EVALUATION OF A NEW NANO-FILLED RESTORATIVE MATERIAL FOR BONDING ORTHODONTIC BRACKETS

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Aim: *To compare the shear bond strength of a nano-hybrid restorative material, Grandio (Voco, Cuxhaven, Germany), to that of a traditional adhesive material (Transbond XT; 3M Unitek, Monrovia, CA, USA) when bonding orthodontic brackets.* ***Material and methods:*** *Forty teeth were randomly divided into 2 groups: 20 teeth were bonded with the Transbond adhesive system and the other 20 teeth with the Grandio restorative system, following manufacturer's instructions. Student* t *test was used to compare the shear bond strength of the 2 systems. Significance was predetermined at* $P \leq .05$*.* ***Results:*** *The* t *test comparisons (*$t = 0.55$*) of the shear bond strength between the 2 adhesives indicated the absence of a significant (*$P = .585$*) difference. The mean shear bond strength for Grandio was 4.1 ± 2.6 MPa and that for Transbond XT was 4.6 ± 3.2 MPa. During debonding, 3 of 20 brackets (15%) bonded with Grandio failed without registering any force on the Zwick recording. None of the brackets bonded with Transbond XT had a similar failure mode.* ***Conclusions:*** *The newly introduced nano-filled composite materials can potentially be used to bond orthodontic brackets to teeth if its consistency can be more flowable to readily adhere to the bracket base.*
World J Orthod 2007;8:8–12.

Since the introduction of the acid-etch bonding technique, the concept of bonding various resins to enamel has developed applications in all fields of dentistry, including the bonding of orthodontic brackets. There are a number of factors that can potentially contribute to the bond strength between enamel and the orthodontic bracket, including the type of enamel conditioner, acid concentration, length of etching time, composition of the adhesive, bracket base design, the bracket material, the oral environment, as well as the skill of the clinician.[1–14]

In 1955 Bowen[15] used an epoxy resin as a binder to particles of fused silicon dioxide and porcelain powder, in an attempt to develop thermal expansion characteristics equal to that of tooth structure. Bowen[16] also proposed that a coupling agent, such as a surface-active co-monomer, should be used to act as a link between the polymeric binder and the mineral content on the tooth surface. Phillips[17] suggested the addition of

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inorganic inert fillers to conventional polymethacrylate resin to improve its mechanical properties and to further reduce thermal expansion. He was the first to use the term "composite resin" to describe this improved adhesive/filling material.

In general, a resin-based composite is defined as a 3-dimensional mixture of 2 or more chemically different materials that have distinct interfaces. Such a combination is described as incorporating 3 phases[18]:

1. *Organic phase:* This phase is essentially the matrix for the system in which the filler particles are suspended. The most commonly used agents for the matrix are Bisphenol A glycidyl dimethacrylate (Bis-GMA), modified Bis-GMA, urethane dimethacrylates (UDMA), triethylene glycol dimethacrylate (TEG-DMA), and diluents.
2. *Interfacial phase:* This phase contains the coupling agents, mostly silanes, that facilitate the bonding between the inorganic fillers and the organic matrix.
3. *Inorganic phase:* The inorganic filler particles are added to the organic matrix and their bonding is mediated by the coupling agent. Inorganic filler particles help provide strength to the composite resin system.

More recent advances in the performance of these materials included the introduction of flowable composite resins and also condensable ones that behave like amalgams clinically. These composite resins are characterized by a higher filler load, improved filler matrix interface, and improved handling properties.[19]

With the introduction of newer composite resins, various classification systems have been used to categorize them. The first such classification was introduced by Lutz and Phillips[18] in 1983 and was based on the average size of the filler particles, manufacturing techniques, and the chemical composition of the filler particles.[20] One classification scheme was based on filler particle size and new terms were introduced, including macrofillers (10 to 100 microns), midifillers (1 to 10 microns), minifillers (0.1 to 1 micron), and microfillers (0.01 to 0.1 micron). In general, the difference in filler size influences the properties of the composite, eg, the larger the filler particle size the harder and more resistant to wear the composite will be, but the more difficult to polish. On the other hand, composites with micro fillers give the best surface polish but should not be used in high-stress areas.

Further improvements to the composite resins were accomplished through altered filler packing, higher filler levels, and hybrid filler particles. These changes improved the mechanical properties, reduced coefficient of thermal expansion, produced radio-opaque materials, reduced polymerization shrinkage, and improved esthetics.[21] Reducing polymerization shrinkage has been a key demand in the development of resin-based restorative materials. Since shrinkage occurs mostly in the resin matrix, it has been suggested that an effective method to control shrinkage is to reduce the resin content of the composite. This concept led to the introduction of nano-hybrid restorative materials using nanotechnology.

Polymer nanocomposites are a new class of materials with a unique internal structure and properties and contain nano fillers that are 0.005 to 0.01 micron in size. Geraldeli and Perdigao[22] found that nano-filled composites had a marginal seal in enamel and dentin comparable to total-etch adhesives. Furthermore, Dabanoglu et al[23] found that a high filler degree combined with small particle dimensions reduced abrasion by up to 50% compared to composites of lower filler degree or those with organic (pre-polymerized) fillers. Since these materials have better marginal seals to enamel, their use in bonding orthodontic brackets should be explored. This study compared the shear bond strength (SBS) of a nano-hybrid restorative material (Grandio; Voco, Cuxhaven, Germany) and a traditional adhesive material (Transbond XT; 3M Unitek, Monrovia, CA, USA) when bonding orthodontic brackets.

MATERIAL AND METHODS

Teeth

Forty freshly extracted human molars were collected and stored in a solution of 0.1% (weight/volume) thymol. The criteria for tooth selection included: *(1)* intact buccal enamel, not subjected to any pretreatment chemical agents, such as hydrogen peroxide; *(2)* no cracks due to the pressure of the extraction forceps; and *(3)* no caries. The teeth were cleansed and then polished with a pumice slurry and rubber prophylactic cups for 10 seconds. All teeth were thoroughly washed and dried.

Brackets used

Forty maxillary right central incisor brackets (Victory Series; 3M Unitek) were used. The average surface area for the bracket base was 12.2 mm^2. The surface area was the average obtained from measuring 5 brackets.

Bonding procedure

The 40 teeth were randomly divided into 2 groups: group 1 (Transbond XT Adhesive System) comprised of 20 teeth, which were etched for 15 seconds with 35% phosphoric acid, washed with a water spray for 10 seconds, dried to a chalky white appearance, and the sealant applied (the adhesive was then applied to the bracket base and placed on the tooth and light cured with a halogen light for 20 seconds); and group 2 (Grandio Restorative System). The same protocol as in group 1 was used to etch and seal the teeth in group 2. The nanofilled composite was applied to the bracket base, and the brackets were then placed on the teeth and light cured for 20 seconds.

During bonding with both systems, a 300-g force was applied on each bracket to ensure a uniform adhesive thickness using a force gauge (Correx, Bern, Switzerland).

Shear bond strength testing

The teeth were embedded in acrylic in phenolic rings (Buehler, Lake Bluff, IL, USA). A mounting jig was used to align the facial surface of the tooth to be perpendicular with the bottom of the mold and its labial surface parallel to the force during the shear strength test. Within 30 minutes from the initial bonding, an occlusogingival load was applied to each bracket, producing a shear force at the bracket-tooth interface. This was accomplished by utilizing the flattened end of a steel rod attached to the crosshead of a Zwick Universal Testing Machine (Zwick GmbH & Co, Ulm, Germany). A computer electronically connected to the testing machine recorded the results of each test in megapascals (MPa). Shear bond strengths were measured at a crosshead speed of 5mm/min.

Statistical analysis

Descriptive statistics, including the mean, standard deviation, and minimum and maximum values, were calculated for the 2 test groups. Student *t* test was used to compare the shear bond strengths of the 2 adhesives. Significance was predetermined at $P \leq .05$.

RESULTS

Shear bond strength comparisons

The results of the *t* test comparisons (t = 0.55) of the shear bond strength between the 2 adhesives indicated the absence of significant (P = 0.585) differences (Table 1). The mean shear bond strength for Grandio was 4.1 ± 2.6 MPa and that for Transbond XT was 4.6 ± 3.2 MPa.

Bracket failure rate

During debonding, 3 of 20 brackets (15%) bonded with Grandio failed without registering any force on the Zwick recording. The 3 brackets were excluded

Table 1 Descriptive statistics of the shear bond strength (in MPa) and the results of the Student *t* test comparisons between Grandio and Transbond XT adhesives

Group	N	Mean	SD	Range
Grandio	17	4.1	2.6	0.2–9.3
Transbond XT	20	4.6	3.2	0.4–11.1

N, sample size; SD, standard deviation; $t = 0.55$; $P = .585$.

from the calculations. None of the brackets bonded with Transbond XT had a similar failure mode.

DISCUSSION

Manufacturers have continuously introduced new adhesives in operative dentistry that are more reliable, ie, stronger, adhere better, less prone to leakage at the margins, and/or easier to handle. As new adhesives, composite resins, and bonding techniques are introduced, orthodontists adopt some of these innovations and add them to their armamentarium, including the use of acid-etching primers, stronger adhesives, etc.

It has been suggested that the newly introduced restorative material Grandio has extremely high filler degree and spherical nanoparticles that reduce the organic matrix content and give it a hard surface, compared to conventional composites.[23] This quality would also improve its wear and abrasion resistance, as well as enhance the marginal seal to enamel.[22]

The present findings indicate that the new restorative system Grandio achieves shear bond strength values that are not significantly different from those obtained with Transbond XT. On the other hand, the consistency of the adhesive paste was fairly thick and did not flow readily. As a result, the paste needed to be forcibly pushed into the retention pad of the bracket base for it to adhere before being placed on the tooth. This difficulty in handling the material might explain why 3 out of 20 brackets (15%) failed to register any force value on the Zwick machine recording. As a result, it is suggested that, for orthodontic purposes, the manufacturer should consider reformulating the composition of Grandio to produce a paste with a more flowable consistency that can readily penetrate the mesh of the bracket base. When such modifications are introduced, Grandio should be considered a potentially useful adhesive for bonding orthodontic brackets.

CONCLUSION

New materials that are introduced in operative dentistry can potentially have orthodontic applications. One such material is Grandio, a nano-filled restorative material. With modifications in their flow characteristics, these materials can potentially be used to bond orthodontic brackets to teeth.

REFERENCES

1. Surmont P, Dermont L, Martens L, Moors M. Comparison in shear bond strength of orthodontic brackets between five bonding systems related to different etching times: An in vitro study. Am J Orthod Dentofacial Orthop 1992;101:414–419.
2. Britton JC, McInnes P, Weinberg R, Ledoux WR, Retief DH. Shear bond strength of ceramic orthodontic brackets to enamel. Am J Orthod Dentofacial Orthop 1990;98:348–353.
3. Newman GV. Adhesion and orthodontic plastic attachments. Am J Orthod 1969;56:573–578.
4. Newman GV, Snyder WH, Wilson CW. Acrylic adhesives for bonding attachments to tooth surfaces. Angle Orthod 1968;38:12–18.
5. Retief DH, Dreyer CJ, Gavron G. The direct bonding of orthodontic attachments to teeth by means of an epoxy resin adhesive. Am J Orthod 1970;58:21–40.
6. Retief DH. A comparative study of three etching solutions: Effects on contact angle, rate of etching, and tensile bond strength. J Oral Rehabil 1974;1:381–389.
7. Mulholland RD, DeShazer DO. The effect of acidic pretreatment solutions on the direct bonding of orthodontic brackets. Angle Orthod 1968;38:236–243.
8. Mizrahi E, Smith DC. Direct cementation of orthodontic brackets to dental enamel. Br Dent J 1969;127:371–375.
9. Zachrisson BU. Cause and prevention of injuries to teeth and supporting structures during orthodontic treatment. Am J Orthod 1976;69:285–300.
10. Newman GV. Epoxy adhesives for orthodontic attachments: Progress report. Am J Orthod 1965;51:901–902.
11. Thanos CE, Munholland T, Caputo AA. Adhesion of meshbase direct bonding brackets. Am J Orthod 1979;75:421–430.
12. Gorelick L. Bonding metal brackets with a self-polymerizing sealant-composite: A 12-month assessment. Am J Orthod 1977;71:542–553.
13. Zachrisson BU, Brobakken BO. Clinical comparison of direct versus indirect bonding with different bracket types and adhesives. Am J Orthod 1978;74:62–77.
14. Wickwire NA, Rentz D. Enamel pretreatment: A critical variable in direct bonding systems. Am J Orthod 1973;64:499–512.
15. Bowen RL. A new restorative material. J Dent Res 1955;34:738.
16. Bowen RL. Development of an adhesive restorative material. In: Adhesive Restorative Dental Materials II. Univ of Virginia Workshop, Public Health Service Publication No. 1494. Washington DC: US Government Printing Office, 1966:225–231.
17. Phillips RW. Recent improvement in dental materials that the operative dentist should know. J Am Dent Assoc 1966;73:84.
18. Lutz F, Phillips RW. A classification and evaluation of composite resin systems. J Prosthet Dent 1983;50:480–488.
19. Lang BR, Jaarda M, Wang RF. Filler particle size and composite resin classification systems. J Oral Rehabil 1992;19:569–584.
20. Ferracane JL. In vitro evaluation of resin composite, structure, property relationships, development of assessment criteria. Trans Acad Dent Mater 1989;2:6–35.
21. Schedle A, Franz A, Rausch-Fan X, et al. Cytotoxic effect of dental composites, adhesive substances, compomers and cements. Dent Mater 1998;14:429–440.
22. Geraldeli S, Perdigao J. Microleakage of a new restorative system in posterior teeth. J Dent Res 2003(special issue A): 126 (www.dentalresearch.org).
23. Dabanoglu A, Kunzemann KH, Hickel R, Korary F. Three body wear resistance of resin composites. EFCD Conference, Munich, 2003.