Original Article

Comparison of Push-Out Bond Strength of Two Bulk-Fill and One Conventional Composite to Intracanal Dentin in Severely Damaged Primary Anterior Teeth

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Abstract

Objectives: This study sought to compare the push-out bond strength of two bulk-fill and one conventional composite to intracanal dentin in primary anterior teeth.

Materials and Methods: This in vitro, experimental study was conducted on 39 primary anterior teeth, which were randomly divided into three groups. After cleaning and shaping, the root canals were filled with Metapex in such a way that after the application of 1mm light-cure liner on top of it, the coronal 3mm of the canal remained empty for composite post space. Z250 conventional composite was used in group 1 and SonicFill and Filtek bulk-fill composites along with Single Bond 2 were used in groups 2 and 3, respectively. The samples were subjected to thermocycling. One-millimeter thick sections were made of the mid-root and subjected to push-out bond strength test. Mode of failure was determined under a stereomicroscope at ×25 magnification. The data were analyzed using one-way ANOVA.

Results: The mean (±standard deviation) push-out bond strength was 11.40±4.23MPa, 10.94±6.69MPa and 8.79±4.12MPa in the conventional, SonicFill and Filtek groups, respectively. The difference in this regard among the three groups was not statistically significant (P=0.397).

Conclusions: Based on the results, bulk-fill composites, similar to conventional types, can be successfully used for the fabrication of composite intracanal posts in primary teeth to decrease the treatment time in children.

Keywords: Composite Resins; Dentin; Tooth, Deciduous

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INTRODUCTION

Despite the decreased prevalence of dental caries in the recent years, it is still a common chronic disease of the childhood [1]. Early childhood caries is a threat to primary dentition. It primarily affects the cervical third of the maxillary incisors and then the primary first molars [2,3]. Due to the small size of crown of incisor teeth, progression of caries causes extensive destruction of the crown [4] and results in an unesthetic appearance, which may negatively affect the behavioral development and personality of children [5].

Insufficient residual tooth structure compromises the effective bond of tooth-colored restorative materials to the crown. In such cases, use of intracanal posts can increase retention. Fabrication of post and core restorations is sometimes necessary to obtain adequate retention, further stabilize the composite crown and resist masticatory forces. Therefore, fabrication of intracanal posts is recommended after pulpectomy of such teeth [6-9]. Several types of posts are available for use in pediatric dental procedures including composite posts [10-14], orthodontic wires [15,16], prefabricated metal posts [17], nickel-chromium posts with retentive forms [18], biological posts [10,12,19] and fiber-reinforced posts [1,20]. Irrespective of the type of post, its length must be one-third of root length in order not to interfere with the development of permanent successors [21].

Composite posts are commonly fabricated in primary teeth by pushing the composite resin into the canal and compressing it to achieve a tapered intracanal post [21]. The incremental technique is often used for the application of composite resin in order to minimize the stress due to polymerization shrinkage and achieve optimal mechanical properties [22-24]. However, this technique has some drawbacks as well including the possibility of gap formation or contamination in-between the increments, bond failure between layers, difficult application in small cavities with limited access and being time consuming because of separate application and curing of increments [25]. At present, restorative materials with fewer procedural steps and shorter working time are highly preferred by clinicians. Recent advances in this respect led to the introduction of bulk-fill composites. Bulk application of these composites appears to have overcome the limitations of incremental technique [26-28]. Bulk-fill composites have easier application and decrease the treatment time [29]. They are especially useful for composite restorations in uncooperative children [30]. Bulk-fill composites have lower filler content and larger filler particles (>20μ) compared to conventional composites [30]. Lower filler content decreases hardness [31] with no change in the suggested curing time (by use of a light curing unit). In other words, the same level of light exposure required for incrementally applied conventional composites would suffice for bulk-fill composites applied in twice the thickness of conventional composite increments [32]. Bulk-fill composites are more translucent for the blue light than the conventional composites. Several strategies have been proposed to increase the curing depth such as decreasing the amount of filler and their larger size and subsequently decreased surface between fillers and organic matrix and application of a more efficient photoinitiator compared to camphorquinone [32].

This study sought to assess and compare the push-out bond strength of intracanal posts fabricated with two bulk-fill and one conventional composite to intracanal dentin in primary anterior teeth. In case of achieving adequate bond strength, bulk-fill composites can be used as an alternative to conventional types due to faster and simpler application, which is an advantage in treatment of children.

MATERIALS AND METHODS

The study protocol was approved by the Human Ethics Review Committee of the School of Dentistry, Tehran University of Medical Sciences (code: IR.TUMS.REC.1394.319). This in vitro, experimental study was conducted on 39 primary anterior teeth with severe caries, sound roots and without obvious root resorption, which were extracted since the parents did not consent to restorative treatment. The parents consented to the use of extracted teeth in this study. According to Memarpour et al, [9] and using one-way ANOVA Power Analysis, the minimum sample size for each of the three groups was calculated to be 13 teeth via Minitab software taking into account $\alpha=0.05$, $\beta=0.2$, mean difference=50 and standard deviation=40.4. The teeth were stored in saline until the experiment. Prior to the study, the teeth were immersed in 0.5% chloramine T solution and refrigerated at 4°C for one week; then they were stored in saline. Tooth crowns were cut by high speed hand piece (Pana Max, Tokyo, Japan) and fissure diamond bur under water irrigation at one-millimeter above the cementoenamel junction. Next, the following steps were performed for all teeth:

The root canals were instrumented one millimeter short of the working length by K files (Mani Inc., Tokyo, Japan) for three sizes after the initial file and irrigated with saline. The root canals were dried with paper points (Gapadent, Tianjin, Korea) and to simulate the clinical conditions, were filled with Metapex paste (Metabiome, Chungbuk, Korea) one millimeter short of the working length and 5mm apical to the level of cutting (4mm apical to the root canal

Table 1: Characteristics of the composites used

Composite	Composition	Manufacturer
Filtek Z250 (Z250, A2, N482264)	Bis-GMA, Bis-EMA, TEGDMA, UDMA zirconia, silica (82 wt%, 60 vol%)	3M, ESPE, St. Paul, MN, USA
Sonic Fill (SF, A2, 5026722)	Bis-GMA, TEGDMA, EBPDMA Silica, glass, oxide, (83.5 wt%, 69 vol%)	Kerr, Orange, CA, USA
Filtek Bulk-fill (FB, A2, N540884)	Bis-GMA, UDMA, Bis-EMA, procrylate resins Ytterbium trifluoride, zirconia, silica (64.5 wt%, 42.5 vol%)	3M ESPE, St. Paul, MN, USA

orifice). A thin layer (approximately one-millimeter) of light-cure liner (Lime-Lite Light Cure Cavity Liner, Pulpdent Co., MA, USA) was applied on the Metapex. The liner was light cured for 30 seconds using a LED light-curing unit (Woodpecker, Henan, China). There was approximately 4mm distance to the level of cutting and 3mm space was available for placement of composite in the root canal. To prevent extrusion of root canal filling material from the apex, light-cure liner was also applied on the apex and light cured (in order to prevent wash out of the filling material). The teeth were randomly divided into three groups. The teeth with different canal diameters were equally distributed among the three groups so that the groups had equal number of central incisors, lateral incisors and canine teeth. The root canals were then filled with composite according to the manufacturers' instructions as follows (characteristics of the materials used are presented in Table 1):

Group 1. The root canals were irrigated and dried. They were then etched with acid etchant (Swiss TEC, Coltene Whaledent, New Delhi, India) for 10 seconds, rinsed for 10 seconds with air/water spray and slightly dried with cotton pellets (for wet bonding). Two layers of Single Bond 2 bonding agent (3M ESPE, St. Paul, MN, USA) were applied, air-dried for 3-5 seconds (each layer separately) and light cured for 20 seconds. Conventional composite was applied in two 2mm-thick increments and each layer was light cured for 40 seconds.

Group 2. The root canals were washed and dried. Application of bonding agent was similar to that in group 1. Next, 4mm of SonicFill bulk-fill composite (Kerr, Orange, CA, USA) was applied using Sonic hand piece in one-step and cured for 40 seconds.

It should be noted that SonicFill is a sonic-activated, bulk-fill composite with high viscosity. It contains specific modifiers, which are activated by sonic energy. Sonic energy decreases the viscosity of composite by 87% and converts it to a flowable composite. After discontinuing the sonic energy, the composite converts back to its primary viscous state and can be carved and contoured.

Group 3. The root canals were irrigated and dried. Application of bonding agent was similar to that in group 1. Next, 4mm of Bulk-fill composite (3M ESPE, St. Paul, MN, USA) was applied in one increment and light cured for 40 seconds. The LED light curing unit used was the same for all groups and had a light intensity of 800mW/cm2. During light curing, the tip of the light-curing unit was in contact with the sectioned tooth surface. The samples were then thermocycled (TC300, Vafaie Industrial, Tehran, Iran) for 500 cycles between 5-55°C with a dwell time of 20 seconds and transfer time of 10 seconds. After thermocycling, the samples were mounted in blocks containing polyester and 1mm thick slices were sectioned at the mid-root using a cutting machine with a water-cooled diamond blade (250B Labcut, Extec, Crop, Enfield, CT, USA). The broken slices were excluded. Both sides of each slice were photographed by a digital camera (Cyber-Shot DSC-HX100v, Sony, Tokyo, Japan) and the cross-sectional area of composite on both sides was calculated using

Table 2: The mean push-out bond strength of the three composites

Composite	Mean (MPa)	Minimum (MPa)	Maximum (MPa)	Standard deviation
Conventional (Z250)	11.4090	6.28	17.97	4.23645
SonicFill bulk-fill	10.9433	0.64	23.03	6.69215
Filtek bulk-fill	8.7991	3.31	16.50	4.12477

Auto CAD 2014 software (Autodesk, CA, USA). The camera was adjusted in the same position for all sections. The cross-sectional area was calculated using the formula S=H(A1+A2)/2; where A1 was the circumference of one side, A2 was the circumference of the other side and H was the height of the root section (in mm) measured by a digital caliper (CMT, Zhejiang, China).

The samples were then subjected to push-out bond strength test in a universal testing machine (2050, Zwick Roell, Ulm, Germany). Load was applied by a cylindrical stainless steel plunger at a crosshead speed of 0.5mm/minute in apico-cervical direction until fracture [33]. Maximum load at the time of composite debonding was recorded in Newtons (N). The load in N was divided by the cross-sectional area in mm2 to report the push-out bond strength value in MPa.

The samples were also inspected under a stereomicroscope (SZX2-2b16, Olympus, Tokyo, Japan) at ×25 magnification to determine the mode of failure, which was categorized as adhesive (fracture in the bonding), cohesive (fracture in dentin or composite) and mixed (fracture in the bonding and composite or dentin). The data were analyzed using SPSS version 21 (SPSS Inc., IL, USA). One-way ANOVA was used to compare the push-out bond strength of the three groups.

RESULTS

The mean (± standard deviation) push-out bond strength to intracanal dentin was 11.40±4.23MPa, 10.94±6.69MPa and 8.79±4.12 MPa in the conventional, SonicFill and Filtek groups, respectively. The difference in this regard among the three groups was not statistically significant (P=0.397; Table 2).

The highest frequency of the modes of failure belonged to the mixed type in conventional group and adhesive type in SonicFill and Filtek groups. The frequency of the modes of failure in the three groups is shown in Table 3.

DISCUSSION

Correct selection of dental materials is an important factor in esthetic tooth restorations. Composite resins are more commonly used for restoration of anterior teeth since they provide acceptable esthetics [2].

Several factors affect the bond strength of composite to dentin in vitro including the type and age of tooth, degree of dentin mineralization, bonded dentin surface, type of bond strength test (shear or tensile), storage medium, humidity of the environment, substrate moisture and testing conditions. These factors can be responsible for the variability in bond strength test results of previous studies [22-32,34].

Push-out bond strength test applies a shear load to the composite-bonding agent and bonding agent-dentin interfaces. The push-out test better simulates the clinical setting than the linear shear test [35]. Thus, we performed the push-out bond strength test in the current study.

The bond strength of conventional, SonicFill and Filtek composites to intracanal dentin was 11.40±4.23MPa, 10.94±6.69MPa and 8.79±4.12MPa, respectively. The difference in this regard among the three groups was not statistically significant (P=0.397). The bond strength in SonicFill group showed greater deviation, which seems to be due to the technical sensitivity of application of SonicFill or incorrect use of sonic hand piece. Afshar et al, [33] in 2015 reported the push-out bond strength of a conventional composite along with 5th, 6th and 7th generation bonding agents to intracanal

Table 3: The frequency and percentage of the modes of failure in the three groups

Group		Adhesive	Cohesive in dentin	Cohesive in composite	Mixed
Conventional composite (Z250)	Frequency	2	1	2	8
	Percentage	15.3	7.6	15.3	61.5
SonicFill bulk-fill composite	Frequency	7	0	0	6
	Percentage	53.8	0	0	46.1
Filtek bulk-fill composite	Frequency	7	0	0	6
	Percentage	53.8	0	0	46.1

dentin of primary anterior teeth to be 13.6MPa, 13.85MPa and 12.28MPa, respectively; no statistically significant difference was noted among the groups in this respect. In their study, the mean bond strength value of conventional composite along with 5th generation bonding agent was slightly higher than the corresponding value in our study. This difference is probably attributed to the difference in type of teeth, storage conditions, operator’s skills, type of composite (Z250 versus P60) and thermocycling of samples in our study. Afshar et al, [33] did not perform thermocycling.

Caixeta et al, [36] in 2015 evaluated the push-out bond strength of conventional and bulk-fill composites along with Adper Scotchbond adhesive to bovine incisors. Bulk-fill composite showed the lowest bond strength with significant differences with other groups.

The bond strength values reported in our study were higher than those in the study by Caixeta et al, [36] in contrast to their findings, our results did not reveal a significant difference between conventional and bulk-fill composites. The difference in dentin substrate (human versus bovine), type of composite and type of bonding agent used may explain the controversy in the results of the two studies.

Oskoee et al, [37] in 2013 assessed the push-out bond strength of fiber-reinforced composite posts with different adhesive systems to intracanal dentin of permanent teeth. The push-out bond strength values in their study were higher than those in the current study.

The diameter and number of dentinal tubules in primary dentin are higher than those in permanent dentin. As the result, the available dentin substrate for the bond to adhesives is lower in primary teeth (lower amount of intertubular dentin) [38]. On the other hand, peri-tubular dentin, which is demineralized faster in the etching process, is thicker in primary teeth compared to that in permanent teeth. Thus, the available substrate for bonding further decreases in primary teeth [39]. Such histological differences may be responsible for decreased bond strength to dentin of primary compared to permanent teeth.

Ilie et al, [30] in 2014 assessed the shear bond strength of high-viscosity bulk-fill, low-viscosity bulk-fill and a nanohybrid composite to primary and permanent molar teeth using two self-etching adhesive systems. They reported higher bond strength values in most groups compared to our values, which may be explained by the differences in the type of composite resins and bonding agents as well as different tests (shear versus push-out) and expertise of the operators. Moreover, differences in the morphology and structure of dentin close to dentinoenamel junction and dentin close to pulp chamber can also be responsible for the variability in the mean bond strength values. The dentin close to dentinoenamel junction contains fewer dentinal tubules with smaller diameters compared to dentin close to pulp chamber. Thus, in dentin far from the pulp chamber, higher amounts of calcified dentin (which is the main substrate for etching and bonding) are available, yielding higher bond strength values. Therefore, difference in bond strength values in our study and the study by Ilie et al, [30] may be due to the histological differences in coronal dentin (dentin far from the pulp chamber) and root dentin (dentin close to the pulp chamber) as well as the different cross-sectional areas, to which the load was applied. In terms of the mode of failure, adhesive and mixed types had higher frequency in our study, which was similar to the findings of previous studies on primary dentin [40]. Evidence shows that the mode of failure in dentin and enamel of primary teeth is mainly of adhesive and mixed types [37]. Cohesive failure occurs in response to lower loads when the cross-sectional area is larger while adhesive failure is more common in smaller cross-sectional areas [40]. It has been stated that >14MPa load is required for the cohesive failure to occur [41]; on the other hand, there are studies reporting that cohesive failures are not rare in primary dentin, due to the low microhardness of deep dentin. Some others have claimed that a weak correlation exists between the mode of failure and bond strength to primary dentin [40].

Further assessment of fracture mode in the current study revealed almost equal distribution of bond strength values in the three groups. The conventional composite group had the highest bond strength, and cohesive and mixed failure modes were dominant in this group. Adhesive failure had the lowest frequency in this group. By a reduction in bond strength, the frequency of cohesive failures gradually decreased while the frequency of adhesive failures increased. Adhesive failures had a higher prevalence in bulk-fill composite groups, which may be related to weaker bond of these composites to the bonding agent used or higher cohesive strength of these composites.

CONCLUSION

Based on the results of the current study, bulk-fill composites, similar to conventional types, can be successfully used for the fabrication of composite posts in root canals of primary teeth to decrease the treatment time in children.

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