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Full Length Article

Interfacial degradation of adhesive composite restorations mediated by oral biofilms and mechanical challenge in an extracted tooth model of secondary caries

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ABSTRACT

Objective: To study the combined effect of simulated occlusal loading and plaque-derived biofilm on the interfacial integrity of dental composite restorations, and to explore whether the effects are modulated by the incorporation of sucrose.

Methods: MOD-class-II restorations were prepared in third molars. Half of the specimens (n = 27) were subjected to 200,000 cycles of mechanical loading using an artificial oral environment (ART). Then, both groups of specimens (fatigued and non-fatigued) were divided into three subgroups for testing in CDC-reactors under the following conditions: no biofilm (Control), biofilm with no sucrose (BNS) and biofilm pulsed with sucrose (BWS). BNS and BWS reactors were incubated with a multispecies inoculum from a single plaque donor whereas the control reactor was not. The BWS reactor was pulsed with sucrose five times a day. The biofilm challenges were repeated sequentially for 12 weeks. pH was recorded for each run. Specimens were examined for demineralization with micro-CT and load capacity by fast fracture test.

Results: Demineralization next to the restorations was only detectable in BWS teeth. Fracture loads were significantly reduced by the concomitant presence of biofilm and sucrose, regardless of whether cyclic mechanical loading was applied. Cyclic loading reduced fracture loads under all reactor conditions, but the reduction was not statistically significant.

Conclusions: Sucrose pulsing was required to induce biofilm-mediated degradation of the adhesive interface.

We have presented a comprehensive and clinically relevant model to study the effects of mechanical loading and microbial challenge on the interfacial integrity of dental restorations.

1. Introduction

During their lifetime, dental composite restorations are exposed to an array of environmental factors involved in the breakdown of the adhesive interface between the restorative material and the dental tissues. For instance, when the polymerization shrinkage stress of a dental composite exceeds the interfacial bond strength, delamination and gap formation at the interface occurs [1–3]. These gaps are susceptible to infiltration by oral fluids, acids, metabolites and colonization by oral bacteria [4–6]. Even if the initial shrinkage stress is not sufficiently high to cause delamination, the mechanical, chemical and biological stresses from oral functions can contribute to interfacial degradation [7]. Ultimately, the loss of the marginal sealing facilitates oral bacteria accumulation at the interface, which may lead to secondary caries around composite restorations.

Masticatory forces from normal chewing and para-functional habits can impose great stress at the adhesive interface. Although the mechanical degradation of dental composite materials has been largely characterized [7–10], much less is known about the effect of mechanical challenge on the interfacial integrity of dental restorations. The few studies published so far show that cyclic loading leads to mechanical weakening of the adhesive interface regardless of the fatigue configuration (i.e. tensile, bending or compression) [11–13]. Moreover, similar to the fracture strength of monolithic materials, an inverse correlation between number of loading cycles and bond strength values has been shown [12,14]. These data suggest that cyclic mechanical loading can affect the integrity of the bond irrespective of the initial bond strength of the adhesive interface. Thus, fatigue is relevant when

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exploring interfacial degradation processes.

In addition to mechanical challenge, biological and chemical agents present in oral fluids and food can affect dental composite restorations. Research by Santerre and coworkers demonstrated that esterase activity of saliva promotes the breakdown of condensation bonds present in dental composite polymers [15–19]. Those studies focused on the composite material, however, biological degradation effects on the adhesive interface remain largely unknown. A recent study showed that exposure of model restorations to esterases increased the amount of microbial leakage along the interface [20], suggesting that biological degradation could contribute to the interfacial breakdown.

Oral biofilms have been proposed to have a role in the degradation of the interface [21]. Recent data demonstrated that *Streptococcus mutans*, an oral pathogen, possesses esterase activity capable of degrading dental composites and dental adhesives [22] implying a potential microbial mechanism for degrading the adhesive interface.

In the mouth, oral biofilms produce organic acids by fermenting carbohydrates from diet [23], thus promoting the demineralization of hard dental tissues [24]. In addition, oral bacteria secrete a large array of enzymes and other metabolic products that might degrade the adhesive interface. To gain insight into the role of oral bacteria in the degradation process, we previously investigated the effect of a multispecies oral microcosm biofilm on the interfacial integrity of model dental restorations [25]. In that model, dentin-composite disks prepared with two different restorative systems were exposed to oral biofilms, and then tested under diametral compression. During the microbial challenge, half of the specimens were exposed to a sucrose-pulsed biofilm to explore the contribution of sucrose as an environmental factor. A reduction in the debonding load was observed in both groups exposed to biofilm compared to the control (no biofilm), although only the reduction seen in the sucrose-fed biofilm group was statistically significant.

Most of the factors involved in interfacial breakdown are commonly studied in isolation. In the oral cavity, multiple challenging factors may be present at the same time, and they might contribute synergistically to the degradation process. The aim of this study was to examine the combined effect of mechanical loading and microbial challenge on the interfacial integrity of composite restorations placed in extracted teeth, and to explore whether the effects of those challenges were modulated by environmental factors, such as sucrose.

2. Materials and methods

2.1. Specimen preparation

De-identified extracted human third molars were collected from oral surgery clinics at the University of Minnesota and in the Minneapolis/Saint Paul metropolitan area. Only teeth free of caries, fractures and cracks were included. The molars were cleaned of soft tissues and hard deposits (when present), and stored in 1% thymol solution. Mesio-occlusal-distal (MOD) class II cavities were prepared using a modified flat end tapered burs (SS White Burs Inc., Lakewood, NY, USA). The dimensions of the cavities were ~2.5 mm wide and ~2.5 mm deep for the occlusal box, and ~3 mm wide and ~1.5 mm deep for the proximal box. All teeth were restored using Adper™ Single Bond Plus adhesive system (SB) and Z100™ Restorative (Z100) system (3M ESPE, St. Paul, MN, USA) (Table 1). Briefly, 35% phosphoric acid (Scotchbond etchant, 3M ESPE, St. Paul, MN, USA) was applied to dentin and enamel for 15 s and rinsed with water. Gentle air-drying was used to avoid collagen collapse in dentin. Two consecutive coatings of SB were rubbed on the internal walls of the preparation and polymerized for 20s. The teeth were restored with 2 mm thick increments of Z100. Each layer was polymerized for 20 s with an Elipar™ S10 curing light (3M ESPE, St. Paul, MN, USA) operated at 1200 mW/cm The samples were polished after 24 h of water storage. A finishing diamond stone was used to remove excess material from the restoration margin before polishing was conducted with Progloss™ One Step Composite Polishers (Kerr Corporation, Orange, CA, USA). A total of 54 MOD class-II composite restorations were made.

Table 1
Compositions of composite and adhesive used for Class-II restorations (obtained from manufacturer's data sheets (3M ESPE)).

Product	Composition	Batch number
Z100™ Restorative	Silane treated ceramic, triethylene glycol dimethacrylate (TEGDMA), bisphenol a diglycidyl ether dimethacrylate (BISGMA), 2-benzotriazolyl-4-methylphenol.	N649950
Adper Single Bond Plus	Ethyl alcohol, silane treated silica (nanofiller), bisphenol a diglycidyl ether dimethacrylate (BISGMA), 2-hydroxyethyl methacrylate (HEMA), glycerol 1,3-dimethacrylate, copolymer of acrylic and itaconic acids, water, diurethane dimethacrylate (UDMA) diphenyliodonium hexafluorophosphate, ethyl 4-dimethyl aminobenzoate (EDMAB).	N561025

2.2. Fatigue (chewing simulation)

Half of the specimens (n = 27) were mounted in Teflon rings with self-curing acrylic resin (Dentsply Caulk, Milford, DE, USA). Each mounted specimen was positioned in the mandibular chamber of an artificial oral environment (ART), developed by the Minnesota Dental Research Center for Biomaterials and Biomechanics [26] (Fig. 1). A 6 mm diameter steatite bead attached to the upper arm was used as the antagonist. The target loading point was located in the functional cusp

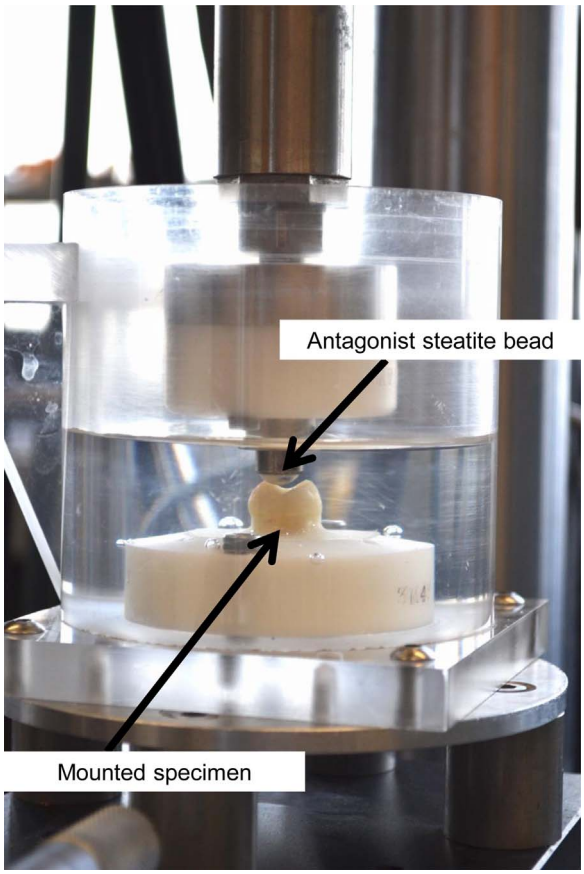

Fig. 1. Cyclic loading setup. Each tooth was mounted in acrylic resin and located in the lower chamber of the artificial oral environment. A steatite bead attached to the upper loading arm acted as the antagonist.