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Development of a composite resin disclosing agent based on the understanding of tooth staining mechanisms

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ABSTRACT

Objectives: To characterize the surface composition of dental enamel and composite resin, assess the ability of dyes with different affinities to stain these surfaces, and use this information to develop a disclosing agent that stains composite resin more than dental enamel.

Methods: One hundred and ten sound extracted teeth were collected and 60 discs of composite resin, 9 mm diameter and 3 mm thick, were prepared. X-ray photoelectron spectroscopy (XPS) was employed to determine the elemental composition on the different surfaces. A tooth shade spectrophotometer was used to assess the change in shade after staining the surfaces with different dyes.

Results: XPS analysis revealed that surfaces of both outer dental enamel and composite resin contained relatively high amounts of carbon, specifically hydrocarbons. Both dental enamel and composite surfaces were stainable with the hydrophobic dye ($p < 0.05$); however, the composite resin was stained more than the dental enamel ($p < 0.05$).

Conclusions: The hydrophobic surface of dental enamel and composite resin might explain their high affinity to be stained by food and beverages containing hydrophobic molecules. The composite resin is more stainable by hydrophobic dyes than dental enamel. We used this information to develop an agent for disclosing composite resins that could be used to visualize composite resins that need to be removed.

Clinical significance: Removal of composite resin can be problematic, time consuming and stressful to the dental practitioner. A composite disclosing agent would help the dental practitioner identify the composite resin and facilitate its removal without damaging the adjacent healthy tooth tissues.

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1. Introduction

The appearance of teeth, and specifically their colour, is a major concern to many people; indeed, the demand for products that treat tooth staining and discoloration has greatly increased in the past decades.[1] The cause for extrinsic enamel stains has been ascribed to molecules adsorbed within the dental biofilm or dental plaque; such molecules may also be retained on the tooth surface through ion exchange reactions and/or form a stain-enamel complex.[1–3] Beverages such as coffee, tea, or red wine are known to cause tooth discoloration, most likely because of their high content of polyphenols that essentially provide their colour.[1,4–6] Polyphenols may adhere to the enamel surface by interacting directly with the tooth surface or by binding to the salivary proteins.[7–11] In liquid, polyphenols interact with proteins and polysaccharides by hydrophobic and hydrogen bond interactions.[12] Also, they have a high affinity with proline residues present in the salivary proteins adherent on the enamel surface. This association is mainly hydrophobic and occurs via the aromatic phenolic rings of polyphenols; hydrogen bonds formed via the many hydroxyl groups present in polyphenol structure play a secondary role.[13,14] Despite these pieces of information, the overall mechanism of how polyphenols form extrinsic stains on the tooth surface is still not completely understood.

Enamel surface composition has been postulated as a contributing factor to many processes, such as caries formation, bio-film buildup, crack propagation and tooth staining.[15–21] Characterizing enamel surface is thus crucial to understand these processes taking place at the interface between the tooth and the surrounding environment. Surprisingly, little is known about the distribution of elements and functional groups on tooth enamel surface and it is still unclear why certain molecules have high affinity to adhere to the outer enamel surface.

Composite resins are among the most frequently used materials for aesthetic restorations in dental practice due to their resemblance to teeth, ability to bond to enamel and dentine, and good mechanical properties.[22,23] However, although the quality of composite resins has improved greatly, the problem of their discoloration over time is still unsolved.[23,24]

Composite discoloration might be due intrinsic or extrinsic factors.[24] One of the most important intrinsic factors is monomer oxidation over time; however, this can be reduced using light curing and excluding benzoyl peroxide from the composites.[25] Extrinsic discoloration is a result of the interaction between colourants in beverages with the composite material.[24–28] However, the mechanism of extrinsic discoloration is still not fully understood.

In the case of tooth enamel, significant amounts of the outer enamel need to be removed in order to obtain flat surfaces for contact angle measurements, even in the incisors which have relatively flat surfaces. Therefore, contact angle measurements performed on the outer enamel surface do not essentially evaluate the hydrophobicity/hydrophilicity of the outer enamel surface itself but rather the inner layers.

In this study we chose XPS and staining with different dyes as ways to get some information on the hydrophilicity/hydrophobicity of enamel and composite resin surfaces.

We hypothesize that the outer enamel surface is different from the rest of the enamel, and has more hydrophobic molecules that can bind polyphenols. In order to test our hypothesis, we designed an ex vivo study and characterized the surface of enamel and composite resins, and assessed the ability of a hydrophobic, a cationic and an anionic dye to stain their surfaces.

2. Materials and methods

2.1. Materials

2.1.1. Chemicals

All chemicals were obtained from Sigma–Aldrich Canada Co. (Oakville, Ontario, Canada), except for the two natural dye powders, paprika and turmeric, which were purchased from Selection (Montreal, Quebec, Canada). Oil Red (OR) (~0.5%), methylene blue (MB) (~1%), acid fuchsin (AF) (~1%), turmeric solution (~0.1%) and paprika solution (~0.1%) were prepared to perform the staining experiments. OR was prepared by stirring 0.5 g of its powder per 100 ml 99% isopropanol overnight before filtering the mixture, while MB was prepared by dissolving 1.0 g of its powder per 100 ml deionized water. AF was prepared by dissolving 1 g of its powder per 100 ml of deionized water and 1 ml of glacial acetic acid. Turmeric and paprika solutions were prepared by dissolving 0.1 g of their powder per 100 ml of ethanol and acetone respectively.

2.1.2. Tooth collection and preparation

A sample of 110 sound maxillary anterior teeth (free of caries, stains, cracks, demineralization or severe pitting or atypical intrinsic stains, and/or a history of tooth bleaching) was collected from adult patients with dental conditions that required tooth extraction. The extraction procedure was performed in the McGill Undergraduate Dental Clinic after obtaining approval from McGill University Health Center Ethical Committee and the signed informed consent from the patients. Upon extraction, teeth were immersed in 10% formalin solution (BF-FORM, Fisher Scientific, Canada) for 1 week. The specimens were then cleaned with DW in an ultrasonic bath (FS20D Ultrasonic, Fisher Scientific, Canada) for 60 min at 25 °C and polished for 1 min with a low-speed dental handpiece (M5Pa, KAB-Dental, USA) using SiC cups (Pro-Cup, sdsKerr, Italy) and dental prophylaxis pumice of low abrasive capability (CPRTM, ICCARE, USA). Then, the teeth were rinsed again in an ultrasonic bath before storing them in labelled Eppendorf tubes with 10% formalin solution for further analysis. The entire sample of 110 was divided into 11 groups of ten teeth each; eight groups were used in the staining procedure and the remaining three groups were employed to characterize the tooth surface elemental composition. For characterization, each tooth was cut into thin sections of enamel (1–1.5 mm thick) using a carbide bur (FG56, SDS Kerr, Orange, CA) adapted to a high speed dental hand piece (TA98LW, Synea, Canada) cooled with DW. Ten of the outer sections were assigned to the outer enamel surface