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Effect of surface treatments on the mechanical properties and antimicrobial activity of desiccated glass ionomers

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ABSTRACT

Objectives. The purpose of this study was to evaluate the effect of various surface treatments on the mechanical properties and antibacterial activity of desiccated glass-ionomer (GI) and resin-modified glass-ionomer (RMGI) materials.

Methods. One hundred GI and RMGI specimens were fabricated in a mold, stored in 100% humidity for 24 h, placed in air to desiccate for 24 h, and then stored for one week in one of the five media [casein phosphopeptide–amorphous calcium phosphate (CPP–ACP), chlorhexidine (CHX), sodium fluoride (NaF), cetylpyridinium chloride (CPC), or 100% humidity (control)]. Fifty GI and RMGI specimens were tested in flexure to determine flexural strength and modulus, with the fragments used for Knoop hardness testing. The remaining 50 GI and RMGI specimens were covered with a suspension of *Streptococcus mutans* and incubated for 24 h. The bacterial suspension was removed and the specimens were washed. Sterile saline was added, vortex mixed, serially diluted, and plated. CFU/mLs were calculated after 3 days of incubation.

Results. Compared to the 100% humidity control group, surface treatment of the desiccated GI and RMGI materials had a variable effect on the mechanical properties. In general, NaF provided the greatest improvement in flexural strength and modulus. Surface treatment of the desiccated GI or RMGI specimens with CHX or CPC resulted in no growth of the *S. mutans*. NaF resulted in significantly lower CFU/mL than CPP–ACP, which was significantly lower than the control group.

Significance. Surface treatment with 5% NaF provides improved antimicrobial and strength properties of desiccated GI or RMGI materials.

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1. Introduction

According to limited epidemiological studies, approximately ten percent of the general population suffers from perpetual xerostomia, and an estimated 30% of the population, 65 years and older, endures this condition [1–4]. There are several possible etiologies for a patient experiencing xerostomia, which may be the result of medications, history of radiation therapy, or diagnosis of systemic disease such as Sjögren's syndrome [5]. The most common cause of xerostomia is medication-induced as a large population of elderly adults is treated by at least one medication that impairs salivary function [4]. Typically, a patient suffering from xerostomia or salivary dysfunction may experience detrimental intraoral consequences such as oral discomfort, rampant and recurrent caries, increased risk of chronic infections, and desiccation of dental restorations—all of which can lead to a decrease in quality of life for the patient [5].

Selecting a restorative material with suitable physical, chemical, and clinical properties that matches to the xerostomic patients' needs is not only imperative in terms of treating and managing patients' dental disease but also is essential to their prognosis and the safeguarding of their oral health. For these patients, treatment using fluoride-releasing restorative materials may be advantageous due to their potential ability to inhibit caries progression, prevent secondary caries development, and promote mineralization as found in in vitro studies [6]. Even though today's fluoride-releasing restorative materials may have shortcomings (e.g., desiccation, hydrolysis, and dimensional instability) that limit their application, what makes these fluoride-releasing restorative materials attractive is their unique potential to leach and absorb (recharge) ions other than fluoride (e.g., CPP–ACP, CHX, or CPC) [7].

Apart from restoring a tooth from a diseased condition to a non-cariogenic state, the common intention behind placing these fluoride-releasing restorations is to modify the local environment, including that for adjacent teeth, since the effect of leachable components from a polyalkenoate acid-based restoration is well documented from in vitro studies [8]. However, from a homeostasis perspective, in reality, the oral environment probably exerts a greater impact on these restorative materials than the ion-leaching influence from the restorations themselves. For example, the lack of salivary buffering in xerostomic patients may reduce normal plaque pH, which can alter the mechanical and surface properties of GIs accordingly [1–4].

GIs and RMGIs are sensitive to dimensional change when exposed to either a wet or dry environment. Previous studies have shown that conventional GIs and RMGIs are vulnerable to dehydration stress [9,10]. Severe dehydration may produce loss of adhesion or debonding from tooth structure, shrinkage, and microleakage resulting in failure of the restoration or recurrent caries [9–11]. Just as conventional GIs may undergo hygroscopic dimensional change when exposed to a moist environment, they may also contract under desiccated conditions and lose adhesion to tooth structure [9]. Furthermore, the addition of resin to GIs as seen in RMGIs has not improved the susceptibility of the material to dehydration. In a study by Sidhu et al. when RMGI and conventional GI restorative materials were placed in Class V preparations of extracted human mandibular third molars and subjected to dehydration stress in vitro, after a period of time both materials demonstrated adhesive gap formation at the dentin interface [10]. In an in vitro study by Watson, the strength of a RMGI material near dentin is weakened during dehydration resulting in shrinkage and cracking at the interface of the restoration with tooth structure [12]. Clinically, the effect of dimensional change from dehydration of the material is manifested as debonding from tooth structure [10]. Furthermore, compounded by cyclic fatiguing, small debonding disturbances have the potential to turn into marginal defects, which past clinical studies [13] have shown that detectable defects in restoration margins have an increased risk of secondary caries formation.

Currently, the conventional GI's acid-base chemistry continues to serve as a platform for future fluoride-releasing materials. An attractive goal is to create a restorative material that can not only offer the capability of fluoride release or uptake but can also assist in treating the localized microbes and mineralization by adding CPP–ACP, CHX, NaF or CPC into the conventional GI or RMGI. Secondary caries remains as one of the leading causes of replacement of restorations due to the colonization of bacterial biofilm at the tooth–restoration interface [13,14]. *Streptococcus mutans* is the major contributing microorganism involved in the pathogenesis of dental caries in humans [15]. Studies have shown that levels of *S. mutans* in dental plaque of conventional glass ionomers (GIs) and resin-modified glass ionomers (RMGIs) is lower compared to composite resin restorations [16,17]. In addition, several in vitro studies have demonstrated that GI and RMGI, incorporated with agents like CPP–ACP, CHX, NaF, and CPC, can assist in hindering the formation of plaque biofilm, inhibiting demineralization, and preventing secondary caries in tooth structure adjacent to the restoration [7,18–20].

For example, CPP–ACP has been incorporated into GIs as a bioactive additive since ACP is a precursor to hydroxyapatite [21,22]. CPP that contains the peptides with a continuous sequence of anionic amino acids (SerP–SerP–SerP–Glu–Glu), which maximizes the solubility of calcium phosphate through stabilization of ACP bound to the phosphopeptides, have shown to be anticariogenic [23,24]. The reason for the mixing of CPP with the ACP component into the GI system is to facilitate increased efficiency of the transport of calcium and phosphate ions into the tooth. By increasing the CPP concentration in a leachable restorative material, this will alter the osmotic diffusion gradient and serve as a high concentration reservoir from which calcium and phosphate ions can be released into the enamel subsurface lesion [18]. In an acidic oral environment, CPP–ACP has the ability to increase release of calcium, phosphate, and fluoride ions, which inhibits demineralization and promotes remineralization of enamel; a process in which the demineralized enamel crystalline voids receive a net mineral gain of calcium, phosphate, and fluoride ions [22,25].

CHX gluconate (0.12%), commonly found as topical antimicrobial mouth rinse, is considered the "gold standard" in its role as an antiplaque and antigingivitis agent [26]. CHX is effective against both gram-positive and gram-negative bacteria and acts by increasing cell membrane permeability and