

Fracture Resistance of a Bulk-Fill and a Conventional Composite and a Combination of both for Coronal Restoration of Severely Damaged Primary Anterior Teeth

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Abstract

Objectives: This study aimed to compare the fracture resistance of a bulk-fill and a conventional composite and a combination of both for coronal restoration of severely damaged primary anterior teeth.

Materials and Methods: In this in vitro experimental study, 45 primary anterior teeth were randomly divided into three groups. After root canal preparation, the canals were filled with Metapex paste such that after the application of 1 mm of light-cure liner, 3 mm of the coronal third of the canal remained empty for composite post fabrication. Filtek Z250 conventional composite was used in group 1, Sonic-Fill bulk-fill composite was used in group 2 and Sonic-Fill with one layer of Filtek Z250 as the veneering were used in group 3. Adper Single Bond 2 was used in all groups. The teeth were thermocycled, and fracture resistance was measured by a universal testing machine. The mode of fracture was categorized as repairable or irreparable. Data were analyzed using one-way ANOVA.

Results: The mean fracture resistance was 307.00 ± 74.72 , 323.31 ± 84.28 and 333.30 ± 63.96 N in groups 1 to 3, respectively ($P=0.55$). The mean fracture strength was 14.53 ± 2.98 , 15.08 ± 2.82 and 15.26 ± 3.02 MPa in groups 1 to 3, respectively ($P=0.77$). The frequency of repairable mode of failure was 80% for the conventional, 73.6% for the bulk-fill and 80% for the bulk-fill plus conventional group, with no significant difference ($P>0.05$).

Conclusions: Bulk-fill composites can be used for coronal reconstruction of severely damaged primary anterior teeth similar to conventional composites to decrease the treatment time in pediatric patients.

Key words: Filtek Bulk Fill; Composite Resins; Dentin; Tooth, Deciduous
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INTRODUCTION

Early childhood caries is a common pattern of dental caries in children, which primarily affects the maxillary incisors and primary first molars [1]. It has high progression rate and is primarily seen in the cervical third of the maxillary incisors, leading to complete destruction of crown [2]. These lesions can decrease the efficiency of mastication and result in loss of vertical facial height, parafunctional habits, impaired speech and behavioral and psychological problems in children [3,4].

Therefore, it is important to preserve the primary dentition until natural exfoliation of primary teeth [1].

On the other hand, dental treatments in hard-to-manage young children are challenging, and general anesthesia may be required for most cases [2,5,6].

Many parents prefer restorative treatments for severely damaged primary anterior teeth of their children compared to extraction and use of a space maintainer [7]. However, considering the small size of these teeth, caries progression can

result in extensive destruction of tooth structure [8], which makes their restorative treatment a real challenge for pediatric dentists. For this purpose, it is important to use esthetic restorative materials with adequate strength and durability and shorter chair time. Of tooth-colored restorative materials, composite resins are commonly used due to their optimal esthetics, fracture strength and wear resistance [9]. Their incremental application is recommended to decrease polymerization shrinkage stress and achieve adequate mechanical properties [10-12]. This method is the gold standard for application of composite resins [11]. However, it has shortcomings such as the possibility of void formation between increments, bond failure between increments, difficult application in small cavities with limited access and increased chair time due to incremental application and separate polymerization of each layer [13]. In an attempt to overcome these limitations, bulk-fill composites were introduced to the market [14-16]. They can be applied into the cavity as bulk with minimal polymerization shrinkage during curing. Bulk-fill composites do not need incremental application. Thus, they simplify the restorative procedure and decrease the duration of treatment [17]. They are especially favorable for use in uncooperative children [18]. The manufacturers claim that 4-5 mm thick increments of bulk-fill composites can be placed in the cavity as bulk and cured [19-21].

According to the information provided by the manufacturer, the SonicFill system is a unique, sonic-activated bulk-fill system comprised of a specially designed hand-piece and a new composite material with unidose tips. The composite is a combination of flowable and universal composites and incorporates a highly-filled proprietary resin with special modifiers that react to sonic energy. As sonic energy is applied to the hand-piece with five different levels of flowability, the modifier causes the viscosity to drop by up to 87%. As the result, the

composite flow increases and it better adapts to the cavity walls [22]. When the handpiece is off, the composite becomes viscous again, and can be better carved [23,24].

Many studies have evaluated the properties of an optimal intracanal post for anterior primary teeth [9,25,26]. Evidence shows that packing the composite into the canal and creating a short composite post is among the simplest and most-effective methods suggested for restoration of severely damaged primary anterior teeth [27]. Composite posts have a modulus of elasticity similar to that of intracanal dentin and bond to tooth structure. They have adequate mechanical retention and result in better distribution of occlusal forces. Easy use, not requiring laboratory fabrication, low cost and optimal adaptation are among the favorable properties of composite posts [28,29].

Studies on the application of bulk-fill composites in primary anterior teeth are limited. Given that the clinical service and fracture resistance of bulk-fill composites are confirmed, they can be used as an alternative to conventional composites particularly in pediatric dentistry to simplify the procedure and decrease the treatment time. Thus, this study aimed to assess and compare the fracture resistance of SonicFill bulk-fill composite, Z250 conventional composite and a combination of both (conventional composite covered with a layer of bulk-fill composite) for coronal restoration of severely damaged primary anterior teeth.

MATERIALS AND METHODS

This in vitro experimental study evaluated 45 primary anterior teeth with almost complete roots (at least two-thirds of the root length was present) extracted due to severe caries. The study was approved in the ethics committee of Tehran University of Medical Sciences (code:IR.TUMS.DENTISTRY.REC.1396.3340).

The teeth were randomly divided into three groups. Considering the significant effect of cross-sectional

area on the results and for the purpose of standardization, teeth with different diameters were equally distributed among the three groups.

Sample size was calculated to be 15 in each of the three groups according to a study by Seraj et al, [30] using one-way ANOVA power analysis feature of Minitab software assuming $\alpha=0.05$, $\beta=0.2$, minimum significant difference of 130 and standard deviation of 113 N.

The teeth were rinsed with saline and stored in 0.5% chloramine T solution at 4°C for one week prior to the experiment. The samples were kept in saline during the experiment.

The crowns were cut by a high-speed hand-piece (Pana-Max, Tokyo, Japan) and a diamond fissure bur (No 837L/010; Tizcavan, Tehran, Iran) under water irrigation at 1 mm above the cemento-enamel junction (CEJ). The canals were filed to 1 mm shorter than the working length using three sizes of K-files higher than the initial file and rinsed with saline. The canals were dried with paper points (PT Dent, Burnaby, BC, Canada) and filled with Metapex paste (Metabiome, Chungbuk, Korea) 1 mm short of the working length and 4 mm apical to the canal orifice. This was done to prepare a space for composite post. Light-cure cavity liner (Lime-Lite, Pulpdent Co., USA) was applied on the root canal filling material and cured for 30 seconds using a LED light curing unit (Woodpecker, Guangdong, China) with a light intensity of 800-1000 mW/cm² and cured. Excess material was removed such that 3 mm of space was available for application of composite into the canal. To prevent extrusion of filling material from the apex, light-cure liner was applied over the apex and cured.

The teeth were randomly divided into three groups for the application of composite resins. Table 1 shows the characteristics of the materials used in this study. After preparation of samples, the canals were filled with composite, and proper size celluloid crowns (3M ESPE, St. Paul, MN, USA) were used for coronal restoration of teeth (3 mm of composite as root canal filling material and 5 mm for coronal restoration).

Table 1. Characteristics of the composites used in this study

Composite	Composition	Manufacturer
Sonic-Fill (SF, A2, 5026722)	Bis-GMA, TEGDMA, EBPDMA Silica, glass, oxide (83.5wt%, 69vol%)	Kerr, Orange, CA, USA
Filtek Z250 (A2, N482264)	Bis-GMA, Bis-EMA, TEGDMA, UDMA Zirconia, silica (82wt%, 60vol%)	3M, ESPE, St. Paul, MN, USA

All materials were used according to the manufacturers' instructions as follows:

Group 1: The canals were rinsed, dried and etched with etchant (3M ESPE, St. Paul, MN, USA) for 10 seconds, rinsed for 10 seconds using air and water spray and dried by placing a cotton pellet in the canal for wet bonding. Two layers of Adper Single Bond 2 (3M ESPE, St. Paul, MN, USA) were applied, air sprayed for 3-5 seconds and cured for 20 seconds. Next, 8 mm of Z250 conventional composite (3M ESPE, St. Paul, MN, USA) was applied incrementally. Each increment had 2 mm thickness (3 mm applied in the canal and 1 mm above the CEJ in two steps, each with 2 mm thickness and the remaining 4 mm was applied into the celluloid crown). Each layer was cured for 40 seconds (increments inside the crown were cured for 40 seconds from the buccal, 40 seconds from the lingual and 40 seconds from the occlusal).

Group 2: Rinsing and drying of the canal and application and curing of the bonding agent were the same as in group 1. Next, 8 mm of SonicFill bulk-fill composite (Kerr, Orange, CA, USA) was applied using the sonic handpiece in two increments, 4 mm each. Each layer was cured for 40 seconds (increments inside the crown were light-irradiated for 40 seconds from the buccal, 40 seconds from the lingual and 40 seconds from the occlusal).

Group 3: Rinsing and drying of the canal and application and curing of the bonding agent were the same as in group 1. Next, 4 mm of SonicFill was applied into the canal using sonic handpiece and cured for 40 seconds. Afterwards, 3 mm of SonicFill composite was applied into the celluloid crown and cured for 40 seconds, and then 1 mm of Z250 conventional composite was applied as the veneering into the celluloid crown. The incisal edge of this crown had 1 mm distance from the previously applied SonicFill composite. Curing was performed for 40 seconds (increments inside the crown were cured for 40 seconds from the buccal, 40 seconds from the lingual and 40 seconds from the occlusal). This group was designed because in use of some bulk-fill composites, especially flowable types, it has been recommended to apply one layer of conventional composite over the stress-bearing areas to increase hardness and prevent wear. This group was included to find out whether addition of one layer of conventional composite would affect the results.

The teeth restored with composite were then thermocycled (TC300, Vafaei Industrial, Tehran, Iran) for 500 cycles between 5-55°C with 20 seconds of dwell time and 10 seconds of transfer time. After thermocycling, the samples were mounted in acrylic resin in a cylindrical mold to 1 mm below the CEJ.

To assess fracture resistance, the samples were subjected to compressive load at 148° angle and a crosshead speed of 0.5 mm/minute. Load application to the palatal mid-third close to the incisal edge was continued until restoration fracture. The obtained values were considered as the fracture resistance of samples. To assess the fracture strength in megapascals (MPa), the load at fracture was divided by the cross-sectional area in square millimeters (mm²). The cross-sectional area was calculated using AutoCAD 2016 software.

To assess the mode of failure, the samples were evaluated by the examiner and were classified according to the location of fracture into two

groups of repairable (fractures above the CEJ) and irreparable (fractures below the CEJ).

The fracture resistance of the three groups was compared using one-way ANOVA. P<0.05 was considered statistically significant.

RESULTS

The three groups were not significantly different in terms of the mean fracture resistance (P=0.55, Table 2, Fig. 1).

Table 2. Mean fracture resistance of the three groups in Newtons (N)

Composite	Mean	Min	Max	Standard deviation
Conventional (Z250)	307.00	230.03	460.21	74.72
Bulk-fill (Sonic-Fill)	332.31	227.11	480.22	84.28
Z250 + Sonic-Fill	333.30	250.34	447.14	63.96

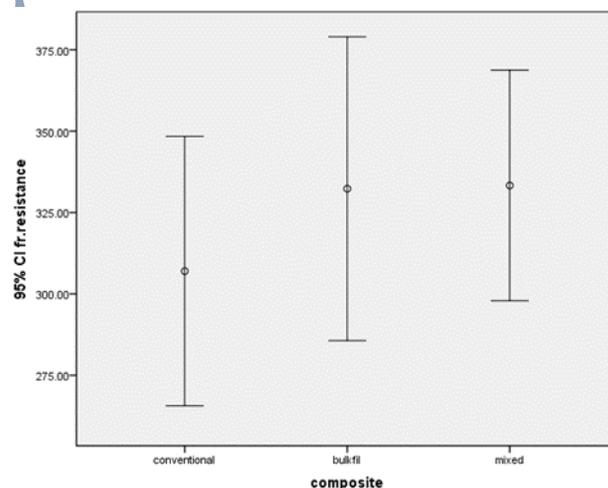


Fig. 1. Error bar of the mean and 95% confidence interval of fracture resistance in the three groups

The three groups were not significantly different in terms of the mean fracture strength either (P=0.77, Table 3, Fig. 2).

Table 3. Mean fracture resistance of the three groups in megapascals (MPa)

Composite	Mean	Min	Max	Standard deviation
Conventional (Z250)	14.53	10.31	20.60	2.98
Bulk-fill (Sonic-Fill)	15.08	10.31	21.09	2.82
Z250 + Sonic-Fill	15.26	9.56	20.23	3.02

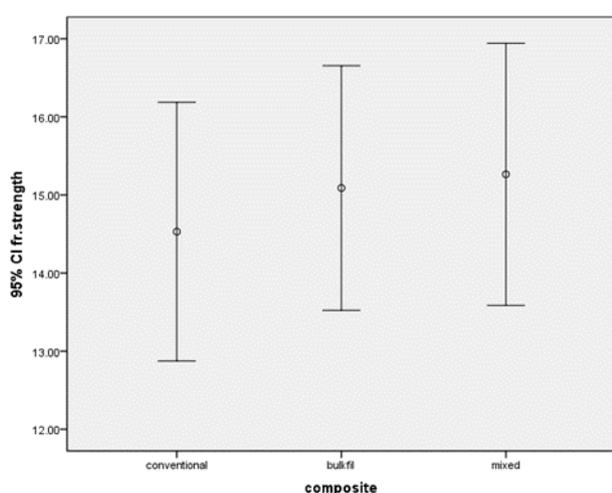


Fig. 2. Error bar of the mean and 95% confidence interval of fracture strength in the three groups

The frequency of repairable mode of fracture was 80% for the conventional, 73.6% for the bulk-fill and 80% for the bulk-fill plus conventional group, with no significant difference ($P > 0.05$, Table 4).

Table 4. Frequency percentage of each type of fracture in the three groups

Fracture mode	Z250 + SonicFill		Bulk-fill (SonicFill)		Conventional (Z250)	
	Number	Percentage	Number	Percentage	Number	Percentage
Irreparable	3	20	4	26.6	3	20
Repairable	12	80	11	73.4	12	80

The percentage of repairable fracture in all three groups was higher than irreparable fracture. Figures 3 and 4 show samples of repairable (above the CEJ) and irreparable (below the CEJ) fractures.



Fig. 3. Repairable fracture (above the CEJ)



Fig. 4. Irreparable fracture (below the CEJ)

DISCUSSION

This study assessed and compared the fracture resistance of SonicFill bulk-fill composite and Filtek Z250 conventional composite and a combination of both for coronal restoration of severely damaged primary anterior teeth. The results showed that the mean fracture resistance of the three groups was not significantly different ($P = 0.55$). The fracture strength of the three groups was not significantly different either ($P = 0.77$). The percentage of repairable fracture in all three groups was higher than irreparable fracture.

Composite resins can be successfully used for reinforcement of weakened tooth structure [31,32].

Mechanical and physical properties of direct composite resins such as fracture toughness, hardness and polymerization shrinkage are variable. Thus, the properties of restorative materials should be taken into account prior to restoration of severely damaged teeth [33].

Many previous studies have attempted to find the restorative material of choice for restoration of endodontically treated teeth since long-term prognosis of such teeth depends on the durability and quality of final restoration [34,35]. For restoration of such teeth, the restorative material must have adequate fracture resistance to withstand masticatory forces [36,37]. This is especially important in restoration of severely damaged primary teeth because the remaining tooth structure in such teeth is limited and they have higher risk of trauma and fracture [9,38]. The current results showed that the fracture resistance of SonicFill bulk-fill composite was slightly, but not significantly, higher than that of Filtek Z250 conventional composite.

Atalay et al. [33] evaluated the fracture resistance of 72 endodontically treated maxillary premolars restored with conventional nanohybrid, bulk-fill flowable and fiber-reinforced bulk-fill composites. They concluded that the fracture resistance of the three groups was not significantly different, which was in agreement with our findings. Isufi et al, [39] also found no significant difference in fracture resistance of 60 endodontically treated permanent molars restored with conventional and flowable bulk-fill composite (they applied a 1.5 mm veneering of conventional composite over the occlusal surface of bulk-fill composite). They concluded that bulk-fill composites can be used as an alternative to conventional composites for faster build-up of endodontically treated molars. Taha et al, [40], Ilie et al, [41], Agarwal et al, [42] and Kim et al. [21] reported similar results. Despite differences in the methodology of these studies and type of teeth (primary/permanent, anterior/posterior), type of composite resin used and the expertise

and experience of the operator, the same findings were obtained in our study.

The basis of bulk-fill and conventional composites is the same [43]; however, modifications made in the monomer chemistry, size and content of fillers and polymerization kinetics [17] enable bulky application of bulk-fill composites in 4 mm thickness [19-21]. Simplified procedure and decreased treatment time are the main advantages of bulk-fill composites; however, these modifications might have affected the physical properties of composites such as their toughness and strength. But, the existing studies on this topic mainly show that most bulk-fill composites have the minimum requirements for successful restoration of teeth [33,39,41].

The lowest fracture resistance was 227.11 N in our study. Mountain et al. [44] in their study on 3 to 6-year-olds reported that maximum bite force was 12.61 to 353.6 N (mean value of 196.6 N) in three points in the first and second molars and central incisors. This value was reported to be 126 N in early primary stage and 240 N in late primary stage in the study by Owais et al [45]. Since the range of fracture resistance was 227.11 to 480.22 N in our study, it may be concluded that fracture resistance of all groups was within the clinically acceptable range.

In this study, we tried our best to standardize the teeth in terms of factors affecting the fracture strength such as root diameter, length of intracanal post, crown height and method of coronal reconstruction. To standardize teeth in terms of root diameter, teeth with different root canal diameters were equally (and randomly) assigned to the three groups. The intracanal post was 3 mm and the coronal tooth height was 5 mm. The crowns were built-up using celluloid crowns, which were selected according to the size of each tooth. Thus, the three groups were only different in terms of type of composite resin. In one of our study groups, teeth were built-up with bulk-fill composite and then a conventional

layer of Filtek Z250 was applied over it as the veneering. This was done since the manufacturers of some bulk-fill composites, especially the flowable types, recommend applying one layer of conventional composite in areas under stress and occlusal loads to compensate for lower hardness and wear of these composites [33,39,41]. Our results showed that the combined group had a slightly higher fracture strength than other groups, which was not significant. Thus, it seems that SonicFill bulk-fill composite alone is sufficiently strong for tooth restoration and does not require a veneering layer. Our findings in this respect were in line with those of Atalay et al, [33], Toz et al, [46], Ozturk-Bozkurt et al, [47] and Yasa et al [48].

Another issue in this regard is the color of these composites. As mentioned earlier, bulk-fill composites are more translucent than conventional composites [19]. In our study, crowns built-up with bulk-fill composites were more translucent than the conventional group as well. Thus, application of an additional layer of veneering using conventional composite can also enhance esthetics. This does not change the working time and not only enhances esthetics, but also can increase the fracture strength.

Evidence shows that packing the composite into the canal and creating a short composite post is among the simplest and most-effective methods suggested for restoration of severely damaged primary anterior teeth [27]. Thus, we packed the composite into the canal for coronal restoration of teeth in our study.

Seraj et al. [30] measured the fracture resistance of composite posts, glass fiber prefabricated posts and quartz-fiber posts to be 278.7, 284.7 and 343.2 N, respectively. They concluded that all three types of posts can be used for restoration of severely damaged primary anterior teeth. The fracture resistance of the conventional composite group in our study was 307 N. Considering the differences in the methodology of the two studies, our results were close to theirs.

Baghalian et al. [49] measured the fracture resistance of composite post in primary maxillary teeth to be 268.19 N, which was not significantly different from that of intact fiber glass and split-ended fiber glass posts; considering the differences in methodology, their result was close to ours. They stated that use of intracanal post is imperative for composite restoration of severely damaged teeth when the remaining tooth structure is not sufficient to provide adequate retention. Paryab et al. [27] compared the fracture strength of composite and resin-modified glass ionomer cement for coronal restoration of severely damaged primary anterior teeth (intracanal post and coronal build-up) and found no significant difference between the two groups. However, the fracture strength of conventional composite in our study was higher than the reported value in their study (14.5 MPa versus 5.03 MPa). This difference can be attributed to different methods of preparation of samples, the operators' skills and the angle of load application (148° versus 90°).

Load was applied to teeth at 148° angle in our study. This angle is 135° for the occlusal forces applied to permanent maxillary incisors with class I occlusion [50]. In primary teeth, considering the straighter position of incisors, this angle is 148°. Baker et al. [51] suggested this angle in their study on primary teeth.

Regarding the mode of failure, fractures above the CEJ were considered to be repairable and those below the CEJ were considered to be irreparable. Varvara et al. [52] in their study on permanent central incisors considered cracks over the bone margin to be repairable and those below the bone margin to be irreparable. Some others considered the fractures in the coronal third of the root to be repairable [53]. However, since the crown lengthening surgery is not routinely performed for pediatric dental patients, we considered fractures above the CEJ to be repairable according to Seraj et al, [30], Paryab et al, [27] and Atalay et al [33]. The frequency of

repairable mode of failure was 80% for the conventional, 73.6% for the bulk-fill and 80% for the bulk-fill plus conventional group, with no significant difference. This result was in line with those of previous studies regarding the repairable type of fracture (above the CEJ or above the bone margin) to be the dominant type.

This study had an in vitro design. As we know, clinical situations cannot be well simulated in vitro. However, we performed thermocycling to better simulate the clinical environment and increase the accuracy of results. Further studies are required on other types of bulk-fill composites and their use with different bonding agents. Also, clinical studies are required to obtain more reliable results.

CONCLUSION

Within the limitations of this in vitro study, SonicFill bulk-fill composite, similar to conventional composite can be used for coronal restoration of severely damaged primary anterior teeth to decrease the treatment time. However, it should be noted that SonicFill bulk-fill composite needs its own specific hand-piece, which increases the costs of treatment.

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