Original Article

In Vitro Fracture Resistance of Permanent Molars with Undermined Walls Restored With Different Materials and Techniques

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Received 9 May 2021 and Accepted 5 June 2021

Abstract

Introduction: Restoration of freshly erupted permanent first molars with extensive caries is a challenge in pediatric dentistry. This study aimed to compare the fracture resistance of permanent molars with undermined walls restored with amalgam and composite resin along with cusp reduction, reinforcement of the walls with glass ionomer (GI) or no further intervention. **Methods:** This experimental in-vitro study evaluated 72 freshly extracted sound human third molars with almost equal dimensions. After cavity preparation, the teeth were then randomly divided into three groups. In group 1, the undermined area was reinforced with light-cure GI. Group 2 received a 2 mm cuspal cap, and group 3 received no intervention. Half of the teeth in each group were restored with composite resin and the other half with amalgam. The teeth then underwent thermocycling and their fracture resistance was measured by a universal testing machine. Data were analyzed using two-way ANOVA. **Results:** No significant difference was noted in fracture resistance among three procedures in teeth restored with composite (P=0.589). However, this difference was significant in teeth restored with amalgam (P=0.001). **Conclusion:** The current results indicated when esthetics is not a priority, applying amalgam restorations with GI-reinforced undermined walls might be suitable for restoration of freshly erupted permanent first molars with extensive caries.

Keywords: Fracture Resistance, Permanent Molar, Restoration, Glass Inomer

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Mohammadzadeh Z, Mohammadipoor H, khorakian F. In vitro fracture resistance of permanent molars with undermined walls restored with different materials and techniques. J Dent Mater Tech 2021; 10(2): 114-120.

Introduction

Dental amalgam has been the restorative material of choice especially for large cavities in load-bearing areas for many decades. However, safety concerns regarding the possible mercury toxicity, unesthetic appearance due to metallic color, and poor adhesiveness necessitating mechanical retention forms all contributed to its gradual replacement with composite resins (1). The first generations of composite resins were only indicated for primary carious lesions in low stress-bearing areas. However, improvements in adhesion strategies and mechanical properties of composite resins led to their popularity for posterior restorations (2, 3). Composite resins have some advantages such as more conservative preparation design, superior esthetic properties, and optimal adhesion to tooth structure which may strengthen the remaining tooth structure (4) or even reinforce the weak dentinal walls (5).

When the carious lesion undermines the cusps, it should be restored with a restorative material to protect the cusp against fracture; thus, crowns or full-coverage amalgam and composite resin restorations in adults or stainless steel crowns in children are often indicated for this purpose. If the thickness of the residual wall is ≥ 2 mm, there is no need to use additional materials to increase tooth resistance, and a direct resin restoration would suffice. However, when the wall thickness is ≤ 1.5 mm, reinforcement is required (6). Direct full-coverage restorations are often preferred by patients and are less costly than indirect crowns (7). Also, they improve the fracture resistance compared with restorations with no cuspal coverage (5). Polymerization shrinkage of full-coverage composite resin restorations may lead to deformation of tooth walls, cuspal deflection, or even enamel cracks and cuspal fracture (8). When the polymerization stress overcomes the bond strength, the interfacial sealing is lost, resulting in gap formation, leakage, postoperative tooth hypersensitivity, marginal staining, secondary caries, or even pulp necrosis (9).

The “composite-laminated glass ionomer (GI)” or the “sandwich technique” refers to the replacement of a substantial part of composite resin with GI cement, which is recommended for patients at high risk of caries (10). This technique has benefits such as caries prevention by providing a good marginal seal. GI type of cements can spontaneously bond to dentin and release fluoride. They have easy flow and can therefore easily fill the hard-to-reach areas and porosities in the internal surfaces and proximal boxes of class II cavities. They also provide superior adaptation and can serve as a flexible intermediate layer to relieve the stress of polymerization shrinkage of composite resin (11). Application of materials with a low modulus of elasticity is generally accepted to minimize the formation of cervical gaps and marginal leakage (12). The effectiveness of GI cement as an intermediate layer in composite resin restorations has been confirmed by previous studies to ensure better marginal adaptation (10-13).

Similarly, the application of GI cement or composite resin as a liner beneath the weakened and undermined walls of compromised teeth may increase the quality, longevity, and fracture resistance of amalgam restorations, particularly in cavities with thin walls in young children. As previously stated by Eidelman and Odont, composite bonding to undermined enamel walls of amalgam restorations can prevent the fracture of unsupported cusps and recover up to 65% of the lost cuspal stiffness (8).

It appears that restoration of severely weakened molar teeth with one layer of composite resin or GI cement might have advantages over the conventional composite or amalgam restorations (14, 15). Therefore, the purpose of this *in vitro* study was to assess the fracture resistance of permanent molars with undermined cusps supported by one layer of bonded composite or GI in comparison with full cusp coverage of teeth with extensive occlusal caries with amalgam or composite resin. The null hypothesis was that the cavity design (cusp preservation or cusp reduction) and the type of restorative material and liner (composite resin, GI, or amalgam) would have no significant effect on the overall fracture resistance of permanent molars with undermined cusps.

Materials and Methods

This in vitro experimental study evaluated 72 recently extracted sound human third molars, which had been extracted for periodontal, orthodontic or other purposes. The teeth had similar coronal dimensions. Ethical approval was obtained from the Human Research Ethics Committee of Mashhad University of Medical Sciences, Iran (IR.MUMS.DENTISTRY.REC.1397.081). Residual soft tissues, calculus, and dental plaque were removed by hand instruments, rubber cup and pumice slurry, and the teeth were then thoroughly rinsed with water. The teeth were then examined under a stereomicroscope (Dino lite Pro, Anmo Electronics Co., Taiwan) at X10 magnification and those with caries, cracks, or developmental and structural defects in the enamel structure were discarded and replaced. The selected teeth were then stored in 1% chloramine T solution at 37°C until the experiment. The teeth were then mounted in auto-polymerizing acrylic resin (Acropars, Marlic Co., Tehran, Iran) up to 1 mm cervical to their cementoenamel junction (CEJ). The longitudinal axis of the teeth was parallel to that of the mold.

Cavity preparation and restoration procedures

Class I cavities were prepared in the occlusal surface of the teeth by using a 1 mm straight diamond fissure bur in a high-speed handpiece under oil-free water irrigation. The cavities had approximately 3 mm depth and two-thirds of the intercuspal distance was removed. All cavity walls were prepared parallel to each other with a 90° cavosurface angle. No beveled edges were apparent on the cavosurface angles of the preparations. Next, a 1 mm round diamond bur was used to undermine all dentinal walls of the cavities by 1 mm. All cavities were prepared and checked by one operator who ensured the same size of the cavities by using a periodontal probe and standard burs. An individual not involved in the study blindly divided the prepared teeth into 6 groups of 12 teeth according to the preparation design and the restoration procedure as follows:

Group I: The teeth in this group were restored with amalgam specimens (GS-80, SDI- Australia).

This group served as the positive control group.

Group II: The teeth in this group were restored with composite resin Z250 composite resin (3M ESPE, St. Paul, USA) This group also served as the positive control group.

Group III: After primary cavity preparation, the undermined cusps were strengthened by using light-cure GI (GC, Tokyo, Japan). The cavity was then restored with amalgam.

Group IV: After primary cavity preparation, the undermined cusps were strengthened by using light-cure GI (GC, Tokyo, Japan). The cavities were then restored with composite resin. For this purpose, 35% phosphoric acid (Ultra-etch; Ultradent, South Jordan, UT, USA) was applied for 20 s over the enamel margins and for 10 s over the dentin substrate. Then, it was rinsed with air/water spray for 20 s, followed by gentle air drying to avoid desiccation. After that, two consecutive layers of Adper Single Bond 2 (3M ESPE, St. Paul, MN.USA) as an etch and rinse light-cure adhesive would be applied with a microbrush; the excess material was gently air-thinned, and the surface was cured by a LED curing unit (Bluephase C8; Ivoclar Vivadent, Schaan, Liechtenstein) with an intensity of 800 mW/cm^2 for 20 s. Finally, Z250 composite resin (3M ESPE, St. Paul, MN.USA) was applied using the incremental technique (12). The thickness of each increment was < 1.5 mm to ensure adequate polymerization. Each increment was polymerized for 20 s using a LED curing unit with a light intensity of 800 mW/cm^2 in contact with the occlusal surface of each tooth. The power density was checked after five exposures.

Groups V and VI: The weak cusps were reduced by 2 mm, and four slots with 0.5 mm depth and 1 mm width were prepared on each reduced cusp with ¼ round bur. Then, the matrix band was placed and secured using a Tofflemire matrix retainer (Tofflemire matrix; Miltex Inc., York, PA, USA). The matrix was tightened and held by finger pressure against the gingival margin of the cavity, such that the preparations could not be overfilled at the gingival margin. The teeth were then restored with amalgam and composite resin, respectively.

After 24 h of storage in an incubator at 37°C and 100% humidity, the amalgam fillings were polished with black and brown polishing rubbers, respectively. The composite resin samples were finished with fine-grained flame and football-shaped diamond burs, followed by the polishing steps with twisted rubber wheels.

To simulate the thermal changes in the oral cavity, all teeth underwent thermocycling in a thermocycler (Nemo Co., Mashhad. Iran) between 5°C and 55°C with a dwell time of 15 s and a transfer time of 15 s for 5000 cycles**.**

Testing procedure

The teeth were subjected to compressive load application in a universal testing machine (model STM-20; Santam, Tehran, Iran). A smooth stainless steel cylinder with a head 6 mm in diameter was mounted in a custom-made testing head to ensure that it would come into contact with the facial and lingual cuspal slopes. The cylindrical head came into contact with both the restoration and the cavity margin. The testing machine applied load parallel to the longitudinal axis of the tooth at a crosshead speed of 1 mm/min until tooth fracture. The failure load of restorations was recorded in Newtons (N).

Statistical analysis

The normal distribution of the data was evaluated by the Shapiro-Wilk test. Two-way ANOVA and independent samples t-test were applied to compare the fracture resistance of the study groups. A 95% confidence interval was used to evaluate the statistical significance using SPSS version 18 (SPSS Inc., Chicago, IL, USA).

Results

This study compared the fracture resistance of third molars with different cavity preparation designs restored with different restorative materials and techniques. Table 1 shows the mean and standard deviation of fracture resistance of the teeth. The Shapiro-Wilk test revealed a normal distribution of data (P>0.05). Based on two-way ANOVA, the interaction effect of the type of restorative material and technique of cuspal reinforcement on fracture resistance was significant (P=0.010). When composite resin was used for cavity restoration, no significant difference was noted in fracture resistance (P=0.589) while amalgam showed significant differences (P=0.001). In teeth restored with amalgam, the mean fracture resistance was significantly greater in the groups reinforced with GI and amalgam alone compared with the capped group.

In both GI-reinforced groups, the mean fracture resistance was not significantly different from that in amalgam or composite resin groups (P=0.773). In both groups with cuspal reduction, the mean fracture resistance was significantly higher in the group restored with composite resin compared with amalgam (P=0.038).

There was no significant difference between the groups restored with amalgam and composite resin alone (P=0.064).

Table I. Comparison of fracture resistance of the groups

Reinforcement technique	GI application	Capping	None	ANOVA result
Restorative material	Mean ± std. deviation	Mean ± std. deviation	Mean ± std. deviation	
Amalgam	3964.92[a] ± 1335.84	2220.50[b] ± 850.97	3300.50[a] ± 731.13	F=9.17 P=0.001
Composite resin	3399.45 ± 919.82	3076.83 ± 1036.53	2983.58 ± 1124.90	F=0.54 P=0.589
Independent t-test	T=0.29 P=0.773	T=2.21 P=0.038	T=1.95 P=0.064	

* Similar letters indicate absence of a significant difference between the groups

Discussion

In pediatric dentistry, severely decayed permanent first molars are commonly encountered. Due to severe caries in such teeth, often a thin wall of tooth crown remains after caries removal, which is only composed of enamel. Since such patients are often in the age range of 6-12 years, indirect restorations such as porcelain-fused-to-metal crowns are not indicated for them due to inadequate tooth eruption, absence of complete occlusion, poor cooperation of the child, and high cost. Moreover, many of such teeth do not show pulpal exposure; thus, retention of restorations is another concern. Stainless steel crowns are not a suitable option either due to poor marginal adaptation and risk of recurrent caries, as well as instability of the vertical dimension of occlusion and the need for excessive tooth preparation. Thus, many dental clinicians may have some questions regarding the best treatment approach for such cases, whether to be the reinforcement of undermined cusps, cusp reduction, or no intervention. A suggested treatment option for such cases would be to use an intermediate restorative material. In general, use of intermediate materials with low modulus of elasticity is beneficial to minimize the difference between the modulus of elasticity of the restorative material and that of tooth structure. The modulus of elasticity of GI is lower than that of composite resin and amalgam. Evidence shows that the modulus of elasticity of the liner has a significant effect on fracture resistance of extensive amalgam restorations (11,13). GI applied as a liner absorbs not only the polymerization stress; however, the stress generated by the application of functional forces in the restored tooth. A previous study reported higher fracture resistance of teeth restored with amalgam and composite following GI reinforcement (11,13). Nevertheless, controversial results have also been reported regarding the effect of GI liner in amalgam restorations on fracture resistance; such controversies may be due to the application of different thicknesses of the liner. For example Farah et al. (16) showed that the fracture resistance of amalgam restorations with a liner with low modulus of elasticity was lower than the fracture resistance of restorations with a liner with higher modulus of elasticity.

Cusp capping is another suggested technique for restoration of severely damaged teeth. This study showed that capping of the thin cavity walls, compared with their reinforcement with GI liner or no intervention had no significant effect on fracture resistance. However, when amalgam was used as the restorative material, capping of the walls, compared with their reinforcement with GI or no intervention, significantly decreased the fracture resistance. In this study, the fracture resistance of the teeth restored with composite resin with capped cusps was significantly higher than that of teeth restored with amalgam. This finding was in agreement with the results of Mincik et al, (15) who demonstrated that the fracture resistance was higher in teeth with undermined walls capped with composite resin, compared with those capped with amalgam. Panahandeh et al, (17) and ElAyouti et al. (18) concluded that the fracture resistance of teeth capped and restored with composite resin was higher than that of uncapped teeth. In line with their findings, Ann Soncini et al. (19) reported that posterior teeth restored with composite had a 7 times higher need for repair than those restored with amalgam.

The current study revealed that when reducing the undermined walls, composite resin yielded superior results compared with amalgam. This difference can be attributed to the different nature of these restorative materials. Amalgam is a fragile material, which can cause restoration fracture under compressive forces. Thus, when preservation of the undermined walls is not possible due to the large extent of unsupported walls, the composite resin would be a better choice, irrespective of its fracture resistance, because it has higher elasticity than amalgam. Amalgam has long been used as the restorative material of choice for posterior teeth especially in developing countries. According to the results of this study, when amalgam is selected as the restorative material, the walls are better not to be capped. However, in case of poor cooperation of pediatric patients or other conditions, the treatment time should be shortened as much as possible. In such cases, the tooth can be restored with amalgam with no other intervention (such as reinforcing the walls or capping). It should be noted that the quality of amalgam is also important and can affect its mechanical properties. In contrast to our findings, Basir et al. (20) suggested capping of the undermined walls followed by amalgam restoration. The extent of capping of the walls, type of amalgam used, and its optimal condensation can affect the results as well.

Due to the increased demand for cosmetic dental restorations, composite resins are increasingly used for the restoration of posterior teeth. This study found no significant difference among the three groups restored with composite resin. Therefore, if the clinician selects composite resin as the final restorative material, the tooth can be restored with no additional intervention (such as capping or reinforcement of the walls) if the patient has poor cooperation or if long-term isolation is not possible. Since the use of GI as a liner is time-consuming, and no significant difference was found in fracture resistance of the abovementioned three groups, such teeth can be restored with composite with no intervention or with capping of the walls.

The difference between the current results and previous findings may be attributed to the differences in the storage media of the teeth, crosshead speed of the universal testing machine applying the compressive force, type and design of the load applicator, and difference in anatomical and morphological characteristics of the teeth. Since the quality and quantity of the remaining tooth structure are among the most influential factors on fracture resistance, the extent of undermined walls or the extent of capped walls is also considered an important factor in this respect. Many previous studies on fracture resistance of the teeth used premolars for this purpose (5,14,15). However, in this study, we had to use third molars since extracted sound first molars were hard to collect. We tried to use teeth with similar dimensions. However, due to morphological differences in the structure of third molars and first molars, complete simulation of first molars in terms of size and shape was not possible.

According to the current results, in teeth with deep cavities and thin enamel walls, preservation of intact walls and the use of high-quality amalgam may be a better choice. Preservation of undermined walls and their reinforcement with GI is also a better choice than capping of the walls. In the case of reinforcement of the walls with GI cement, the type of final restorative material would have no significant effect on the fracture resistance. In fact, depending on the clinical situation, the possibility of isolation, and esthetic considerations, both amalgam and composite resins can be used for the restoration of severely damaged permanent molars with undermined cavity walls.

With regard to the clinical implications of the current findings, it can be stated that in young cooperative children, the cavity walls should be preferably reinforced with GI, and then the tooth can be finally restored. In uncooperative children or in the case of difficult isolation, the undermined walls can remain untouched, and the cavity can be restored with a high-quality final restorative material. It should be noted that although the reinforcement of the walls showed superior fracture resistance in this study, the difference was not significant. In case of using amalgam, the walls are better not to be capped. If the residual walls are highly undermined, capping of the walls and final composite restoration can be a suitable treatment option.

Limitations and suggestions:

Unavailability of permanent first molars with standardized size and morphology was the main limitation of this study. Future studies are required on teeth with standardized dimensions. Also, encapsulated GI cements can be used in future studies.

Conclusion

The current results revealed that the fracture resistance of teeth restored with amalgam (with or without GI reinforcement) was higher than that of teeth restored with composite resin, but not significantly. In the case of selection of composite resin as the final restorative material, the undermined walls should be either capped or reinforced.

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Conflict of interest

Current research seem is free of conflict of interest.

Acknowledgment

There is no acknowledgment for this study.

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