

Fracture Strength of Severely Damaged Primary Anterior Teeth after Restoration with Composite Resin and Resin-Modified Glass Ionomer Cement

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Abstract

Background and Aim: Restoration of primary anterior teeth with severe caries extending to the gingival margin is challenging for many clinicians especially in uncooperative children. Resin modified glass ionomer cements (RMGICs) can be suitable for use in such cases since they require fewer application steps than composite resins. This study aimed to assess the fracture strength of severely damaged primary anterior teeth after their coronal build-up using RMGIC and composite resin.

Materials and Methods: This in vitro, experimental study was conducted on 40 primary teeth that met our inclusion criteria. After decoronation, they were cleaned and root canals were filled. In the coronal cavity, one layer of base was applied and an undercut was created in the canal wall above the base. The teeth were divided into two groups of 20 for coronal restoration. In group 1, etching, bonding, intracanal post fabrication and restoration with composite resin were carried out. In group 2, conditioning, intracanal post fabrication and restoration with Fuji II LC RMGIC were performed. After thermal cycles, fracture strength of teeth was measured and compared in the two groups using t-test.

Results: Fracture strength of teeth was not significantly different between two groups restored with composite resin (5.03 ± 2.30 MPa) and RMGIC (5.67 ± 2.38 MPa) ($P > 0.05$)

Conclusion: In the post and crown build up of severely damaged primary anterior teeth with severe caries extending to the gingival margin, Fuji II LC RMGIC can be used as an alternative to composite resin especially in uncooperative children or treatment under general anesthesia.

Key Words: Composite Resins, Fuji II LC cement, Glass Ionomer Cements, Tooth, Deciduous, Incisor, Post and Core Technique, Tooth Fractures

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Introduction

Early childhood caries is a common cause of extensive destruction and loss of primary anterior teeth. Restoration of severely damaged primary anterior teeth is a challenge for many clinicians

[1]. Extraction was the treatment of choice for these teeth for long [1]. Use of polycarbonate and open face stainless steel crowns are among other suggested techniques but they are not popular due to their unesthetic appearance [1].

Introduction and development of bonding systems enable the use of composite resins for coronal reconstruction of teeth [2]. Use of composite resins is a simple, inexpensive and esthetic method for this purpose; however, they are highly technique sensitive. Application of composite resins requires separate etching and application of resin bonding agents on the tooth surface, which prolong the treatment. Also, composite resins are highly hydrophobic and do not provide an ideal bond to tooth surface in presence of moisture [3]. Another shortcoming is the polymerization shrinkage of composite resins, which is responsible for marginal microleakage, marginal discoloration and recurrent caries. These technical problems are aggravated in severely damaged teeth with extension of caries to the gingival margin due to the presence of thinner enamel and gingival crevicular fluid in this area. Poor cooperation of some children further complicates the situation. Composite resins do not release fluoride and do not absorb it either during fluoride therapy. Fluoride release from restorative materials used for restoration of primary anterior teeth is an advantage for prevention of recurrent caries.

Glass ionomers are among tooth-colored restorative materials, which can be used for restoration of primary anterior teeth in uncooperative children due to having fewer procedural steps. Resin-modified glass ionomer cements (RMGICs) have fewer application steps and improved physical properties such as higher wear resistance, moisture resistance, chemical bond, marginal seal and more esthetic appearance compared to conventional glass ionomers [4-7]. According to the manufacturer, RMGICs do not require etching or bonding and are supplied in the form of injectable capsules. They are available in different colors and shades and have high polish ability and translucency similar to that of enamel. Therefore, they can be used for restoration of primary anterior teeth with extensive caries in children with poor cooperation or in case of inadequate or difficult isolation. No previous study has used this material for fabrication of intracanal post and coronal restoration of primary anterior teeth. Thus, this study aimed to assess and compare the fracture strength of severely damaged primary

anterior teeth restored with RMGIC and composite resin.

Materials and Methods

The study protocol was approved in the ethics committee of Tehran University of Medical Sciences (code: 94-01-168-28968). This in vitro, experimental study was conducted on 40 primary anterior teeth extracted due to trauma or orthodontic reasons. The coronal third of crown and two-thirds of root length were sound in these teeth. No severe root resorption, crack or caries extending to the cemento-enamel junction (CEJ) were detected. The teeth had no history of root canal treatment. Also, we attempted to collect teeth with the same diameter at the cervical region. Written informed consent was obtained from the parents.

Sample preparation:

The teeth were cleaned from superficial debris using a prophylaxis brush and non-fluoridated pumice paste. The teeth were immersed in 0.5% chloramine T solution for one week and stored in distilled water until the experiment.

The crowns were cut 1 mm above the CEJ by a diamond bur, and a standard access cavity was prepared. Root canals were instrumented using #25 to #45 K files (Mani, Tokyo, Japan) and after rinsing and drying with paper points, the canals were filled with calcium hydroxide /iodoform paste (Metapex, Metabiomed, Seoul, Korea) up to 4 mm beneath the CEJ. One layer of polycarboxylate cement (Kerr, Orange, CA, USA) was prepared according to the manufacturer's instructions and applied in 1-1.5 mm thickness over the root canal filling as a base such that 3 mm of empty space remained in the root canal beneath the CEJ. After complete setting of cement, root canal walls were cleaned from the paste residues using a round bur and low speed hand piece. Using a round bur and high speed hand piece parallel to the canal walls, a mushroom-shaped undercut was created in the canal wall 3 mm below the CEJ and above the polycarboxylate base measuring 1x0.7 mm. The samples were then randomly divided into two groups of 20 and coded. Each tooth was photographed and the bonding surface area was calculated using AutoCAD 2012 software. The difference between the tooth cross-section and

canal cross-section was then calculated.

Group 1 (control): Enamel and dentin surfaces in the crown and intracanal walls were etched with 35% phosphoric acid (Ultra Etch, Ultradent Products Inc., South Jordan, UT, USA) for 20 seconds and 10 seconds, respectively. Etched surfaces were rinsed for five to 10 seconds and gently air sprayed. Care was taken not to over-dry the dentin surface (wet blotting technique). Two layers of Single Bond (3M ESPE, St. Paul, MN, USA) were applied on etched surfaces by a micro-brush. After five seconds, bonding agent was gently air thinned for five seconds and cured for 10 seconds. Next, Z250 composite (3M ESPE, St. Paul, MN, USA) was incrementally applied obliquely in two layers. Each layer had 1.5 mm thickness and cured for 40 seconds. A transparent matrix band was fixed around the tooth cylindrically at the CEJ and the crown was built-up to 4 mm height from the CEJ using the same composite. The matrix band was cut by a scalpel and removed using an explorer. Light curing was performed using a LED light curing unit (Radii, SDI Co., Victoria, Australia) with a light intensity of 600 mW/cm². Light intensity was calibrated prior to each time of use using a radiometer. Restorations were finished and polished using a fine diamond bur (Teeskavan, Tehran, Iran) and finishing and polishing discs (Sof-Lex, 3M ESPE, St. Paul, MN, USA).

Group 2 (test): Conditioner (GC, Tokyo, Japan) was first applied on tooth surfaces for 10 seconds. After 10 seconds of rinsing, drying was performed for five seconds. RMGIC (Fuji II LC, GC, Tokyo, Japan) was then injected into the canal in 1.5 mm increments according to the manufacturer's instructions and each layer was light cured for 40 seconds. A transparent matrix band was fixed around the CEJ as in group 1 and the crown was built up using RMGIC in two layers up to 4 mm height. The matrix band was removed by an explorer and finishing and polishing of restoration were done as in group 1.

All samples were immersed in distilled water at 37°C for 24 hours and subjected to 500 thermal cycles between 5-55°C with a dwell time of 20 seconds and transfer time of 10 seconds [8]. After preparation of samples, they were immersed in distilled water and incubated at 37°C for one week.

Next, the roots were mounted in acrylic resin blocks to 2 mm below the CEJ.

Fracture strength of restorations was measured by a universal testing machine (Zwick Roell, Ulm, Germany) with a maximum load of 1000 N. Load was applied vertically at a crosshead speed of 1 mm/minute to the middle third of the palatal surface. Load was gradually increased until fracture occurred. Load at fracture was recorded in Newtons (N). The values were then divided by the bonding surface area of each tooth to determine the fracture strength in MPa.

Mode of fracture:

Two observers blinded to the group allocation of samples evaluated the teeth and classified them as follows:

Favorable fracture: Fracture above the CEJ

Unfavorable fracture: Fracture below the CEJ.

Statistical analysis:

The values were compared between the two groups using independent t-test. $P < 0.05$ was considered statistically significant.

Results

Table 1 shows the minimum, maximum and mean fracture strength in the groups. The mean fracture strength in group 2 (intracanal post and RMGIC restoration) was higher than the mean fracture strength in group 1 (intracanal post and composite resin restoration); but this difference was not statistically significant ($P=0.39$).

Table 2 shows the site of fracture relative to the CEJ. In both groups, over 80% of fractures occurred in the crown and therefore, were of favorable type (above the CEJ). Also, both types of failures (above and below the CEJ) occurred within the restorative material mass, and fracture of the tooth structure did not occur in any sample.

Discussion

Primary anterior teeth play an important role in mastication, esthetics and prevention of oral habits such as tongue thrusting and therefore, must be preserved until their replacement with permanent successors. Restoration of severely carious primary anterior teeth (early childhood caries) is challenging for clinicians due to anatomical limitations of primary teeth and poor cooperation

Table 1. Minimum, maximum and mean fracture strength (MPa) in the two groups (n=20)

Group	Minimum	Maximum	Mean	Standard deviation
Control	1.6	9.8	5.03	2.30
Test	2.12	12.08	5.67	2.38

Table 2. Mode of fracture classified as favorable (above the CEJ) or unfavorable (below the CEJ) in the two groups

Group	Favorable Number (%)	Unfavorable Number (%)
Control	17(85)	3(15)
Test	16(80)	4(20)

of children. In cases with early childhood caries, due to the extensive loss of tooth structure and concerns regarding decreased bonding surface area, some strategies must be used to increase retention. Several methods with similar efficacy have been introduced to obtain retention from the canal [9-19]. Evidence shows that intracanal extension of composite material can significantly increase the retention compared to extension of restoration to the cementum [20].

Aside from providing adequate retention for coronal restoration, adequate fracture strength is another important criterion for success of restorations. Since risk of trauma and tooth fracture is high in children, adequate fracture strength of restoration prevents the fracture of tooth structure following load application. Characteristics of intracanal post such as size, shape and material affect the pattern of distribution of load applied to crown and subsequent fracture strength of restoration and tooth structure. Intracanal posts similar to root canals in terms of shape with modulus of elasticity similar to that of dentin result in better distribution of load in case of trauma to tooth crown and decrease the risk of fracture of tooth structure.

Several studies have assessed the fracture strength and mode of fracture of primary anterior teeth restored with composite resin and different strategies to provide retention [20-23]. Some clinical studies have also been carried out [14, 24-

26]. Of the suggested techniques, packing the composite into intracanal space and fabrication of a short composite post is the easiest and most efficient technique suggested for this purpose. Composite posts have a modulus of elasticity similar to that of root dentin and thus, due to bond to tooth structure, they not only provide mechanical retention, but also cause better distribution of functional loads. Easy use, not requiring laboratory procedures, low cost and adequate adaptation are among the advantages of these posts [27]. Use of short composite post and crown was introduced in 1981 and was recommended as an efficient technique in 1986. This technique has shown favorable success rate as high as 100% especially when an undercut is created in the internal root canal wall and the crown is formed short [27,28]. However, composite resins have some limitations for use in uncooperative children and severely decayed anterior teeth.

Some types of prefabricated posts are also available; among which, prefabricated glass fiber posts have a modulus of elasticity close to that of dentin and increase the fracture strength by chemical and mechanical bond to tooth structure [14]. In use of these posts, care must be taken in accurate measurement and adaptation of post to the intracanal space. This increases the working time, which is problematic in uncooperative children. Moreover, composite resins need to be used for

cementation of prefabricated posts and reconstruction of the crown and the same concerns regarding the procedural steps and difficult isolation for composite restorations apply here as well.

Of tooth-colored restorative materials, glass ionomers favorably bond to dentin and cementum and do not require etching and bonding. Also, they are hydrophilic and adequately bond to tooth structure even in presence of moisture. It appears that glass ionomer-based materials may be suitable for coronal build up and fabrication of intracanal post in teeth with extension of caries to the CEJ and may prevent caries recurrence due to fluoride release.

The authors of this study used Fuji II LC RMGIC in a few uncooperative children for restoration of severely damaged primary anterior teeth and noticed its acceptable durability at one and three-year follow ups. This study was designed to assess the fracture strength of Fuji II LC RMGIC used for intracanal post fabrication and coronal restoration of primary teeth compared to the conventional composite resin post and restoration.

In this study, we tried our best to match the two groups in terms of factors affecting fracture strength such as the ferrule effect or root diameter, intracanal post length and height of crown. To match the two groups in terms of ferrule effect, we tried our best to select teeth with the same diameter at the CEJ. Height of post space in the canal was considered to be 4 mm in all teeth based on the presence of permanent tooth bud [21]. Also, in both groups, the crown was fabricated with 4 mm height. The two groups were only different in terms of type of material used for the fabrication of intracanal post and coronal restoration. The statistical tests found no significant difference in fracture strength of RMGIC and composite resin groups.

In our study, fracture strength in composite resin group was lower than that in the study by Seraj et al [20,23] and higher than that in the study by Island and White [21]. Difference in fracture strength in different studies may be due to the variability in size of teeth, direction of applied load and type of restorative material used for reconstruction of crown and fabrication of intracanal post.

In the studies by Seraj et al, [20,23] load was applied at 148° angle relative to the crown. In the study by Island and White [21] load was applied perpendicular to the coronal restoration. In this study, load was applied perpendicular to the samples similar to the study by Island and White, which may explain fracture due to lower magnitude of load compared to the study by Seraj et al. Occlusal loads in primary anterior teeth are applied at a steeper angle compared to permanent teeth (about 148°) [29]. The values obtained following load application at 148° angle are closer to the oral environment but due to some limitations, in the current study, load was applied perpendicular to restorations.

Seraj et al. [20,23] used Z250 composite in their study for intracanal post fabrication and coronal restoration of teeth while Island and White [21] used flowable composite for fabrication of post and coronal restoration. Z250 composite has higher filler content and subsequently higher compressive and fracture strength than flowable composites. In this study, Z250 composite was used. Thus, it seems that although load was applied vertically to the longitudinal axis of tooth crown, the obtained values were higher than that of Island and White [21]. In this study, we tried to accurately calculate the bonding surface area. Since the bonding surface area affects the fracture strength, calculation of fracture strength based on the surface area of samples is more reliable. In studies by Baghalian et al. [22] and Island and White [21] the fracture strength in Newton was used in statistical analyses without taking into account the effect of bonding surface area on the results.

Aside from measurement of bond strength, mode of fracture was evaluated under a stereomicroscope in our study. No significant difference was noted in this regard between the two groups and in both groups, fracture in over 80% of samples was favorable. In a few samples, fractures occurred below the CEJ. Fracture in tooth structure was not seen in any sample. Fracture above the CEJ does not have the risk of root fracture and can decrease concerns regarding trauma. These results showed that Fuji II LC RMGIC has optimal fracture strength comparable to that of composite resin and does not cause fracture of tooth structure. Similar results in the two groups of RMGIC and composite

resin may be related to the technique of fabrication of post in the two groups, which was based on packing the restorative material into the canal, chemical and mechanical bond of these materials to dentin and modulus of elasticity close to that of dentin. These results were in agreement with those of seraj et al [23].

In the afore-mentioned studies, RMGICs were not used for coronal restoration of teeth. Thus, our results in this regard cannot be well compared with those of previous studies.

Considering the ion exchange and strong chemical bond between glass ionomer and tooth structure, the bond strength of glass ionomer to tooth structure increases over time, which can positively affect the fracture strength of coronal restoration and even the tooth structure. Thus, future in vitro studies are recommended to assess the long-term fracture strength of coronal restorations with RMGIC and tooth structure. Also, RMGICs contain fluoride in the form of sodium difluoride. The released fluoride ions can penetrate into the tooth structure and increase the resistance of tooth to plaque accumulation and recurrent caries [4]. Thus, clinical studies are required to assess recurrent caries at the tooth-restoration margins in use of RMGIC compared to composite resin.

Conclusion

The new generation of Fuji II LC RMGIC has the optimal properties of conventional glass ionomers such as fluoride release and bond to tooth structure even in presence of moisture. Moreover, the resin part confers better physical properties to RMGIC compared to conventional glass ionomers.

Considering the fewer procedural steps in application of RMGIC compared to composite resins and similar fracture strength, RMGIC can be used for restoration of primary anterior teeth with severe caries extending to the gingival margin in uncooperative children or in cases with difficult isolation as an alternative to composite resin. The released fluoride over time can increase the clinical service of these restorations in children with high risk of caries.

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