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Microshear bond strength of Nano-Bond adhesive containing nanosized aluminum trioxide particles

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Abstract:

OBJECTIVES: The present study was conducted to evaluate the effect of nanosized aluminum trioxide (Al_2O_3) particles when added to the Nano-Bond adhesive system and its effect on the microshear bond strength of nanocomposite resin to dentin.

MATERIALS AND METHODS: A newly developed adhesive (Nano-Bond) and one type of light-cured resin restorative material (nanocomposite resin) were used in this study. The occlusal surfaces of extracted human molar teeth were ground perpendicular to the long axis of each tooth to expose a flat dentin surface. The adhesives were applied to the dentin surfaces according to manufacturers' instructions. The nanocomposite resin was then placed and light cured for 40 s. After immersion in water at 37°C for 24 h, the specimens were subjected to thermocycling before testing, and a microshear bond test was carried out. The recorded bond strengths (MPa) were collected, tabulated, and statistically analyzed. A one-way analysis of variance and Tukey's tests were used to test for significance between the means of the groups; statistical significance was assumed when the $P \leq 0.05$.

RESULTS: The mean microshear bond strength of the Nano-Bond adhesive system containing nanosized Al_2O_3 at a concentration of 2% was 23.15 MPa (Group B), which was significantly greater than that of the Nano-Bond adhesive system without additives (15.03 MPa, Group A).

CONCLUSIONS: These results indicate that nanosized Al_2O_3 added to the Nano-Bond adhesive system at a concentration of 2% increases the microshear bond strength.

Keywords:

Aluminum trioxide particles, Nano-Bond adhesive, shear bond strength

Introduction

Nearly half of all dental restorations fail within 10 years, and replacement of these failed restorations accounts for 50%–70% of all procedures in restorative dentistry.[1] Composites are popular filling materials because of their esthetics and direct-filling capabilities.[2-7] One main problem, however, is that composite tends to accumulate more biofilms than other restorative materials *in vivo*.[8,9] Biofilms at the restoration margins could produce acids and cause secondary caries, the main reason for restoration failure.[10,11]

From restorative dentistry, the use of bonding agents is known to improve the adhesion of composite resins. Bonding agents create a micromechanical interlock between the dentin collagen and resin by forming hybrid layers.[12]

Bonding agents adhere the composite restoration to the tooth structure to form a functional and durable interface.[13-15] Bonding agent compositions and bond strengths have been improved in previous studies.[16,17] Antibacterial adhesives are promising for combating bacterial infection and reducing recurrent caries at tooth-restoration margins.[18,19]

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Nanosized fillers, such as nanosized aerosol silica filler, were introduced to the field of bonding agents by means of nanotechnology. Nanofiller technology is claimed to increase adhesion to both the enamel and dentin and improves marginal integrity.[20]

Recently, quaternary ammonium dimethacrylate was synthesized and incorporated into resins to inhibit biofilm growth.[21,22]

Traditionally, micro/nanofillers have been introduced into epoxy resins to improve their mechanical performance, for example, silicon, titanium, and aluminum oxides. The use of nanosized aluminum trioxide (Al_2O_3) particles is one approach to improve the mechanical performance of adhesive materials. In these particulate-filled systems, binding at the inorganic filler/epoxy matrix interface has a great effect on the mechanical properties of the adhesive material. Dudkin *et al*.[23] demonstrated that the strength of the epoxy matrix was increased when reinforced by Al_2O_3 because of interactions between the active surface groups of the oxide nanoparticles and the functional groups of the epoxy matrix.[24]

However, whether the addition of filler particles improves the mechanical behavior of these adhesives still remains unclear since their mechanical properties rely on other factors that cannot be studied in isolation using commercial adhesive systems.[25]

The purpose of this study was to evaluate the effect of adding nanosized Al_2O_3 particles at a concentration of 2% to Nano-Bond adhesive on the microshear bond strength of nanocomposite resin to dentin.

Materials and Methods

One available type of adhesive system was used as the control (Nano-Bond adhesive; Pentron Clinical Technologies, USA; lot #183421). Nanosized Al_2O_3 particles at a 2% concentration were added to Nano-Bond adhesive; this and one type of nanofilled composite resin (Artiste Nanocomposite, Pentron Clinical Technologies; lot #182066-185215) were used in this study.

Twenty caries-free freshly extracted human molar teeth were collected to be used in this study. The teeth were cleaned by an ultrasonic scaler and stored in distilled water at 37°C before testing. A dentin slice approximately 1.0-mm thick was cut perpendicular to the long axis of each tooth from the upper middle coronal portion region using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) under water coolant. The occlusal surfaces of the slices were ground with up to 600-grit silicon carbide paper to expose a flat dentin surface.[26-29]

A dentin slices were divided into two main groups (ten each) according to the bonding agent containing nanosized Al_2O_3 particles at a 2% concentration. Group A was tested using the Nano-Bond adhesive system without additives, and Group B was tested using the Nano-Bond adhesive system containing nanosized Al_2O_3 particles at a 2% concentration.

Each dentin slice was acid etched using 37% phosphoric acid gel (Eco-Etch; Ivoclar Vivadent, Schaan, Liechtenstein, Swiss) for 15 s. Then, the dentin slices were rinsed with water spray and dried in an oil-free stream of air for 5 s. The adhesives were applied according to manufacturers' instructions. The adhesives were applied to the entire dentin surface and air-dried for 15 s. A gentle stream of dry air was applied to disperse the material into a thin, uniform, shiny surface, and before irradiation, three or four cylinders (internal diameter: 0.7 mm, height: 1.0 mm) of microbore Tygon tubing (R-3603, Norton Performance Plastic Co., Cleveland, OH, USA) were placed on the flat dentin at different locations. The adhesive was then light cured for 10 s with light-emitting diodes (BG Light Ltd., 4002 Plovdiv, Bulgaria; 430–490 nm).

After irradiation, the tubing was filled with nanofilled composite resin and then light cured for 40 s with the tip as close to the surface as possible. Curing radiometer equipment (LI-189 Li-Cor Inc., Lincoln, NE, USA) was used to ensure steady light intensity throughout the polymerization of all specimens. The specimens were stored under moist conditions at room temperature (23°C) for 1 h before removing the Tygon tubing.

The specimens were immersed in water at 37°C for 24 h, then subjected to thermocycling to simulate clinical thermal stress conditions before testing according to the guidelines set by the American National Standards Institute/American Dental Association[30] and International Organization for Standardization[31] for direct filling resins and dental adhesion.

All specimens were subjected to thermocycling by storing them alternately in water reservoirs at 5°C and 55°C, with the specimen staying in each reservoir for 30 s. This procedure was carried out for 500 cycles and controlled by a computer to simulate thermal stress.[32]

The resin cylinders were then subjected to the microshear bond test.[28] A diagram of the microshear bond test setup is shown in Figure 1. Each dentin slice with the resin cylinders was placed in the lower attachment of a Lloyd universal testing machine (model LRX plus II, Fareham, England) for microshear bond testing.

A thin wire (diameter, 0.20 mm) was looped around each resin cylinder, making contact with half of the

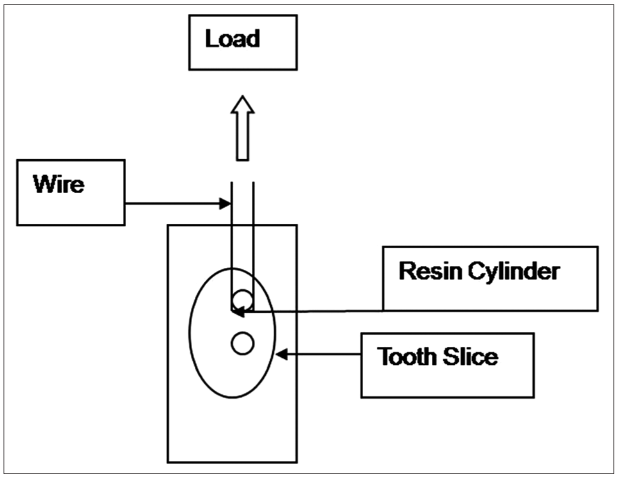

Figure 1: Diagram of the microshear bond test setup

cylinder base, and was placed as close as possible to the resin-dentin interface. A shear force was applied to each specimen at a crosshead speed of 0.5 mm/min until failure occurred. The resin-dentin interfaces of the specimens and the wire loops were aligned as straight as possible to ensure that the same shear orientation was maintained. The loads at failure were recorded, and the data were analyzed by one-way analysis of variance and Tukey's tests were used to test the significance of differences between the means of the tested materials, which were considered statistically significant when the $P \leq 0.05$.

Results

The mean percentages for the tested Nano-Bond adhesive system without additives and Nano-Bond adhesive system containing nanosized Al_2O_3 particles at a 2% concentration are presented in Table 1 and Figure 2.

The Nano-Bond adhesive system containing nanosized Al_2O_3 particles at a 2% concentration (Group B) showed a statistically significantly greater mean microshear bond strength (23.15 MPa) than that of the Nano-Bond adhesive system without additives (15.03 MPa, Group A).

The results of the microshear bond strength test showed a significant difference ($P < 0.05$) between Group B and Group A. The microshear bond strength was increased in the specimens containing nanoparticles of Al_2O_3.

Discussion

The major goals of using dentin bonding systems are to enhance the bonding strength between the resin and the tooth structure, increase the retention of the restoration, reduce microleakage across the dentin-resin interface, and dissipate occlusal stress.[33]

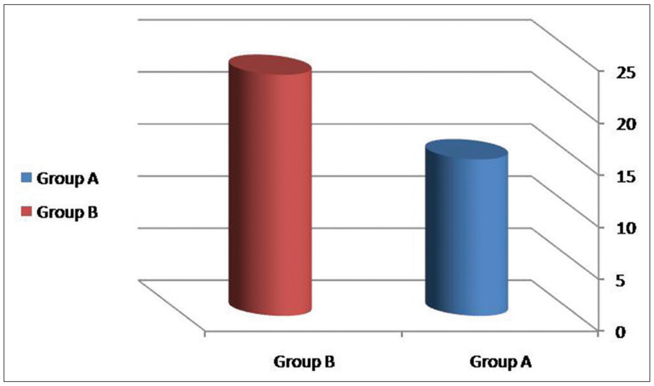

Figure 2: A bar chart of the mean microshear bond strengths (MPa) of the tested Nano-Bond adhesive system groups

Table 1: Comparison between mean microshear bond strength in (MPa) of the tested Nano-Bond adhesive system groups

Material	Mean (MPa)	SD	*P*
Nano-Bond without additives (Group A)	15.03	1.2^{b}	<0.001*
Nano-Bond with 2% Al_2O_3 (Group B)	23.15	1.1^{a}	

*Significant at $P \leq 0.05$. Means with different letters are statistically significantly different according to Tukey's test. SD – Standard deviation

The adhesive layer acts as an elastic intermediate layer (elastic cavity wall) between the cavity walls and the adjacent composite. This layer could resist polymerization shrinkage stress from resin composites and absorbs shocks produced by occlusal loads and thermal cycling.[34]

According to many investigators,[35] the use of filled adhesive resin increases its mechanical properties and improves the marginal and internal seals of composite restorations.

These adhesives may be categorized as mild or strong adhesives depending on their pH and therefore their etching potential.[34] If the adhesive's capacity dissolves the smear layer is limited, the bond strength to dentin with a thick smear layer may be reduced.[36]

The shear bond strength test has been widely used, mainly because of its relative simplicity when compared with the tensile bond strength test, in which it is difficult to align the specimen in the testing machine without creating a deleterious stress distribution.[37,38] Advantages of shear tests include the specimen preparation and simple test protocols.[39]

A new test method using specimens with reduced dimensions has been advocated by some authors[40-42] as a substitute for the conventional shear test: this called microbond or microshear bond strength test. According to these authors, this test would allow for the testing of small areas of material, thus permitting a regional mapping or depth profiling of different substrates and preparing multiple specimens from the same tooth.

The present study used nanosized Al_2O_3 particles at a 2% concentration in the adhesive because the antimicrobial activity of aluminum nanoparticles is due to the release of metal ions and because aluminum ion nanoparticles attach to the surface of bacteria because of their surface charge; the charge of the bacterial surface is negative while that of the aluminum nanoparticles is positive at the pH studied.[43]

The present study showed that the microshear bond strength of Nano-Bond adhesive containing nanosized Al_2O_3 particles at a 2% concentration was greater than that of the Nano-Bond adhesive system without additives. Factors contributing to this effect may include the fact that the number of metal–oxygen (Me-O) bonds increases with the release of residual water and organic solvent during the early stages of drying.[44] Therefore, a further increase in cross-linking and Me-O bonding occurred during the curing regimen because the release of water and solvent from the adhesive is controlled by the cure time[45] and thus increased the bond strength to dentin.

Conclusions

The addition of nanosized Al_2O_3 particles at a concentration of 2% to Nano-Bond adhesive increased the microshear bond strength.

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Conflicts of interest

There are no conflicts of interest.

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