For Healthcare Professionals

Infectious Smiles

Focus on Anti-infectives

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Novel Dental Adhesive Resin with Crack Self-healing, Antimicrobial and Remineralization Properties.

Secondary caries at the tooth-restoration margins is a primary reason for restoration failure. Cracks at the margins lead to leakage which can trap bacteria, producing acids to cause caries. To date, there has been no report on developing an adhesive resin that has self-healing, antibacterial and remineralizing capabilities.

Self-healing microcapsules were synthesized with poly(urea-formaldehyde) (PUF) shells containing triethylene glycol dimethacrylate (TEGDMA) as the healing liquid. The new adhesive contained 7.5% microcapsules, 10% dimethylaminohexadecyl methacrylate (DMAHDM) and 20% nanoparticles of amorphous calcium phosphate (NACP). A single edge V-notched beam (SEVNB) method was used to measure the fracture toughness K_{ic} and the autonomous crack-healing efficiency. An oral plaque microcosm biofilm model was tested.

> “A self-healing adhesive with antibacterial and remineralizing capabilities was developed for the first time. Excellent dentin bond strength, autonomous crack-healing and K_{ic} recovery, and strong anti-biofilm properties were achieved for the new adhesive resin.”

The novel method of using triple agents (self-healing microcapsules + DMAHDM + NACP) is promising for applications in dental adhesives, cements, sealants and composites to combat the two main challenges: fracture and secondary caries.

Composites are popular esthetic alternatives to dental amalgams. Advances in polymer chemistry and fillers have enhanced the performance of composites. However, one main drawback is that composites collect more biofilms than other restorative materials.

Oral biofilms produce acids which can cause tooth caries. Secondary caries at the bonded tooth-composite margins is one of the primary reasons for restoration failures. Therefore, efforts have been undertaken to enhance the tooth-restoration bond strength.

Since secondary caries often occurs at the margins, it is high desirable to develop antimicrobial adhesives to inhibit bacteria and combat caries at the margins.

Recently, novel crack-healing poly(urea-formaldehyde) (PUF) microcapsules containing TEGDMA and *N,N-dihydroxyethyl-p-toluidine* (DHEPT) were synthesized. They were incorporated into a composite containing NACP to obtain crack-healing, antibacterial, and remineralization capabilities.

The long-term crack-healing of this composite was also demonstrated. However, to date, there has been no report on the development of an adhesive resin with triple benefits of autonomous crack healing, antimicrobial and remineralizing capabilities.

Therefore, the objectives of this study were to develop the first selfhealing, antimicrobial and remineralizing dental adhesive, and determine the effects on dentin bond strength, self-healing efficiency, and the suppression of oral plaque microcosm biofilms for the first time.

The following hypotheses were tested:

(1) Incorporation of self-healing microcapsules, antibacterial DMAHDM and remineralizing NACP into the adhesive would not reduce the dentin bond strength;

(2) Incorporation of the microcapsules would impart autonomous crackhealing to the adhesive;

(3) This autonomous crack-healing adhesive containing DMAHDM and NACP would exhibit strong antimicrobial properties against oral plaque microcosm biofilms.

The dental plaque microcosm biofilm model was approved by the University of Maryland Institutional Review Board. Saliva was used as an inoculum to provide biofilms. To represent the diverse bacterial populations, saliva from ten healthy individuals was collected and combined for the experiments, following a previous study. Saliva was collected from adult donors who had natural dentition without active caries or periopathology, and without the use of antibiotics within the last 3 months. The donors did not brush teeth for 24h and abstained from food/drink intake for 2h prior to donating saliva.

This study represents the first report on the development of an autonomous crack-healing, antimicrobial and remineralizing dental adhesive. The hypotheses were proven that adding microcapsules, DMAHDM and NACP into the adhesive did not negatively affect the dentin bond strength; that adding autonomous-healing microcapsules into the adhesive achieved a substantial autonomous crack-healing efficiency of 67% for the fracture toughness of the resin; and that the autonomous crack-healing adhesive demonstrated strong antimicrobial functions, greatly reducing biofilm metabolic activity and acid production, and reducing biofilm CFU by four orders of magnitude.

The adhesive resin between the tooth substrate and the composite restoration plays a key role in the success of the restoration. It was shown that the adhesive layer could absorb some of the contraction stresses generated in the composite during polymerization and thus could reduce the interfacial micro-leakage.

> “The thickness of the adhesive layer usually ranged from about 20μm to 420μm for various adhesive systems and different clinical application protocols.”

Another important property for the self-healing adhesive is the antibiofilm function. An antimicrobial adhesive is beneficial for three reasons.

First, caries at the margins limits the lifetime of the restorations. Therefore, it is beneficial to reduce the biofilm buildup and acid production to prolong the restoration longevity.

Second, residual bacteria often exist in the prepared tooth cavity; an antimicrobial adhesive could flow into the dentinal tubules and eradicate the residual bacteria.

Third, micro-leakage often occurs between the adhesive resin and the primed dentin, or between the adhesive resin and the restoration, due to the polymerization shrinkage and cyclic loading.

> “These microcracks at the margins provide easy passageways for the bacteria to invade into the interface, where the adhesive surface is surrounded by a large portion of the marginal gaps.”

The antimicrobial adhesive could kill these invading bacteria. In addition, the copolymerization with adhesive resin and immobilization of QAMs indicate that the antimicrobial effect is durable and would not diminish over time. The antimicrobial mechanism of QAMs was suggested to be that when the negatively-charged bacterial cell contacts the positively-charged sites of QAMs, the electric balance of cell membrane could be disturbed, and the bacterium would explode under its own osmotic pressure.

In addition, long-chained quaternary ammonium compounds such as DMAHDM had additional antimicrobial activity by penetrating into the bacterial membrane, like a needle bursting a balloon, resulting in physical damage of bacterial cells. Indeed, the autonomous crack-healing adhesive containing DMAHDM displayed a potent anti-biofilm capability in present study. The reduction of lactic acid of biofilms by two orders of magnitude would be highly beneficial in reducing secondary caries at the margins.

The present study developed a new dental adhesive with triple benefits of

(1) autonomous crack-healing,

(2) antimicrobial function, and

(3) calcium phosphate nanoparticle remineralization capability

The dentin shear bond strength was not negatively affected by the incorporation of the triple agents: autonomous-healing microcapsules, tantimicrobial DMAHDM, and remineralizing NACP.

The novel method of using triple agtents (self-healing microcapsules + DMAHDM + NACP) is expected to be applicable to a wide range of other dental adhesives, cements, sealants and composites to heal cracks and inhibit caries.

Reference

1. Novel dental adhesive resin with crack self-healing, antimicrobial and remineralization properties – *S. Yue et al. 17 May 2018.*