24/48 exposure system, one of the most advanced and versatile exposure systems presently available. CS and THS aerosol were generated using two carousel smoking machines (SM2000, PMI) connected independently to two Vitrocell™ systems. Two exposure sessions per day were performed, resulting in approximately 20 cigarettes or THS HeatSticks per day for 12 days. The exposure experiment was conducted from Monday through Thursday for three consecutive weeks. Specimens were placed in artificial saliva between exposures.

POST-EXPOSURE ASSESSMENT AND ANALYSIS

After each four-day exposure, teeth were subject to a vigorous brushing with toothpaste protocol before the measurement of L*a*b* values. This ensured that absorbed colorant effects were assessed rather than surface effects, which can be brushed away easily. The primary outcome measure was the overall color difference of enamel, dentin, and composite resin restorations before and after exposure to CS or THS aerosol.

Study design

Color change: L*a*b* analysis results



ARTIFICAL AGING RESULTS

Artifical aging did not cause statistically or clinically significant changes in color and did not affect the final outcomes in the composite resins. No difference was found in color match, marginal discoloration, marginal integrity, or surface texture of the restorations between the aged and non-aged specimens. Therefore, the aged and non-aged specimens were pooled for statistical analyses.

EXPOSURE EFFECTS

After exposure for three weeks, CS caused a significant decrease in lightness (L*) and significant increases in redness (a*) and yellowness (b*) of enamel, dentin, and composite resin restorations. A similar trend in color change was found, but to a much lesser extent, in the THS aerosol group. Changes in lightness and redness were significantly higher in the CS group than in the THS aerosol group, but no statistically significant difference in yellowness was found between the two groups.

Enamel, dentin, and composite resin restorations acquired visible reddish-brown stains in the CS group, but not in the THS aerosol group.

Starting from week 1, there were significant differences in color changes from the baseline between the CS and THS aerosol groups in enamel, dentin, and composite resin restorations. Color changes from the baseline in enamel, dentin, and composite resin restorations increased with time in both groups, but to a much lower extent in the THS aerosol group than in the CS group.

CS had a much greater impact on dentin than on enamel, whereas THS aerosol affected dentin and enamel to a comparable extent. Composite resin restorations were affected to a similar extent to dentin and enamel in the THS aerosol group, but in the CS group they were affected to a greater extent than enamel.

After exposure for three weeks, the color match of composite restorations to enamel and dentin deteriorated and marginal discoloration increased in the CS group but not in the THS aerosol group. Marginal integrity and surface texture were not affected in either group.

DISCUSSION

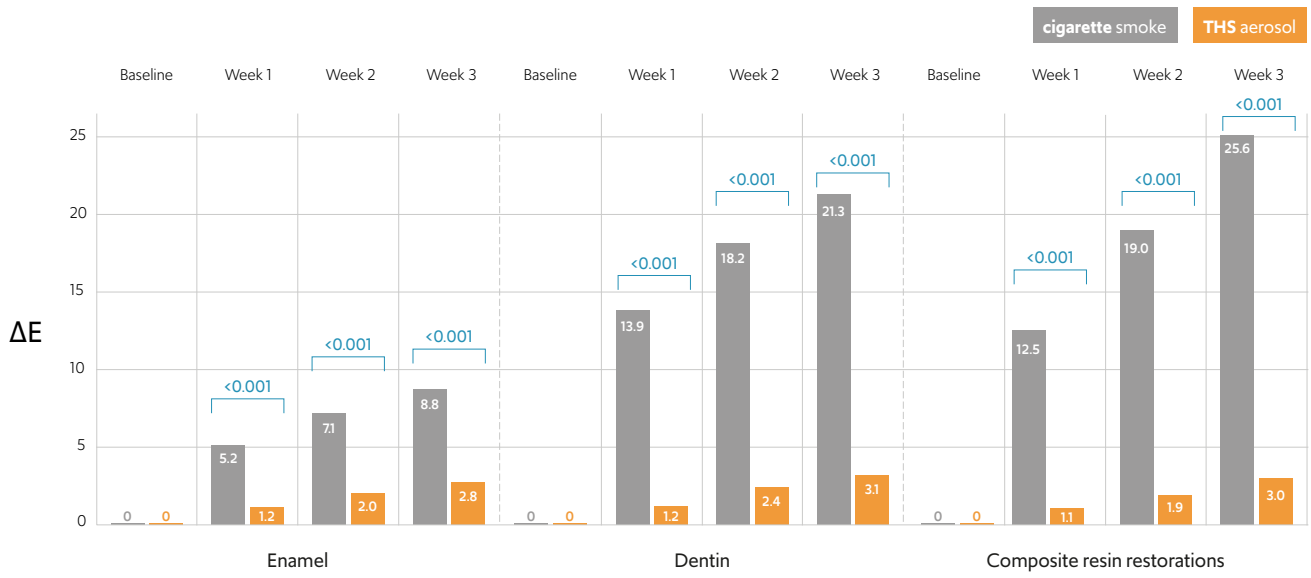
Smoking-related tooth discoloration is most likely caused by pigments in the smoke of burned cigarettes. Therefore, eliminating or reducing exposure to smoke should effectively reduce the risk of smoking-related tooth discoloration. To test this hypothesis, the effects of CS on color stability were compared to those of THS aerosol. THS does not generate smoke through burning tobacco at 600 to 900 °C, as cigarettes do, but instead produces an aerosol through heating tobacco sticks to a much lower temperature (< 350 °C). Heating tobacco at lower temperatures eliminates the production of solid particles and reduces the levels of chemical constituents found in cigarette smoke (CS) by more than 95% on average. In contrast with CS, it was found that THS aerosol did not cause discolorations that were readily discernible with the naked eye. At the end of the experiment, overall color changes were similar among enamel, dentin, and composite resin restorations relative to the baseline in the THS aerosol group, and no color mismatch occurred.

Oral Health and Tobacco Harm Reduction

Cigarette smoke (CS) is detrimental to oral health, as the smoke produced by tobacco combustion contains numerous harmful chemicals that may increase the risks of oral cancer and oral mucosal and periodontal diseases, and may affect treatment outcomes of dental implant and periodontal therapies. Complete smoking cessation is the best approach to eliminate the oral health risks of tobacco products. However, while the prevalence of cigarette smoking has been steadily declining over the years, millions of individuals across the globe continue to use a wide range of tobacco products. Smoking cessation has proven difficult for many smokers, who might benefit from using alternative products that reduce the harm caused by CS. While dental professionals should vigorously promote smoking cessation in their daily practices, it is also important to investigate and understand the potential effects of emerging tobacco products on oral health. For smokers who would otherwise continue smoking, PMI's goal is to offer smoke-free alternatives, Reduced-Risk Products (RRP*), that have the potential to reduce the risk of developing smoking-related diseases as compared with continued smoking.

Dental hard tissues and composite resin restorations were affected to a far lesser extent by THS aerosol than CS, and their discoloration did not reach the threshold of clinical significance.

Overall color change from baseline



CONCLUSION

The study findings indicate that CS causes discoloration of dental hard tissues and color mismatch of esthetic composite resin restorations. Enamel, dentin, and composite resin restorations acquired reddish-brown coloration under CS exposure. Dental hard tissues and composite resin restorations were affected to a far lesser extent by THS aerosol, and their discoloration did not reach the threshold of clinical significance under the experimental conditions used. □

REFERENCES

- Schaller, J. P. et al. Evaluation of the Tobacco Heating System 2.2. Part 2: Chemical composition, genotoxicity, cytotoxicity, and physical properties of the aerosol. *Regulatory toxicology and pharmacology*. 2016; 81(Suppl 2): S27-S47.
- Smith, M. R. et al. Evaluation of the Tobacco Heating System 2.2. Part 1: Description of the system and the scientific assessment program. *Regulatory toxicology and pharmacology*. 2016; 81(Suppl 2): S17-S26.
- Zanetti, F. et al. Effects of cigarette smoke and tobacco heating aerosol on color stability of dental enamel, dentin, and composite resin restorations. *Quintessence International*. 2019; 50(2): 156–66.
- Zhao, X. et al. Effects of cigarette smoking on color stability of dental resin composites. *American Journal of Dentistry*. 2017; 30(6): 316–22.

*Reduced-Risk Products ("RRPs") is the term we use to refer to products that present, are likely to present, or have the potential to present less risk of harm to smokers who switch to these products versus continued smoking. We have a range of RRPs in various stages of development, scientific assessment and commercialization. Because our RRPs do not burn tobacco, they produce far lower quantities of harmful and potentially harmful compounds than found in cigarette smoke

The study was partially funded by Philip Morris International.

FULL STUDY DATA AVAILABLE:
bit.ly/PMI-Teeth1-data