Antibacterial orthodontic cement to combat biofilm and white spot lesions

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Introduction: White spot lesions are an undesired side effect of fixed orthodontic treatment. The objective of this research was to develop an antibacterial resin-modified glass ionomer cement (RMGIC) containing nanoparticles of silver (NAg) for prevention of white spot lesions. **Methods:** NAg was incorporated into a commercial RMGIC. The NAg-enhanced cement was compared with the unaltered RMGIC and with a commercially available composite that does not release fluoride. The experimental and control products were used to bond brackets to 80 extracted maxillary first premolars. Enamel shear bond strength and the adhesive remnant index scores were determined. A dental plaque microcosm biofilm model with human saliva as the inoculum was used to investigate biofilm viability. Bacteria on the sample surface and bacteria in the culture medium away from the sample surface were tested for metabolic activity, colony-forming units, and lactic acid production. **Results:** Adding NAg to RMGIC and aging in water for 30 days did not adversely affect the shear bond strength compared with the commercial RMGIC control ($P > 0.1$). The RMGIC with 0.1% NAg achieved the greatest reductions in colony-forming units, metabolic activity, and lactic acid production. The RMGIC with 0.1% NAg inhibited not only the bacteria on the surface, but also the bacteria away from the surface in the culture medium. Incorporation of NAg into RMGIC greatly reduced biofilm activity. **Conclusions:** This novel RMGIC reduced biofilm formation and plaque buildup and could inhibit white spot lesions around brackets. The method of using NAg may apply in a wide range of dental adhesives, cements, sealants, and composites to inhibit biofilm and caries. (Am J Orthod Dentofacial Orthop 2015;148:974-81)

White spot lesions around brackets are a great complication in patients having fixed orthodontic treatment, especially those with poor oral hygiene.[1] These lesions are due to demineralization of the enamel by organic acid produced by biofilms around the brackets.[2] Many methods can decrease or prevent white spot lesions: improving oral hygiene, modifying diet (low carbohydrate), and treating with topical fluoride.[1,2] However, these methods depend on patient compliance and therefore are unreliable.[2] Hence, preventive measures that do not require patient compliance might be more effective in preventing white spot lesions.

Resin-modified glass ionomer cements (RMGICs) have been used as bracket-bonding adhesives because of their fluoride-releasing capabilities and ability to bond orthodontic brackets with acceptable bond strengths.[3,4] Many studies have shown that RMGICs are more effective than composite resins for reducing enamel demineralization around brackets.[5,6] However, previous studies have reported that RMGICs tend to accumulate more cariogenic streptococci than do composite resins because of their rough surfaces, high surface-free energy, and polarity.[7,8] Furthermore, the authors of most studies have concluded that the duration of fluoride release is short. The fluoride released from the RMGICs began with an initial burst at the time of bonding, followed by a rapid decrease.[3,4] Accordingly, it is desirable to incorporate antimicrobial agents into RMGICs to improve their cariostatic effect.

Silver has a long history of use in medicine as an antimicrobial agent.[9,10] It has been shown to possess

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antibacterial, antifungal, and antiviral functions and is an effective antibacterial agent against many microorganisms.[9,10] Recent studies have developed antibacterial nanocomposites and dentin-bonding agents containing nanoparticles of silver (NAg) with a potent antibacterial activity.[11-14] However, there has been no report on the incorporation of NAg into RMGICs. Furthermore, previous studies have found that the antimicrobial properties of fluoride are limited, and its release occurs mainly beneath the orthodontic brackets, where often it is inefficient or unsuccessful in preventing decalcification away from the brackets.[3,4] In contrast, it was reported that NAg-containing resin has a long-distance killing capability because of silver ion release.[15] Therefore, it is beneficial to incorporate NAg into RMGICs, and the NAg and fluoride could be complementary agents in inhibiting white spot lesions both beneath and away from the orthodontic brackets.

Hence, the objectives of this study were to develop a novel RMGIC containing NAg for the prevention of white spot lesions. A dental plaque microcosm biofilm model with human saliva as the inoculum was used to investigate biofilm viability.[11,12] The following hypotheses were tested: (1) incorporating NAg into RMGIC would not compromise the enamel bond strength, (2) RMGIC containing NAg would have much stronger antibacterial effects than a commercial RMGIC control, and (3) RMGIC containing NAg will inhibit not only bacteria on its surface, but also bacteria away from its surface in the culture medium.

MATERIAL AND METHODS

A commercial RMGIC (Fuji ORTHO LC; GC Corporation, Tokyo, Japan), called "Fuji," was used as the parent system. Silver 2-ethylhexanoate (Strem Chemicals, Newburyport, Mass) of 0.1 g was dissolved into 0.9 g of 2-(tert-butylamino)ethyl methacrylate (TBAEMA; Sigma-Aldrich, St Louis, Mo).[11,12] TBAEMA improved the solubility by forming silver-nitrogen bonds with silver ions to facilitate silver salt to dissolve in the resin solution.[11,12] Previous studies showed that NAg sizes ranging from 2 to 5 nm could be used.[11,12] In our study, measurement of 100 particles yielded 2.7 ± 0.6 nm (mean and standard deviation). TBAEMA contains reactive methacrylate groups that can be chemically bonded in the resin upon photopolymerization. The silver solution was incorporated into Fuji at silver 2-ethylhexanoate/(Fuji + silver 2-ethylhexanoate) mass fractions of 0.05% and 0.1%. Preliminary study indicated that adding 0.15% or more of NAg turned the Fuji to a yellow-brown color.

The Fuji cement was used without added NAg as a control. A commercially available composite that does not release fluoride (Transbond XT; 3M Unitek, Monrovia, Calif) was used as a second control. Transbond XT was selected because it has been widely tested in several studies and has been shown to have suitable enamel bond strength, but it has no antibacterial effects.[16,17] The following 4 orthodontic adhesives were investigated: (1) Transbond XT, control (TB control); (2) Fuji + 0% NAg (Fuji control); (3) Fuji + 0.05% NAg; and (4) Fuji + 0.1% NAg.

Eighty extracted maxillary first premolars were randomly divided into 4 groups of 20 each. Each tooth was embedded vertically in a self-curing acrylic resin (Lang Dental Manufacturing, Wheeling, Ill), taking into account the buccal axes of the clinical crowns, so that their labial surfaces would be parallel to the force during the shear bond testing. Metal premolar orthodontic brackets were used. The mean base surface area was 9.63 mm^2.

For group 1, the enamel was etched for 30 seconds with 37% phosphoric acid (Scotchbond; 3M ESPE, St Paul, Minn) and then rinsed for 10 seconds. Each tooth was dried with a stream of air until a chalky white appearance was observed.[16] Transbond XT primer (3M Unitek) was applied to the etched surfaces in a thin, uniform coat. Then, Transbond XT light-cured adhesive paste (3M Unitek) was applied to the bracket base and pushed against the enamel surface. A bracket placement pliers was used to hold and keep the bracket in position on the center of the enamel surface. A 300-g force was applied vertically (buccolingually) on the bracket for 5 seconds using a force gauge (Correx, Bern, Switzerland) to ensure uniform bonding pressure and adhesive thickness.[17] Excess adhesive around the bracket base was removed with a clinical probe, and then the specimens were photo-cured (Demetron VCL 401; Kerr, Orange, Calif) for a total of 40 seconds. The curing light was held against the bracket and the tooth on the mesial aspect for 20 seconds followed by 20 seconds against the distal aspect at a constant distance of 3 mm and at a 45° angle to the enamel surface.[5,6]

For groups 2 through 4, we used RMGICs that, according to the manufacturer and the literature, can be used for bonding brackets without acid etching.[5,6] Hence, the bonding procedure consisted of pumicing the enamel surface for 10 seconds with flour pumice, followed by a rinse of 10 seconds with water. Each tooth was then wiped with a moist cotton roll to ensure that the bonding surface was not desiccated, and excess water was removed.[5,6] Then RMGIC adhesive paste was applied to the bracket base, and