ARTICLE / INVESTIGACIÓN

Effect of push-out bond strength of a conventional and a bulk-fill composite resin as a biotechnological technique to root dentin of primary anterior teeth

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Abstract: This study aimed to compare the push-out bond strength of a bulk-fill and a conventional composite resin to root dentin of primary anterior teeth using a 7th-generation dentin bonding agent. This in vitro study evaluated 24 primary anterior teeth randomly divided into two groups: Filtek P60 conventional and Filtek bulk-fill composite resins. Single Bond Universal adhesive was used for bonding. After filling the coronal part of the canal with composite resin, the teeth were mounted in acrylic resin and sliced to obtain a 1-mm-thick section of each root. Next, the sections underwent the push-out bond strength test. After determining the push-out bond strength, the failure mode was determined under a light microscope at ×40 magnification. The data were analyzed with two-way ANOVA and t-test. The mean push-out bond strength was 13.37±4.40 MPa in the conventional and 5.40±2.91 MPa in the bulk-fill composite resin groups. This difference was statistically significant (P=0.001). In the conventional group, 50% of failures were cohesive in the traditional combined resin group, while in the bulk-fill composite resin group, 75% of losses were mixed. Filtek P60 conventional composite resin and Single Bond Universal 7th-generation bonding agent were determined as appropriate for fabricating intracanal composite posts in primary anterior teeth.

Key words: Push-out, Bond strength, Bulk-fill composite resin, Root dentin, Primary anterior teeth.

Introduction

Preserving primary teeth is of utmost importance[1-5]. Early childhood caries (ECC) is a common cause of early primary tooth loss, which refers to the presence of one or more carious (cavitated or non-cavitated), lost or restored tooth surfaces in any of the primary teeth of a 71-month-old child or younger[6,7]. Severe ECC refers to any sign of caries in smooth surfaces of the teeth in children under the age of 3. ECC often results in losing a significant portion of tooth structure and pulpal involvement[8]. Therefore, restoration of teeth with ECC remains a challenge in pediatric dentistry. Stainless steel crowns used to be the treatment of choice for such teeth. However, many parents no longer accept them due to their unesthetic appearance[9].

A suitable restoration for such teeth should restore the primary function while providing favorable esthetics[10]. Open-face crowns, polycarbonate crowns, and composite resin restorations have been suggested to treat carious primary teeth[11]. Composite resin restoration of severely damaged teeth often requires pulpectomy and placement of intracanal post to serve as a retainer[12]. In addition, the fabrication of a post and core is imperative to retain and stabilize the composite resin crown and resist masticatory forces[13]. In cases where a small amount of coronal tooth structure remains, restorations with posts often result in a better function than those without a post[14]. Several posts can be used for this purpose, such as prefabricated metal posts, fiber-reinforced posts, orthodontic wires, cast posts with retentive grooves, short composite resin posts, and biologic posts[15,16]. Considering the physiological root resorption in primary teeth, only the coronal 3 mm of the root should be used to obtain adequate retention and resistance in severely damaged teeth[17]. Due to increased demand for esthetics, composite resin and fiber posts are increasingly used for the anterior teeth due to advantages such as optimal corrosion resistance, biocompatibility, mechanical strength[18], reinforcement of composite resin crown, improved translucency, optimal esthetics, higher flexibility compared with metal posts, and easy application[19,20]. Also, these posts have a modulus of elasticity close to dentin, which decreases stress accumulation and root fracture[21]. Many attempts have been made to enhance the efficacy of dentin-bonding agents while reducing their procedural steps. Thus, some progress was made in multi-step dentin bonding agents, which were difficult for children due to their technique sensitivity and time-consuming nature[22].

In this respect, 7th-generation dentin bonding agents were introduced to simplify the bonding procedure. In this system, acid, primer, and bonding agent are all supplied in one bottle, which facilitates the application of this bonding agent in non-cooperative children[23]. Conventional methacrylate-based composite resins have long been used to restore primary anterior teeth. However, limited curing depth and the possibility of an inadequate degree of conversion of monomers to polymer in deep areas are among

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the drawbacks of conventional composite resins[24], which can deteriorate their physical, mechanical, and biological properties[25,26]. They can be applied in bulk to decrease the application steps and save time[27,28]. Also, they can be applied in 4-mm-thick increments (versus 2 mm in conventional composite resins)[29] with lower polymerization shrinkage compared with conventional composite resins[30].

Since severe destruction of primary anterior teeth often necessitates pulpectomy, the reconstruction of such teeth requires efficient dentin bonding agents, and retention should be obtained from the root dentin. Thus, this study assessed the push-out bond strength of a bulk-fill and a conventional composite resin to root dentin of primary anterior teeth using a 7th-generation dentin bonding agent.

Materials and methods

Study design

This in vitro study evaluated 24 primary anterior teeth extracted due to severe coronal caries within the previous six months. The ethics committee of Tehran University of Medical Sciences approved the study.

Teeth preparation

The collected teeth were immersed in 0.5% chloramine T solution for one week and stored in distilled water. The teeth were then decoronated at 1 mm above the cementoenamel junction using diamond discs perpendicular to the long axis of the tooth.

Sample size measuring

The sample size was calculated at 12 in each group according to a previous study by Torres *et al.*[30], assuming alpha=0.5, beta=0.2, a mean difference of 3.3, and a standard deviation of 3.16 using Minitab software.

Inclusion Criteria and Groups

Inclusion criteria were the absence of dental caries and fractures. The teeth were randomly assigned to two groups. The root canals were instrumented with three sizes of k-files (Mani Inc., Japan) and rinsed with saline solution. They were then dried with paper points (PT Dent, USA). After completion of filing, the root canals were not filled with zinc-oxide eugenol to prevent the possible effect on pulpal dentin. Instead, 1 mm of zinc phosphate paste was applied to create an apical seal for composite resin packing. Next, the coronal 3 mm root canal was filled with composite resin to serve as an intracanal post. Patients with COVID-19, dental infections, and neoplastic lesions of the oral cavity have been excluded from the study. Table 1 presents the composition of this study's bonding agent and composite resins.

Single Bond Universal 7th-generation bonding agent was used for bonding composite resins in both groups. In group 1, Filtek P60 conventional composite resin was incrementally applied according to the manufacturer's instructions and packed into the root canal with a condenser. Each layer was light-cured for 20 seconds. In group 2, Filtek bulk-fill composite resin was applied in the root canal in bulk in one step according to the manufacturer's instructions and light-cured for 40 seconds. All the samples in both groups were light-cured using an LED light-curing unit (WoodPecker, China) at a light intensity of 800–1000 mW/cm2. The tip of the light-curing unit was placed 2 mm away from the tooth surface. The samples were incubated in distilled water at 37°C for 24 hours (Kavoosh Mega, Iran) and then underwent 2000 thermal cycles at 5/55°C with a dwell time of 30 seconds and a transfer time of 10 seconds (TC300; Vafaie Industrial, Iran). Next, the samples were mounted in transparent acrylic resin. A section was made at the midpoint of the prepared root of each tooth with 1-mm thickness using a water-cooled diamond blade on a Labcut 250B cutting machine (Extec, corp, Enfield, CT). The push-out bond strength test was then performed using a universal testing machine (2050; Zwick/Roell, Ulm, Germany). Using a stainless steel cylindrical plunger with a diameter matching the root canal, the load was applied to the bonding interface in an apicocervical direction at a 0.5 mm/min crosshead speed. Maximum load causing debonding was recorded in Newtons (N). The load in Newtons was divided by the surface area in square millimeters (mm2) to determine the bond strength in megapascals (MPa). Prior to the push-out test, both sides of the sliced section were photographed by a digital camera (DSC-HX100v CyberShot, Sony, Japan), and the photographs were fed into AutoCAD 2013 software. The cross-sectional area was calculated using the formula A=H((A1+A2)/2) where A1 is the circumference on one side, A2 is the circumference on the other side, and H is the height (thickness) of the root slice in millimeters. The AutoCAD software measured A1 and A2, and H was measured by a digital caliper (Mitutoyo, Japan). After the push-out test, the samples were inspected under a light microscope (SZX2-2b16; Olympus, Japan) at ×40 magnification to determine the mode of failure, categorized as mixed, cohesive, and adhesive.

Materials	Components	Mode/steps of the application	Manufacturer
Single bond universal Self-etch 1-step	MDP phosphate monomer, dimethacrylate resins, HEMA, Vitrebond™ copolymer, filler, Ethanol, water, initiators, silane	The adhesive was rubbed on the tooth surface for 20 s, gently air-dried for 5 s, and cured for 10 s.	**3M, St. Paul, MN, USA**
Filtek P60 %fillers/wt: 83.0	BIS-GMA, UDMA, BIS-EMA	Each increment was applied with 2 mm thickness and cured for 20 s.	**3M, St. Paul, MN, USA**
Filtek bulk-fill %fillers/wt: 64.5	ERGP-DMA, diurethane-DMA, 1,12-dodecane-DMA	Each layer was applied with 4 mm thickness and cured for 40 s.	**3M, St. Paul, MN, USA**

Table 1. Composition of bonding agent and composite resins used in this study.

Data analysis

The data were analyzed with SPSS 22 via t-test at an 0.05 level of significance[31-37].

Results

Push-out bond strength

Table 2 shows the mean push-out bond strength of the two groups. The t-test showed a significant difference in bond strength between the two groups, such that the conventional composite resin yielded a significantly higher bond strength (P<0.001).

Frequency of different modes of failure

Table 3 shows the frequency of different failure modes in the two groups. In the conventional group, 50% of failures were cohesive in the composite resin, while 75% of failures were mixed in the bulk-fill group.

Discussion

Dental sciences have been considered an important part of medical research on human health[38-40]. This study compared the push-out bond strength of a bulk-fill and a conventional composite resin to root dentin of primary anterior teeth using a 7th-generation dentin bonding agent. The mean push-out bond strength of the conventional composite was significantly higher than that of the bulk-fill composite resin. Afshar *et al.*[23] assessed the push-out bond strength of 5th, 6th-, and 7th-generation bonding agents to root dentin of primary anterior teeth and found no significant difference between them. However, the mean value reported for the 7th-generation bonding agent in their study (12.28 MPa) was lower than that in the present study (13.37 MPa) when a conventional composite resin was used. Differences in age and morphology of the teeth, storage media, and operators' expertise may be responsible for the difference in the results. Also, thermocycling was performed in the present study, which was not conducted in the study above.

Some other studies assessed the shear or tensile bond strength of different composite resins and bonding agents to primary tooth crowns. Yaseen and Reddy[22] reported a shear bond strength of 17.39 MPa for the Clearfil S3 Bond 7th-generation bonding agent, which was higher than the value in the present study. This difference might be attributed to using different bonding agents to assess shear bond strength to dentin far from the pulp chamber (dentin close to dentinoenamel junction). Dentin close to the dentinoenamel junction contains fewer dentinal tubules with smaller diameters than dentin around the pulp chamber. Thus, dentin far from the pulp chamber has a higher amount of calcified tissue, which is the main substrate for etching and bonding and can yield higher bond strength. Thus, the difference between the study above and the present study might be attributed to the difference in the histology of bonded dentin in the crown (far from pulp) and root (close to the pulp) and the difference in the cross-sectional area to which the load was applied.

Ilie *et al.*[41] assessed the shear bond strength of two bulk-fill composite resins and two self-etch adhesive systems to primary dentin and reported higher values than the present study. The bulk-fill composite resin used in the present study differed from the bulk-fill composite resins used by Ilie *et al.*[41], which might explain the differences between the results. Pasdar *et al.*[42] compared the mean push-out bond strengths of three intracanal posts, including short composite post (SCP), glass fiber posts (GFPs) cemented with flowable composite resin, and GFP with glass ionomer cement (GFP + GIC), in anterior deciduous teeth, reporting that the mean push-out bond strengths of SCP was 14.74±6.04 Mpa, which was higher than the other groups. This finding was slightly higher than the present study results concerning conventional composite resins. The differences might be attributed to differences in the techniques used and the morphology of the teeth.

The present study indicated higher bond strength of conventional composite resin to primary dentin using a 7th-generation bonding agent than a bulk-fill composite resin. No similar study was found in the literature to compare the present study results. However, bulk-fill composite resins seem not well-compatible with 7th-generation bonding agents. Although limited studies are available on deciduous teeth, many studies have assessed the push-out bond strength of root dentin in permanent teeth with highly controversial results. Oskoee *et al.*[43] evaluated the push-out bond strength of fiber-reinforced composite resin posts to root dentin of permanent teeth using different adhesive systems. They reported that the push-out bond strength values following a one-step self-etch procedure (27.56 MPa) were higher than those in the present study. This finding might be attributed to differences in primary and permanent dentin. The diameter and number of dentinal tubules in pri-

Composite resin	Minimum	Maximum	Mean	Std. deviation	P-value
Bulk-fill	2.81	12.54	5.40	2.91	0.041
Conventional	7.03	21.94	13.37	4.40	

Table 2. Mean push-out bond strength (MPa) of the two groups.

Composite resin		Cohesive in composite	Cohesive in dentin	Adhesive	Mixed
Conventional	Number	6	2	0	**4**
	Percentage	50%	16.7%	0%	**33.3%**
Bulk-fill	Number	0	0	3	**9**
	Percentage	0%	0%	25%	**75%**

Table 3. Frequency of different modes of failure in the two groups.

mary dentin are higher than those in permanent dentin. This would decrease the dentin substrate available for bonding to adhesives (reduction of inter-tubular dentin)[44]. On the other hand, the peritubular dentin, which is demineralized faster during the etching process, is thicker in primary dentin than permanent dentin, further reducing the substrate available for bonding[45]. These histological differences are responsible for lower bond strength to primary dentin than permanent dentin.

Dumami *et al.* (2016)[46], consistent with the present study, showed that the push-out bond strength of a bulk-fill composite resin (SonicFill) was lower than that of conventional composite resins. They attributed the differences in the results to factors that affected the integrity of the bond between the root dentin and the restorative materials. In addition, factors such as polymerization shrinkage, the C-factor, application method, and polymerization of the composite resin were considered significant. The authors suggested further studies. Concerning the mode of failure, in the conventional combined resin group in the present study, 50% of losses were cohesive within the composite resin. In contrast, 75% of failures were mixed in the bulk-fill composite resin group, consistent with a previous study on primary dentin[47]. In the conventional composite resin samples, two-thirds of the failures were cohesive, and one-third were mixed. No case of adhesive failure was noted in this group. This result was in agreement with the bond strength test results in this group. Evidence shows that the fracture mode in primary enamel and dentin is mainly of adhesive and mixed types[17].

However, some authors believe that cohesive failure requires a >14-MPa load to occur[47,48]. On the other hand, it has been reported that cohesive failures are not rare in primary dentin and might be due to the low micro-hardness of deep dentin, while some others claim that there is a weak correlation between the failure mode and bond strength in primary dentin[47]. Considering the advantages of self-etch one-step bonding agents, their application with conventional composite resin is recommended for composite resin post-fabrication in primary anterior teeth. However, the Single Bond Universal 7th-generation bonding agent did not seem compatible with Filtek bulk-fill composite. Therefore, future studies with a larger sample size on the push-out bond strength of other composite resins and bonding agents to primary dentin are required to obtain more accurate results in this respect. Also, the efficacy of bulk-fill and conventional composite resins for reconstructing severely damaged primary anterior teeth with fiber posts should be evaluated. Last but not least, in vivo studies are required to assess the efficacy of bulk-fill composite resins with different bonding agents for composite resin post-fabrication in primary anterior teeth in the clinical setting.

The present study was limited to a low number of samples and also experimental groups. However, the main strong point of this survey is the first using push-out bond strength of a conventional and a bulk-fill composite resin technique to root dentin of primary anterior teeth.

Conclusions

Filtek P60 conventional composite resin and Single Bond Universal 7th-generation bonding agent can be a proper choice for fabricating intracanal composite posts in primary anterior teeth.

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