In-Vitro Investigation of the Fracture Strength of Pulpotomized Primary Molars Restored with Glass Ionomer, Amalgam and Composite Resin with and without Cusp Reduction

[1]Beheshteh Malekafzali [2]Amir Ghassemi [3]Saeedeh Mohtavipour *[4]Faezeh Fotouhi Ardakani [5]Niloofar Goodarzi [5]Mahmood-Reza Fereydooni

[1]Associate Professor, Dept. of Pediatric Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[2]Associate Professor, Dept. of Operative Dentistry, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[3]Assistant Professor, Dept. of Pediatric Dentistry, School of Dentistry, Gilan University of Medical Sciences, Gilan, Iran.
*[4]Assistant Professor, Dept. of Pediatric Dentistry, School of Dentistry, Shahid Sadoughi University of Medical Sciences, Yazd, Iran. E-mail: faezeh.fotuhi@gmail.com
[5]Speciallist in Pediatric Dentistry.

Abstract

Objective: Resistance to fracture is a critical issue when it comes to tooth restoration. The purpose of this study was to evaluate the fracture resistance of pulpotomized primary molars restored with glass ionomer (GI), amalgam and composite resin with and without cusp reduction.

Methods: In this in-vitro experimental study, 60 extracted primary teeth were randomly divided into 6 groups of 10. In all groups except for the control group, conventional pulpotomy and MOD cavity preparation were performed in a way that the cavity isthmus width was equal to two-third of the inter cuspal distance. Group 1 teeth were restored with Kerr amalgam and underwent 1.5 mm cusp reduction, group 2 received Z250 composite resin onlay with 1.5 mm cuspal coverage, group 3 was restored similar to group 2 but without cusp reduction, group 4 was restored as group 3 but with Quixfil composite and group 5 was restored just like the former two groups but with GI. The restored teeth underwent thermocycling and were subjected to Universal Testing Machine with a crosshead speed of 0.5 mm/min. The recorded fracture resistance of specimens was compared. One-way ANOVA was used for statistical analysis.

Results: The mean fracture resistance was 2001.929 in the control group, 904.749 in the amalgam group, 1101.736 in Z250 composite with no cusp reduction group, 1036.185 in the Quixfil composite with no cusp reduction, 945.096 in the Z250 composite with cusp reduction and 850.313 in the GI group. The difference between the control group and other understudy groups was statistically significant ($p<0.0001$) but other differences were not statistically meaningful.

Conclusion: Although in none of the groups the fracture strength was equal to that of intact primary teeth, the obtained values were within the normal range of masticatory forces.

Key words: Amalgam, Composite, Fracture strength, Glass ionomer, Primary molar, Pulpotomy.

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Introduction:

Selection of an ideal restorative material for restoration of pulpotomized teeth is among the goals of dental materials research (1) because these teeth are more susceptible to fracture due to the great loss of tooth structure (2-4). Thus, the restoration should have adequate strength and retention to protect the teeth against masticatory forces and preserve the remaining tooth structure (1, 5).

Fracture resistance of teeth depends on two factors:

A: Dimensions of the prepared cavity and B: The restorative material (2-4). Several factors affect the fracture resistance of teeth with MOD restorations such as isthmus width, pulpal floor depth and thickness of axial dentin between the mesial and distal walls. Other factors such as the extent of carious lesion, intercuspation and cusp morphology also play a role (6).

Several studies have demonstrated that amalgam-restored teeth have less stability than intact teeth; whereas composite-restored teeth have stability equal or even greater than that of intact teeth. Based on a study by Hood *et al*. in 1999, amalgam can act like a wedge in between buccal and lingual cusps and increase the risk of fracture (7). In contrast, bonded composite restorations decrease the deflection of cusps under occlusal forces and by distribution and transfer of functional tensions at the tooth/bonding interface, they have the potential to reinforce weak tooth structure (8, 9).

Daneshkazemi in 2004 evaluated the fracture resistance of composite restorations bonded with dentin bonding agents and GI cements under composite restorations in endodontically treated teeth. They reported the higher fracture resistance of endodontically treated teeth restored with composite resins along with dentin bonding agents (10).

Many studies have been conducted on this topic on permanent teeth but number of similar studies on primary teeth is scarce. This study sought to assess and compare the fracture resistance of pulpotomized primary molars restored with amalgam, composite and GI. Also, fracture resistance of composite restorations with and without cusp reduction was compared.

Methods:

In this experimental study, 60 primary molars extracted because of dentoalveolar abscess or orthodontic treatments were selected based on the following inclusion criteria:

1. Having at least one/third of the remaining root length
2. The width of occlusal caries should not exceed one/third of the intercuspal distance
3. Caries depth at proximal surfaces (gingival floor) should not exceed the level of CEJ

All teeth were stored in screw-top containers containing 0.5% chloramine T solution at room temperature until the preparation of samples and conduction of tests. The teeth were classified based on their size using the below-mentioned formula and randomly divided into 6 groups of 10. Tooth height at the buccal and lingual and tooth width at buccal and lingual dimensions were measured using a digital caliper (Mitutoyo, Japan) with 0.01 mm readability. The distance from the buccal cusp tip to the CEJ and from the palatal cusp tip to the CEJ was measured. The two values were added and divided by 2. The obtained value represented the tooth height. Tooth width was calculated based on tooth thickness at the buccal and lingual height of contour. Tooth height was divided by tooth width to obtain tooth size.

Classification of samples based on the type of restoration they received was as follows:

Group 1. Intact teeth (control group)

Group 2. Teeth restored with Kerr amalgam and underwent 1.5 mm cusp reduction

Group 3. Teeth restored with Z250 along with SE Bond and underwent 1.5 mm cusp reduction

Group 4. Teeth restored with Z250 along with SE Bond without cusp reduction

Group 5. Teeth restored with Quixfil without cusp reduction

Group 6. Teeth restored with Fujifil GI without cusp reduction

For complete reconstruction of reduced cusps, a silicon impression was made. All teeth preparations were done using a high-speed hand piece. After conventional pulpotomy, MOD cavity with an isthmus width equal to two-third of intercuspal distance and mesial and distal box floor at the level of CEJ was prepared. In group 2 and 3 samples, 1.5 mm cusp reduction was done using a fissure bur with ¼ mm diameter. After placement of a 2mm-thick layer of reinforced zinc oxide cement (Zonalin, Kemdent, UK) a 1mm-thick layer of GI cement (Fugi IX, GC, Japan) was placed into the access cavity. Restorative materials were then used according to the manufacturer's instructions to restore cavities.

In group 2, after 1.5 mm cusp reduction, the cavities were restored with Kerr amalgam. The following procedures were performed in groups 3, 4 and 5:

Primer (Clearfil SE Bond, Kuraray, Japan) was applied to the prepared cavity for 20s, gently air dried (no water), bonding agent was applied (Clearfil SE Bond), gently air dried and light cured with QTH Blue Point (Arialuxe, Iran) with 430 mW/cm^2 intensity for 10s.

In groups 3 and 4, Z250 composite resin (3M, USA) was applied in 2mm increments with 20s curing time. In group 5, the increment thickness of Quixfil (Dentsply, Germany) was 4mm. For the placement of final increment, small amount of composite resin was applied to the prepared silicon impression. The tooth was then placed into the impression and light cured for 20s. Group 6 specimens were restored with Fuji IX self-cure GI. During the preparation phases, the teeth were constantly kept wet by using distilled water. After restoration, the teeth were stored in distilled water for 6 days and were subjected to thermocycling (500 thermal cycles at 5-55°C). The teeth were then mounted into cylindrical moulds with 4cm diameter and 2cm height containing self-cure red acrylic resin up to 2 mm below the level of the CEJ (simulating the alveolar bone height around the natural teeth). At the time of setting of acrylic resin, specimens were immersed in distilled water to maintain the humidity of teeth and reduce the heat generated by polymerization. Next, all specimens were subjected to stress in Universal Testing Machine (FBOZO TN, Zwick/Roell). The load applying jaw was a semi-circlewith 3.7 mm diameter and tried to be incontact with both buccal and lingual cusp surfaces. The load was applied with a crosshead speed of 0.5 mm/min perpendicular to the occlusal plane. The load was increased until fracture occurred. Loading phases were recorded in a stress (N) versus strain (mm) diagram using Test Expert software of Universal Testing Machine. The maximum load at failure was determined. After testing, based on the location of fracture site relative to the CEJ, all specimens were visually categorized into two groups of fracture above or below the CEJ and percentage of each mode of failure was determined.

One-way ANOVA was applied for comparison of fracture resistance among groups. Considering the significance of the results, Tukey's test was used for multiple comparisons between groups.

Results:

Descriptive fracture resistance values of the understudy groups are shown in Table 1.

Table 1- Descriptive fracture resistance values in different groups

Group	Number	Mean (N)	SD	95% CI	
				Minimum	Maximum
Control	10	2001.929	633.232	1548.942	2454.916
Amalgam	10	904.749	367.925	641.551	1167.947
Z250 no reduction	10	1101.736	492.651	749.315	1454.157
Quixfil no reduction	10	1036.185	506.743	673.683	1398.687
Z250+ reduction	10	945.0.96	426.007	640.349	1249.843
GI	10	850.313	293.995	640.001	1060.625

Based on the results of ANOVA, the difference between the control and experimental groups was statistically significant but no other significant differences were noted ($p<0.0001$ for control and amalgam groups, $p<0.001$ for control and Z250 composite without reduction, $p<0.0001$ for control and Quixfil composite, $p<0.0001$ for control and Z250 composite with reduction and $p<0.0001$ for control and GI groups). Other multiple comparisons by Tukey's test are demonstrated in Table 2.

Percentage of modes of failure in different groups is shown in Table 3. As observed, amalgam with cusp reduction group had the highest percentage of fracture above the CEJ (100%) and the GI group had the highest percentage of fracture below the CEJ (90%).

Table 2- Comparison of groups based on Tukey's analysis

Group 1	Group 2	Mean difference	P value
Control	Amalgam	1097.18	0.0001 (Significant)
Control	Z250 no reduction	900.19	0.0001 (Significant)
Control	Quixfil no reduction	965.74	0.0001 (Significant)
Control	Z250, no reduction	1056.83	0.0001 (Significant)
Control	GI	1151.62	0.0001 (Significant)
Amalgam	Z250, no reduction	196.99	0.93
Amalgam	Quixfil no reduction	131.44	0.99
Amalgam	Z250, no reduction	40.35	0.99
Amalgam	GI	54.44	0.99
Z250, no reduction	Quixfil no reduction	65.55	0.99
Z250, no reduction	Z250, no reduction	156.64	0.97
Z250, no reduction	GI	251.42	0.83
Quixfil no reduction	Z250, no reduction	91.09	0.99
Quixfil no reduction	GI	185.87	0.95
Z250, no reduction	GI	94.78	0.99

Table 3- Percentage of modes of failure in the understudy groups

	Control	Amalgam with reduction	Z250 no reduction	Z250 no reduction	GI	Quixfil
Above CEJ (%)	30	100	80	40	10	40
Under CEJ (%)	70	0	20	60	90	60

Discussion:

Primary teeth are restored with the aim of reconstruction of their natural contour. In two relatively similar studies by El-Kalla and Garcia-Godoy (1999) and Ajami *et al*. (2004)(11, 12), the control group comprised of amalgam-restored teeth. In our study we used intact teeth as the control group; which made it easier to reach a conclusion. In our study primary teeth D and E were used and the teeth in different groups were matched in terms of their type (D or E) and size similar to what was performed in El-Kalla and Garcia-Godoy study (1999)(11). However, Ajami *et al*. (2004) (12) only used Es. Since the shape and size of teeth can affect their fracture resistance, classification of teeth was done based on crown height and tooth size in the buccolingual dimension because this dimension was indicative of the dimensions of the cavity that was going to be prepared accordingly. This factor is among the most influential factors on fracture resistance when it comes to cavity preparation. Use of a silicon impression in this study enabled us to accurately reconstruct the tooth height.

In the present study, thermocycling (500 thermal cycles at 5-55°C) was done to simulate oral environment. Based on the relevant studies in this respect, thermocycling with 500 thermal cycles seems sufficient (13). Restorative materials used in our study comprised of amalgam (Kerr), Z250 composite resin, Quixfil composite resin and Fuji GI. Amalgam was selected based on its popularity for restoration of primary teeth in Iran. Z250 composite resin is also among the commonly used materials for restoration of posterior primary teeth. The manufacturing company of Quixfil claims that curing is very well done in 4mm-thick increments of this composite. Thus, by bulk placement of composite instead of using the incremental technique, restoration of primary teeth can be expedited. At present, buccolingual layering technique due to decreased polymerization shrinkage is recommended (14). Roberson *et al*. (2002), Morin *et al*. (1984) and Vale (1958) justified the one-third rule and explained that if cavity width at the isthmus exceeds one-third of the intercuspal distance, cusp coverage should be performed (14-16). Thus, in our study, onlay design was chosen in two groups. In our study, materials were not significantly different in terms of fracture resistance; which is in agreement with the results of El-Kalla and Garcai-Godoy (1999)(11). The magnitude of masticatory forces may be responsible for fracture of restorations. By advanced age, the magnitude of these forces increases, reaches a plateau during 20-40 yrs. and declines thereafter. The mean masticatory force in children aged 7-20 yrs. with normal occlusion has reported to be 309.50± 193.75 N in males and 219±144.21 in females. This rate was 186.2 N in males and 203.4 N in females aged 3-5 yrs. (17). Thus, in our study the mean fracture resistance (that was equal to the maximum load applied by the machine), was greater than the natural masticatory forces.

Clinically, masticatory forces have relatively constant magnitude and are exerted during longer time periods with variable speeds and at different directions causing different fracture modes (18, 19). Whereas, in our study, applied loads had constant speed and direction and constantly increased until fracture. As observed, the mean fracture resistance value obtained in our study was much greater than the actual masticatory forces. Since the mean fracture resistance value in the control group was much greater than the rates in permanent teeth, it seems that the clinical requirements in children (considering the maximum reported forces) are met by all the understudy restorative materials.

Although no statistically significant difference was found between the understudy groups, the fracture resistance was higher in value (but not statistically) in bonded composite groups compared to other groups. This relative advantage has been confirmed by the majority of previous studies on resistance of teeth restored with bonded composite resins (19-21).

No statistically significant difference in fracture resistance values of different groups (except for the control group) may be due to the small sample size or different bond strength of primary and permanent teeth.

The obtained prevalence values for modes of failure revealed that in groups with cusp reduction, fractured occurred at a more suitable location (above the CEJ). Thus, the fracture in these groups has a higher chance of repair.

Conclusion:

Fracture resistance of intact primary teeth was found to be 2001.92. None of the suggested techniques were able to raise the fracture resistance up to this value. However, it seems that composite restorations have a higher mean fracture resistance than others.

Conflict of Interest: “None Declared”

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