Broad-spectrum, long-term antibiofilm features of metallic nanoparticles and antibacterial monomers on dental adhesive and resin composite surfaces

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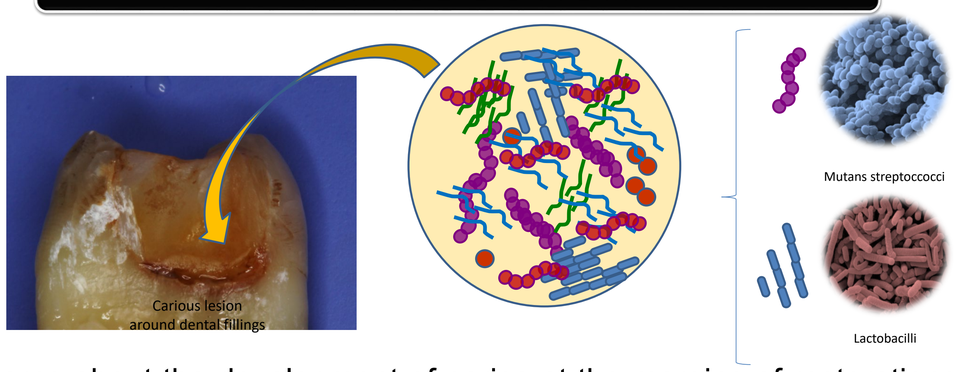
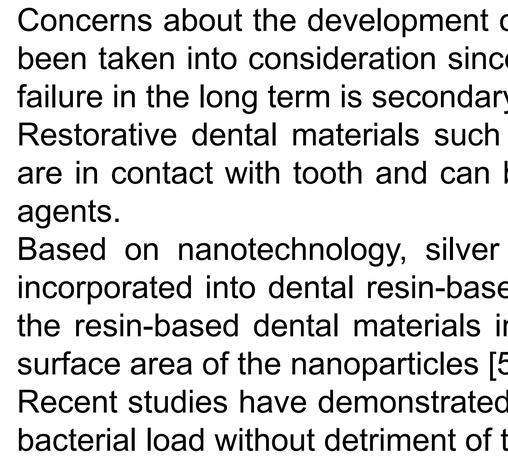
INTRODUCTION



- Concerns about the development of caries at the margins of restorations have been taken into consideration since the main reason for composite restoration failure in the long term is secondary caries [1-4].
- Restorative dental materials such as resin composite and adhesive systems are in contact with tooth and can be the ideal vehicle for delivering anticaries agents.
- Based on nanotechnology, silver nanoparticles (NAg) were developed and incorporated into dental resin-based materials. These nano-sized particles in the resin-based dental materials increased the ion release due to the higher surface area of the nanoparticles [5-8].
- Recent studies have demonstrated the capability of these materials for reduce bacterial load without detriment of their mechanical properties [1-4].

MATERIALS AND METHODS

NAg incorporation into dental materials



The incorporation of NAg into dental resins was shown to be promising to achieve a strong antibacterial activity [2,3]. NAg could be formed in the resin in situ, thus avoiding the agglomeration issue. Silver 2-ethylhexanoate powder (Strem, New Buryport, MA, USA) could be dissolved in 2-(tert-butylamino) ethyl methacrylate [1,2]. This Ag solution was then mixed into a resin at 0.05-0.10% mass fraction of silver 2-ethylhexanoate.

Cationic quaternary ammonium monomers into dental materials

Synthesis of Quaternary Ammonium Monomethacrylates

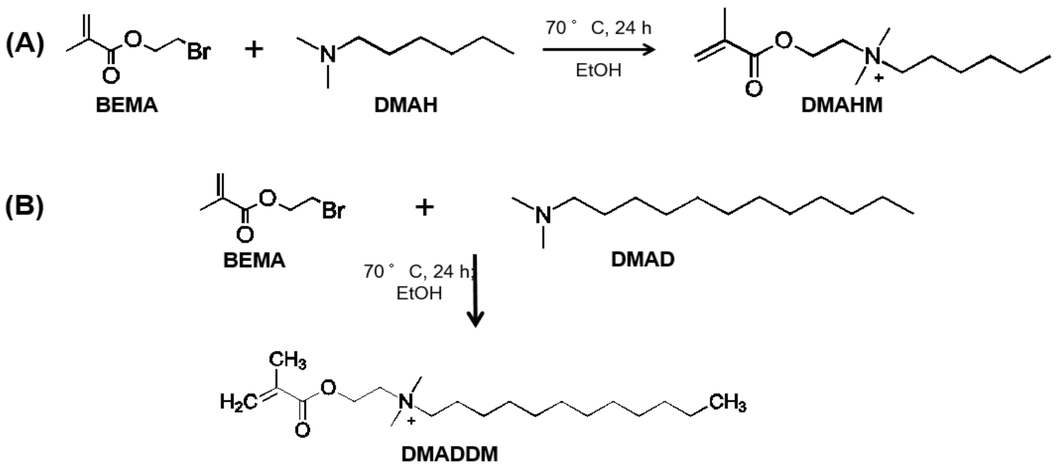


Figure 1. A modified Menschutkin reaction was used to synthesize new antibacterial monomers: (A) DMAHM, and (B) DMADDM. DMAH = *N,N*-dimethylaminohexane. BEMA = 2-bromoethyl methacrylate. DMAHM = dimethylaminohexyl methacrylate. DMAD = 1-(dimethylamino)dodecane. DMADDM = dimethylaminododecyl methacrylate. EtOH = anhydrous ethanol. The number of the alkyl chain length units was 6 for DMAHM and 12 for DMADDM.

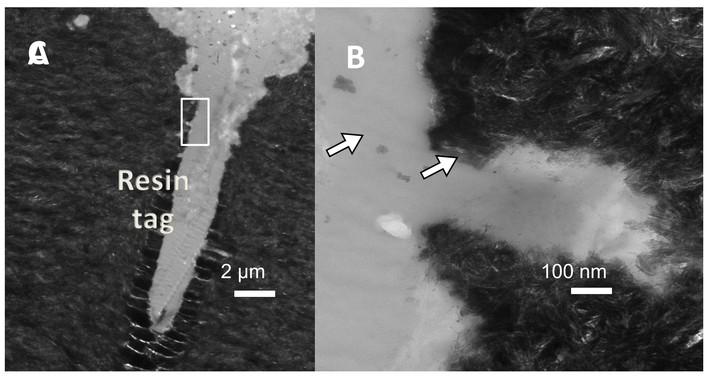


Fig. 2 TEM photomicrographs illustrating the infiltration of experimental adhesive system in demineralized dentin matrix. (A) Apparent long resin tag formation through the dentinal tubules were observed. Deposition of many NAg and NACP particles appeared along the tag (white arrow). (B,C,D) High magnification of selected area (square)

RESULTS

Antibacterial and Mechanical properties

Using a dental plaque biofilm model, colony-forming unit (CFU) counts for total microorganisms, total streptococci, and mutans streptococci were assessed after biofilm growing over 9 mm resin disks for 2 days. [3,4].

Mechanical properties were measured by shear bond test to evaluate the bonding strength of new materials do human dentin.

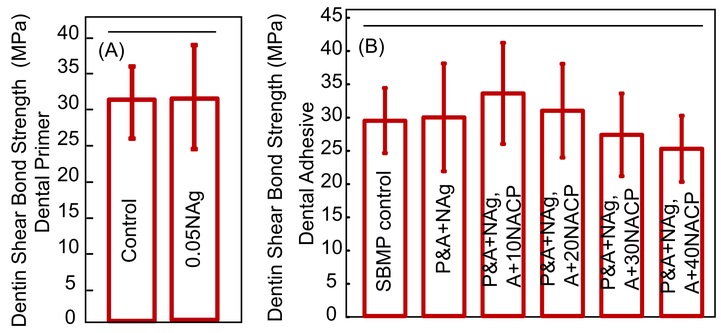
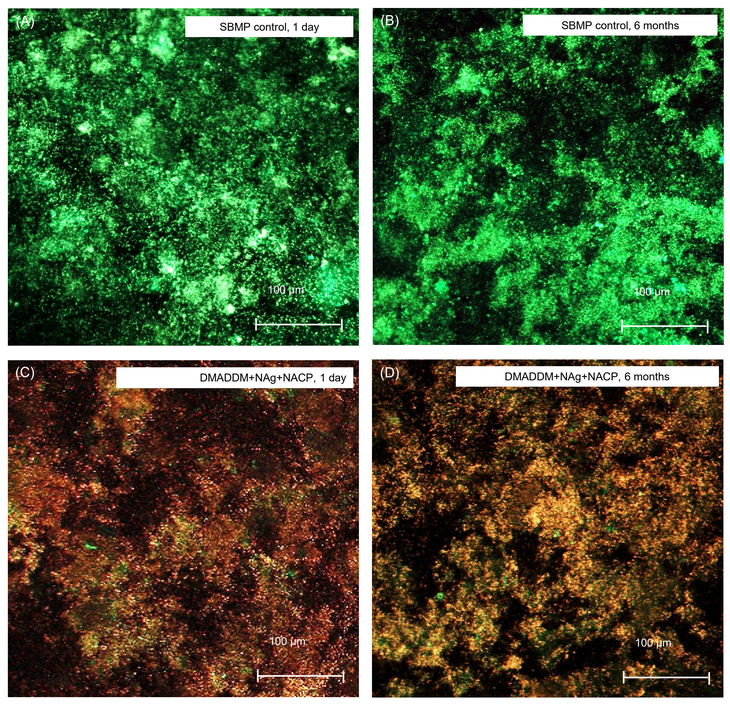


Fig. 3. Dentin shear bond strength. (A) Primer containing 0.05% NAg, and (B) adhesive containing NAg and NACP (0-40%). Adding NAg and NACP into the bonding agent did not significantly decrease the dentin bond strength. The horizontal line indicates values not significantly different from each other ($p > 0.1$). (Adapted from Ref. [4,8] with permission).

Fig. 4. Antibacterial activity of un-curd primers in agar disk diffusion test. Inhibition zone data for total microorganisms, total streptococci, and mutans streptococci, respectively. Each value is mean ± sd (n = 6). Bars with dissimilar letters indicate values that are significantly different ($p < 0.05$). (Adapted from Ref. [3] with permission).



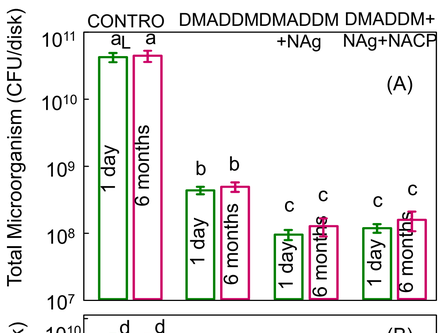


Fig. 5. Dental plaque biofilm colony-forming units (CFU) formed on the surface of dental adhesive containing different antibacterial/remineralizing agents. (A) Total microorganisms, (B) total streptococci, and (C) mutans streptococci. Each value is (mean ± sd; n = 6). After 6 months, the combining agents reduced the biofilm CFU of the commercial SBMP control by more than two orders of magnitude. In each plot, four groups were tested as listed at the top of the figure: Control; control + DMADDM; control + DMADDM + NAg; control + DMADDM + NAg + NACP. Values with dissimilar letters are significantly different ($p < 0.05$). (Adapted from Ref. [9] with permission).

Fig 6. Fluorescence images of biofilm grown on the adhesive surface to investigate the antibacterial activity of the adhesive containing DMADDM + NAg + NACP at 1 d and 6 months, respectively. Live bacteria were stained green, and dead bacteria were stained red. Live and dead bacteria in close vicinity and on the top of each other appeared yellow or orange. (Adapted from Ref. [9] with permission).

CONCLUSION

The new nanostructured formulations have the potential to reduce residual bacteria in the tooth cavity and inhibit the invading bacteria along the tooth-restoration margins, the main reason for dental restoration failure.

ACKNOWLEDGEMENTS

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