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Research Article

Comparison of the Bond Strength of Conventional and Bulk-Fill Resin Composites to Healthy and Periodontally-Involved Dentin and their Chemical Properties

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Abstract

Aim: The present study aimed to compare the bond strength of conventional and bulk-fill resin composites to healthy and Periodontally-involved dentin and their chemical properties.

Method and Materials: In the present experimental study, 6 normal molars and another 6 molars suffering from chronic periodontitis were collected and each group was divided into two subgroups: A group was restored with conventional composite (Herculite XR, Kerr) in an incremental layering technique and another one was restored with bulk-filled composite (Tetric N ceram, Ivoclar). Ten beams from each group and microtensile bond strength test were evaluated by a universal testing machine. To evaluate chemical changes, 10 dentinal disks with 1 mm thickness from CEJ of normal teeth and teeth suffering from chronic periodontitis were prepared for the FTIR test. Data was analyzed using the one-way ANOVA and Tukey's test.

Results: Microtensile bond strength of normal dentin was more than the Periodontally-involved dentin. There were significant differences in microtensile bond strength between normal dentin filling with bulk-filled composite and other groups (P = 0.000).

In the FTIR analysis, the highest difference was between normal dentin and Periodontally-involved dentin in mineral content that significantly decreased in periodontally-involved dentin.

Conclusion: Bond strength of bulk-filled composites was higher than conventional composites. As a result of decreasing mineral contents, the bond strength decreased in the periodontally-involved dentin.

Keywords: *Bulk-Filled Composites; Microtensile Bond Strength; Periodontal Diseases; FTIR*

Introduction

Photopolymerizable resin-based composites (RBC) have been considerably modified since their introduction. Continuous efforts have been made to improve operating techniques for developing its physical and mechanical properties. However, complications of the polymerization shrinkage stress are still main issues in their application [1,2] leading to the microleakage, marginal gap formation, recurrent caries, pulpal irritation, cuspal deflection and tooth crackes [3,4] and even the tooth loss [5].

Various strategies have been developed to reduce restorative complications in direct posterior composite restoration. They include the improvement of materials (new resin composites with modified monomers such as ormocer, silorane, patended UDMA) [6] and clinical procedures (incremental layering technique, the use of a flowable lining layer and the modulation of the photoinitiation mechanism).

The incremental technique is a standard protocol for placement of resin composites in cavity preparations exceeding 2 mm [1]. The resin composite restoration has to be cured in increments to prevent clinical failures from a non-optimally cured resin composite and decrease the elution of non-reacted monomers [7]. However, this technique has some disadvantages such as the time consuming and the risk of incorporating voids or contamination between increments [3,8]. The clinicians are still seeking for easier and quicker composite restorations with less shrinkage [1].

A new kind of material, ''bulk-fill'', has had a vast popularity among dental practitioners and it is claimed that it can be applied at a single 4-mm layer with low shrinkage stress [3,9] because of higher translucency and modifications in the filler content and/or the organic matrix [3,10].

Modified monomer (patented urethane dimethacrylate) caused slower modulus development leading to the stress reduction without any decreased conversion rate [3,11,12]. In addition, the incorporation of a potent initiator system such as Ivocerin enhances the polymerization [13].

There is insufficient literature on all their aspects. On the other hand, the adequate adhesion to dentin and cementum is an important issue in composites that usually have no proper bond strength compared with enamel [14]. The attachment loss in the periodontitis disease is a reason why a tooth's root is exposed to the oral environment [15].

Periodontitis is an inflammatory disease which irreversibly distracts tooth supporting tissues [16,17]. The severity and degree of this destructive disease depend on the host interaction and microorganism [16]. Studies indicates that the reduction of extracellular collagen is the main problem in chronic periodontitis and it occurs by collagenase and matrix metalloproteinase enzymes. Neutrophils, which immigrate to connective tissues, release this enzymes [18]. They may also affect mechanical properties of tooth dentin. Some studies evaluated the root dentin microhardness in normal dentin and the dentin suffering from periodontitis and found the smaller microhardness in dentin that was exposed to periodontal diseases [19-21].

Since bulk-fill composites lower the shrinkage stress and the presence of many patients in the elderly society with chronic periodontitis and cervical lesions with compromised bond strength, the present study evaluated chemical feathers of periodontally affected dentin and microtensile bond strength of bulk-fill composites to cervical dentin in a tooth suffering from chronic periodontitis.

Materials and Methods

Microtensile bond strength

In the present pilot experimental study, 6 extracted sound human third molar without any crack, restoration and periodontal disease and 6 extracted sound human third molar in patients with generalized chronic periodontitis disease were stored in thymol solution at 4°C for no longer than a month.

After removing residual periodontal tissues, dentinal surface was obtained just from cementoenamel junction using a diamond disk (Diamant Gmbh, D and Z, Goerzallee, Berlin, Germany). Samples were mounted and exposed dentin surfaces were polished by 600 grit silicon paper for the Microtensile test. Dentin surfaces were etched with 37% phosphoric acid (Kerr, Orange, Italia) for 15s. After rinsing for 15 seconds, the excessive water was removed by absorbent paper without dentin dehydration. Afterwards, OptiBondTM Solo Plus (Kerr, Orange, CA, USA) was applied according to the manufacturer's instruction and light-activated for 20 seconds by the light emitting diode (1200 mW/cm^2, Bluephase C8, Ivoclar Vivadent, Schaan, Liechtenstein). The samples were then placed in mold; and each group was divided into two subgroups according to composite types.

In one of them, the conventional composite, Herculite XR (Kerr, Orange, italia), was inserted in 4m layer by incrementally 2 mm layer (according to manufacturer's instruction); and each layer was light cured for 40 seconds in a continuous mode at a light intensity of 1200 mW/cm^2. In another group, the bulk-filled composite (Tetric N-Ceram Bulk fill, Ivoclar vivadent, Schaan, Liechtenstein) was inserted in 4mm layer (according to manufacturer's instruction) and light cured for 40 seconds. The mold was removed after curing.

The research groups were thus defined as follow:

A. Healthy teeth/Herculite composite
B. Healthy teeth/Bulk-filled composite
C. Periodontally-involved teeth/Herculite composite
D. Periodontally-involved teeth/Bulk-filled composite

Specimen were longitudinally sectioned into 2 axes (mesiodistal and buccolingual) across the bonded interface with cutting machine CNC (NEMO, IRAN) to create 10 beams for each group in order to obtain sticks with a sectional area of approximately 1*1 mm. The sticks attached with cyanoacrylate adhesive gel to a caliper; and the test was performed in a universal testing machine (SANTAM, Iran) at a crosshead speed of 1.0 m/minute until the fracture.

The failures were classified as adhesive, cohesive in dentin, cohesive in resin, or mixed through an optical stereomicroscope observation with 50 x magnification. Table 1 shows specifications of applied materials for restorative procedures.

Material	Major components	Manufacturer
Tetric® NCeram	Bis-GMA, Bis-EMA, UDMA, barium aluminium silicate glass, Isofiller, ytterbium fluoride, spherical mixed oxide, camphorquinone plus an acyl phosphine oxide, dibenzoyl germanium derivative, 80% filler	Ivoclar vivadent, Schaan, Liechtenstein
Herculite XR	Uncured Methacrylate Ester Monomers Non-hazardous inert mineral fillers, non-hazardous activators and Stabilizers	Kerr, Orange, italia
OptiBond™ Solo Plus	Bis-GMA, HEMA, glycerol phosphate dimetacrylate (GPDM), sodium fluorosilicate, initiator, ethanol, water	Kerr, Orange, CA, USA
Acid Etch	Phosphoric acid 37%	Kerr, Orange, italia

***Table1:** Materials used in restorative procedures.*
Bis-GMA: Bisphenol A Diglyceryl Ether Dimethacrylate; HEMA: Hydroxyethyl Methacrylate; UDMA: Urethane Dimethacrylate; Bis-EMA: Bisphenol A Polyethylene Glycol Diether Dimethacrylate.

FTIR

In the present study, 10 sound human extracted molar teeth with no periodontal problems and 10 sound human teeth, which were extracted due to severe chronic periodontitis diseases, were collected after removing residual tissue tags stored in 0.1% thymol solution until they were required for examination.

Teeth were cut from CEJ by CNC cutting machine (NEMO, Iran); and dentin discs with 1 mm thickness were prepared. Samples were placed in a desiccator for drying and they were then grinded and the spectroscopy was done by a spectroscope machine (Nicolet 380, USA). The absorption peak was measured in phosphate (900 - 1200 cm^{-1}), amid (1600 – 1700 cm^{-1}) and carbonate (872 cm^{-1}).

Statistical analysis

Data was analyzed using the one-way ANOVA test and Tukey's test (α = 0.05) after evaluating the normal data distribution by Kolmogorov–Smirnov test.

Result

Table 2 presents the mean microtensile and respective standard deviation for all groups.

Groups	Number	Mean (N)	Standard Deviation
A: Healthy teeth/Herculite	10	11.66^{b}	5.41
B: Healthy teeth/Bulkfilled	10	17.95^{a}	7.56
C: Periodontal involved teeth/ Herculite	10	8.97^{b}	4.19
D: Periodontally involved teeth/Bulkfilled	10	9.50^{b}	4.04

Table 2: *The mean microtensile value and their standard deviation.*
The difference between groups showed with letter.

The highest mean of microtensile value was observed in group B (healthy teeth/Bulk-filled) and the lowest mean of microtensile value was observed in group C (Periodontally-involved teeth/Herculite). The mean microtensile bond strength value was significantly different between groups. (P = 0.000) Tukey's test indicated that despite statistical significant difference between group B (healthy teeth/Bulk filled composite) and other groups, there was no significant difference between other groups. The adhesive failure mode was mostly observed in all groups (Table 3).

Experimental groups	Adhesive	Cohesive	Mixed
Healthy teeth/Herculite	8	0	2
Healthy teeth/Bulk-filled	9	0	1
Periodontally involved teeth/ Herculite	8	1	1
Periodontally involved teeth/ Bulk-filled	10	0	0

Table 3: *Mode of failure in experimental groups.*

The highest difference was seen between healthy and periodontally-involved teeth in mineral content according to the FTIR analysis. In teeth with periodontal disease, the mineral content (carbonate and phosphate) was strongly lower than the healthy dentin. The organic content (amid) was almost equal in both groups (Figure 1).

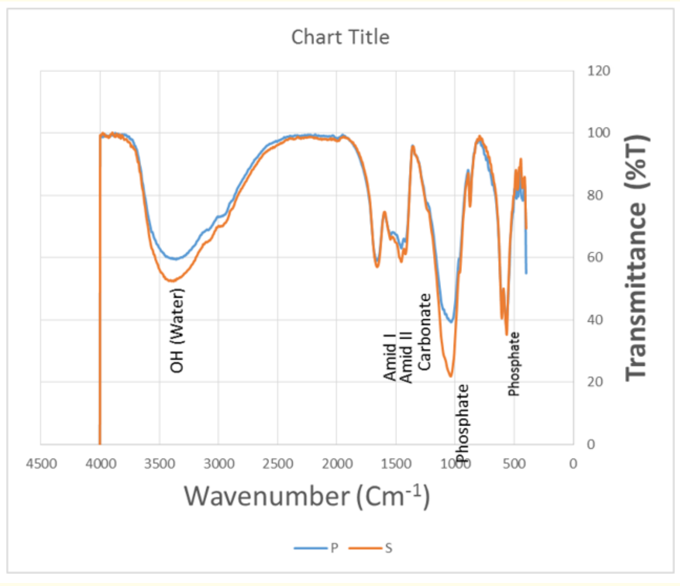

Figure 1: *Comparison the spectra of healthy and periodontally involved dentin.*
(The spectrum of each dentin is calculated from the mean of the recorded intensities for each wave number of samples of that group).

Discussion

In the present *in-vitro* study, the microtensile bond strength of bulk-filled composite was higher than the conventional one both in sound tooth and tooth suffering from periodontal disease that rejected the null hypothesis of research.

Van Ende A., *et al.* and Roggendorf MJ., *et al*. who applied the bulk-fill technique, found a good interfacial adaptation and satisfactory microtensile bond strength to cavity-bottom dentin in high C-factor cavities [22,23]. A clinical trial study with a 36-month follow up evaluation of a bulk-fill restorative resin compared to the nano-fill indicated better clinical performance according to the marginal discoloration and marginal adaptation [24]. In the present study, the bulk-fill composite also had better bond strength than conventional composites. In bulk-filled materials, there is a polymerization modulator (patented urethane di-methacrylate) that results in a slower modulus development allowing for stress reduction without decreasing conversion rates. In the investigation, we used Tetric N-ceram bulk-filled composite containing Ivocerin (bis-(4-methoxybenzoyl) diethyl-germane) photo initiators. This germanium based photoinitiator can absorb more light in the range of 400 - 450 nm. Photoactivation of Ivocerin forms at least two radicals that initiate the radical polymerization, but only a radical can be created in camphorquinone/amine systems, which are present in the conventional material, resulting in less efficient initiation of polymerization [25]. It can allow polymerization in deeper increments without compromising physical properties of the resin composite. This composite also has a specially-patented filler that acts as a shrinkage stress reliever. The manufacturer of this material claimed that due to the low elastic modulus of this patented filler, the shrinkage stress reliever slightly expanded during the polymerization and played like a spring amongst glass fillers with a higher modulus of elasticity. Tetric N-Ceram bulk fill has prepolymerized fillers that attenuate the elastic modulus containing a translucent filler and matrix to pass light through the material. Finally, the polymerization shrinkage and contraction stress in Tetric N-Ceram bulk-fill resin composite are decreased during the polymerization leading to a good marginal seal that allows increments of up to 4 mm to be inserted [1,26].

All of above-mentioned cases indicate that how tetric N-ceram had higher micro tensile bond strength than Herculite XR composite resin restoration material. The research result indicated that the micro tensile bond strength of both bulk-filled and conventional one in periodontal-involved teeth was lower than teeth that was not suffering from the periodontal disease.

Mechanical and chemical properties of root dentin exposed to the periodontal-disease may present significant changes due to differences in the microbial flora involved in cervical dentin caries, thereby affecting the dentin bond strength in cervical areas [20]. The dentin micro-hardness may be different in normal and periodontal-involved teeth because of modifications in organic and inorganic structures of teeth exposed to periodontal diseases. These alterations affect the polymerization shrinkage and bond strength and it can be proven by the FTIR test in the present study.

FTIR is a useful tool for molecular identification and follow-up of chemical reactions. Since it was assumed that there were differences in chemical structures of healthy teeth and teeth suffering from chronic periodontal disease, teeth of both groups were evaluated by the FTIR.

In the present study, the FTIR analysis indicated that healthy dentin and dentin suffering from chronic periodontal disease were different in mineral content (two groups of phosphate and carbonate); and the mineral content in teeth involved with chronic periodontal disease was lower than the healthy teeth.

There was also changes in amounts of water in the dentin structure, but changes in the water content were not very reminiscent due to our study on the drawn teeth. Studies generally indicates that the lower volume of mineral content in dentin was replaced by water and thus the dentin with periodontal disease had a higher volume of water than the healthy dentin, so that the healthy ivory had an abundance of about 14%, but it varied from 14% to 53% in a dentin with periodontal disease [27,28].

Various studies indicated that the dentin mineral content played a very important role in the bond strength of composite to dentin [29-31].

It can indicate that the lower bond strength of periodontal-involved teeth to composite resin restoration materials can be related to their chemically changes as seen in results of the present study. Lower mineral content in teeth with periodontal involvement indicated lower bond strength to resins material than the not-involved one.

Conclusion

The following conclusion can be drawn according to limitations of the present study:

1. Bond strength in bulk-filled composites was more than conventional composites.
2. As a result of decreasing the mineral content, the lower bond strength was seen in periodontally-involved dentin.

The bulk-fill composite materials may be very useful due to their advantages in applied technique and they may improve the bond strength. However, further studies especially *in vivo* are necessary to verify the improved clinical performance of bulk-fill composite resins.

Conflict of Interest

No potential conflict of interest was reported in the present study.

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