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Characterization, mechanistic analysis and improving the properties of denture adhesives

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ABSTRACT

Objective. Denture adhesives are widely used to avoid the detachment and sliding of dentures. However, the adhesion properties can be affected by variation in mouth conditions such as the level of salivation. The objective of this study was to understand the effect of environmental conditions on the adhesion properties of a commercially available denture adhesive named as Poligrip® Free manufactured by GlaxoSmithKline Ltd., UK and to identify the reasons for the observed variation in its adhesion strength.

Methods. The failure mechanisms of denture adhesive have been assessed through using different physical, mechanical and thermal characterization experiments. All methods were used in different pH, temperatures, and salivation conditions and at the end, a strategy was proposed to overcome the failure of the paste in hyposalivation as well.

Results. In vitro models mimicking the denture gingival interface were designed to evaluate the adhesion properties of the investigated adhesive. Changes in the adhesion strength in response to three major factors related to the oral conditions including level of salivation, pH, and temperature were measured. The results of lap shear, tensile test, and internal interactions suggested a cohesion failure, where the lowest adhesion strength was due to hyposalivation. Fourier transform infrared spectroscopy (FTIR) and rheological analysis confirmed the importance of hydrogen bonds and hydration in the adhesion strength of the paste.

Significance. The investigated scenarios are widely observed in patient using denture adhesives and the clinical reports have indicated the inconsistency in adhesion strength of

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the commercial products. After identifying the potential reasons for such behavior, methods such as the addition of tripropylene glycol methyl ether (TPME) to enhance internal hydrogen bonds between the polymers are proposed to improve adhesion in the hyposalivation scenario.

1. Introduction

Dentures are commonly used especially by elderly population. Approximately, 600 million people are 60 years or older all around the world. This number is projected to be about two billion by 2050. Almost 80% of this population are living in developing countries [1,2]. Through the next decades, dental specialists should solve the challenge of preparing dental support for a rising number of elderly who fail to keep their own natural teeth. To avoid the unwanted movement and slide of dentures in the mouth, adhesives which are shear thinning pastes are widely employed. Proper adhesion of dentures to gum (or gingival tissue) can improve patients' comfort. In addition, the use of denture adhesives can result in a reduction of denture mediolateral movement and dislodgment as well as a greater bite force [3,4].

A denture adhesive should be ideally biocompatible non-irritating, and could adhere properly to the oral mucosa. They should be easy-to-apply and easy-to-remove, and maintain adhesion strength for 12–16 h. A denture adhesive interacts with the denture surface from one side and the underlying oral mucosa from the other side over a certain period of time. To apply the adhesive, a thin layer of the material is applied to the interior surface of denture, which is then placed on top of gum (Fig. 1a). The adhesion strength of denture adhesives is maximized shortly after their application [5]. Immediately, after adhesive application and exposure to saliva, paste's water content increases which results in the enhancement of paste viscosity and adhesion. Thus, it is expected that the level of saliva affects the adhesion properties of the paste. This is in line with clinical observation showing the significant impact of saliva level on the performance of denture adhesives in different patients [6–8]. The adhesive, however, should maintain its properties in various conditions such as variation in the level of pH, temperature induced by different foods, and level of salivation [9,10].

In this study, the adhesion strength of Poligrip® Free manufactured by GlaxoSmithKline Ltd. (GSK, UK) was characterized. The adhesive is in the form of a shear thinning paste (Fig. 1b). The tested adhesive is comprised of carboxymethyl cellulose (CMC) and poly(methyl vinyl ether/maleic acid) (PMVEMA) as hydrophilic components and mineral oil and petrolatum as hydrophobic compounds. The hydrophilic compounds absorb and maintain water to enhance the adhesion strength and the hydrophobic compounds prevent excessive swelling and dissolution of the paste [11–13].

To measure the adhesion properties, *in vitro* models mimicking the denture oral mucosa interface were developed and used for measuring lap shear and tensile adhesion strength of the paste in various conditions including different pH values, levels of salivation, and temperature. Also, Fourier transform infrared spectroscopy (FTIR), modulated temperature differential scanning calorimetry (MTDSC), scanning electron microscopy (SEM), thermogravimetric analysis (TGA), denture surface morphology, and viscosity measurement were performed to identify the mechanisms resulting in the observed properties.

2. Materials and methods

2.1. Materials

All materials and chemicals were purchased from Sigma–Aldrich Co. (St. Louis, USA) and were used as received without further purification unless mentioned otherwise. The artificial saliva used in the experiments was an aqueous solution containing 0.4 g/L KCl, 0.4 g/L NaCl, 0.906 g/L $CaCl_2{\cdot}2H_2O$, 0.690 g/L $NaH_2PO_4{\cdot}2H_2O$, 0.005 g/L $Na_2S{\cdot}9H_2O$ and 1 g/L Urea based on Fusayama Meyer Formula (Table 1) [14]. The pH of the saliva was adjusted by using the hydrochloric acid and sodium hydroxide 1 M solution. The Super Poligrip® Free denture adhesive was used throughout the experiments. The denture adhesive contained PMVEMA, CMC, petrolatum, cellulose gum, and mineral oil. The commercial denture resin made of heated poly methyl methacrylate and monomer ethylene dimethacrylate (Dentorium convertible acrylic-heat cure, Dentorium®) was purchased from Dentorium Products Co., Inc. (Farmingdale, NY) and used according to manufacture recommendation [15]. CMC (Fig. 1c) and PMVEMA (Fig. 1d) were obtained from Ashland Inc. Company (Covington, USA) and were prepared with concentrations of 24% (w/v) and 30% (w/v), respectively.

Table 1 – Artificial saliva composition.

Saliva composition	g/L
KCl	0.4
NaCl	0.4
$CaCl_2{\cdot}2H_2O$	0.906
$NaH_2PO_4{\cdot}2H_2O$	0.690
$Na_2S{\cdot}9H_2O$	0.005
Urea	1

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