

Comparison of the Effect of Direct and Indirect Composite Resin Restorations on the Fracture Resistance of Maxillary Premolars: An In Vitro Study

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Abstract

Objective: Fracture resistance of the remaining tooth structure against masticatory forces is among the problems encountered when restoring extensive cavities. However, reinforcement of the remaining tooth structure may be possible by the use of adhesive restorative materials. Tooth reinforcement may be affected by the physical properties of direct and indirect composite resin restorations. The aim of this study was to compare the effect of direct and indirect composite resin restorations on the fracture resistance of maxillary premolars with mesio-occluso distal (MOD) cavities.

Methods: In this in-vitro experimental study, 24 human caries-free maxillary premolars with no restorations or cracks that had been extracted within the previous 6 months were selected and MOD cavities were prepared with a buccolingual width equal to two-third of the intercuspal distance. The teeth were divided randomly into 3 groups of 8 each: A (direct restoration), B (indirect restoration) and C (preparation without restoration) and underwent fracture test with universal testing machine. ANOVA and Tukey's tests were used for statistical analysis; the level of significance was set at 0.05.

Results: The mean fracture resistance was 1314.75 ± 332.26 , 1192.25 ± 352.45 and 382.45 ± 142.51 for direct restoration, indirect restoration and preparation without restoration groups, respectively. There was no significant difference between groups A and B ($P=0.60$), whereas the difference between groups A and C ($P=0.00$) and also B and C ($P=0.00$) was statistically significant.

Conclusion: Based on the present study results, both direct and indirect composite restorations increase fracture resistance of teeth and could be an ideal option for restoring teeth weakened by wide cavity preparations.

Key words: Composite restoration, Inlay, Fracture resistance, Premolar tooth

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Introduction:

Reduction in tooth stiffness after the preparation of large cavities and increased risk of tooth fracture are among the common problems in restorative dentistry (1). Therefore, providing the resistance form when preparing a cavity is an important principle in operative dentistry. According to a study conducted by Joynt et al, in 1987, preparation of an occlusal cavity reduces the tooth stiffness by 20%. If a marginal ridge is also involved and removed during this preparation the occlusal cavity transforms into a

proximal cavity and the tooth stiffness further reduces by 2.5 folds resulting in an overall 46% reduction in tooth stiffness. If both marginal ridges are included in the cavity preparation design, the stiffness decreases by 63% (2). Dalpino et al, in 2002 showed that both cavity preparation designs of MOD cavity preparation with 1/2 intercuspal distance, rounded internal angles and convergent walls and MOD cavity preparation with 1/2 intercuspal distance and divergent walls weakened the remaining tooth structure (3).

The studies conducted on this subject have

raised hope for reinforcing the remaining tooth structure by the application of adhesive restorative materials (3-5). However some questions still need to be answered; for instance, it is important to know that in what restorative technique the remaining tooth structure is better reinforced and how important is the role of bonding agents in attaching the restorative material to the tooth structure and restoring the primary strength of the tooth after its preparation.

Considering the improved quality of dental materials and progressions made in the manufacturing of bonding agents, reinforcement of tooth structure by the application of composite resins seems possible (6).

Schwartz et al, (2006) believe that composite resins are capable of transmission and distribution of functional stress because of their bonding ability to the remaining tooth structure. According to them, composite resins are capable of reinforcing and restoring the teeth weakened by wide cavity preparations; whereas, intra coronal metal restorations may act like a wedge between the buccal and lingual cusps and increase the risk of cusp fracture. On the other hand, in composite restorations, cuspal flexure under heavy occlusal loads decreases. Therefore, development and propagation of cracks that can eventually lead to tooth fracture are delayed (7). It seems that indirect composite restorations have some differences with direct restorations in terms of their role in tooth reinforcement.

Camacho et al, in 2007 revealed that direct and indirect composite restorations were similar in terms of reinforcing the remaining tooth structure(8); whereas, Sun in 2008 demonstrated that teeth restored with direct composite resin had a significantly greater fracture resistance than teeth with direct and indirect composite inlays (9).

As mentioned earlier, physical properties of direct and indirect composite restorations may affect the fracture resistance of restored tooth. Therefore, the present study was conducted aiming at comparing the effect of direct and indirect composite restorations on fracture resistance of maxillary premolars with MOD cavities.

Methods:

In this in-vitro experimental study, a total of 24 human caries-free premolar teeth with no restorations or cracks were selected. These teeth had been extracted within the previous 6 months and stored in water. Samples were mounted in acrylic molds up to 1 mm below the CEJ and randomly divided into three groups of 8 each: A (direct restoration), B (indirect restoration) and C or the controls (preparation with no restoration).

Period of storing the teeth after their extraction and storing conditions such as the storing medium and temperature are among the factors that can affect the results. In this study, the teeth were stored in water (tap water) after their extraction and throughout the study period. Preparation design was similar in the three groups and was done as follows:

All samples received MOD preparation with 008 burs (Tizkavan, Tehran, Iran). Depth of preparation in all samples was 3 mm from the occlusal surface. For further precision, a specific bur with a 3 mm cutting surface was used. The buccolingual width of the preparation cavity was equal to two-third of the intercusp distance. In order to achieve this goal, the intercusp distance in all samples was measured with a caliper and the obtained figure was recorded. Two-third of the recorded figure was calculated and considered as the box width and the buccal and lingual preparation walls kept the same distance from the central groove. In order to form the walls divergent in the indirect group, the width of cavity at the pulpal floor was formed one millimeter smaller than its width at the occlusal floor. After completion of preparation, all surfaces were washed and air dried using water and air spray. In the direct restoration group, the prepared cavities were etched with 37% phosphoric acid (Ivoclar Vivadent, Schaan, Liechtenstein) for 15 seconds and then rinsed and gently air dried for 5 seconds using water and air spray. Air drying should not cause the dentin surfaces to lose their shine. Excite bonding (Ivoclar/Vivadent, Schaan, Liechtenstein) was uniformly applied on the surfaces with a microbrush. Fifteen seconds later, gentle air spray was used to evenly

distribute the bonding agent. Light-curing was done from one millimeter distance from the occlusal surface for 20 seconds. The first layer of composite resin was applied filling half the cavity depth and light-cured from the occlusal surface with one millimeter distance for 40 seconds. The second increment was then applied and cured for 40 seconds. After removal of matrix band, final curing was done for 40 seconds from the buccal and 40 seconds from the lingual surface. Occlusal surface was finished and polished using composite finishing and polishing burs. In the indirect restoration group, matrix band was placed and paraffin was applied on the internal surfaces of the cavity with a micro brush. The desired thickness was achieved using the air spray. First layer of composite resin was applied filling half the cavity depth and cured from one millimeter distance of the occlusal surface for 40 seconds. Second layer was applied afterwards and cured the same way for 40 seconds. After removing the matrix band, excess material was removed and the occlusal and proximal surfaces were finished and polished with composite finishing and polishing burs. Inlay was then removed from the cavity and the cavity was washed and air dried using water and air spray.

Inlay was cured for 40 seconds from the buccal, lingual, mesial, distal and gingival surfaces and sandblasted. All surfaces in the cavity and the inlay surfaces were etched for 15 and 5 seconds, respectively with 37% phosphoric acid (Ivoclar Vivadent, Schaan, Liechtenstein). After rinsing and air drying, Panavia ED primer II A and B were mixed in equal amounts according to the manufacturer's instructions and applied to all cavity surfaces with a micro brush. Thirty

seconds later, all surfaces were gently air dried. Equal amounts of Panavia F 2.0 base and catalyst (Kuraray Medical Inc, Tokyo, Japan) were mixed for 20 seconds and applied to buccal, lingual and gingival walls of the inlay. Inlay was then placed inside the cavity. After ensuring correct and complete sitting of the inlay, excess Panavia cements were partially cured for 2 to 3 seconds to facilitate their removal. After removal of excess cement, restoration margins were cured for 20 seconds at each surface using LED light-curing system (Metron, Kerr). Margins were then covered with Oxyguard II and samples were exposed to open air for 3 minutes to accelerate the set of Panavia. The control group samples received preparations similar to the other two groups but were not restored. Samples were then loaded to fracture in Instron Universal Testing Machine (model H206) in the Metalogy Department of Tehran University to evaluate their fracture resistance. Specimens were subjected to a compressive axial loading in the Universal testing machine at 1.0 mm/minute by means of a steel ball (6 mm in diameter). Obtained data were entered into SPSS version 13.0 software and the mean fracture resistance in each group was calculated. ANOVA was used to find significant differences in fracture resistance between the groups. Tukey's test revealed the groups with significant differences. $P < 0.05$ was considered statistically significant.

Results:

Results of fracture resistance of understudy groups are presented in Table 1.

Table 1. Comparison of fracture resistance between understudy groups

Understudy group	Minimum (N)	Maximum (N)	Mean± SD
Direct Restoration (Group A)	718	1850	1314.75±332.26
Indirect restoration (Group B)	840	2000	1192.25±352.45
Preparation with no restoration (Group C)	160	550	382.45±142.51

ANOVA revealed significant differences between different groups ($P=0.00$). Tukey's test was used to find significant differences between

the understudy groups and yielded the following results:

A. No significant difference was found

between groups A and B in fracture resistance (P=0.60)

- B. Significant difference was detected between groups A and C (P=0.00)
- C. Significant difference was found between groups B and C (P=0.00)

Discussion:

The effect of bonded composite restorations on improving fracture resistance in large MOD cavities has been widely investigated (1, 10-14). Cusp fracture in teeth with extensive MOD cavities restored with amalgam has been frequently seen due to the inability of this material in reinforcing the weakened cusps (1, 13,15).

For direct restoration of endodontically treated posterior teeth, an optimal restorative material should have the durability of amalgam and be able to increase fracture resistance by bridging the remaining cusps together. Numerous studies have documented the successful application of composite resins for restoring pulpless teeth and it has been confirmed that tooth weakening subsequent to MOD cavity preparation can be successfully compensated with composite restorations along with the application of bonding agents (4).

Reeh in his study in 1989 reported that the fracture resistance of composite restorations with enamel and dentin etch was significantly greater than that of composite restorations with enamel etch only because in the first group a large dentin surface is available for bonding to composite resin (16).

Several studies have supported the use of bonded composite resins as the final restoration for endodontically treated teeth (4,17,18). Bonding agents provide adequate retention for the composite resin and form an adherent bridge between buccal and lingual cusps in severely weakened teeth (4). In other words, these materials increase cuspal stiffness through cuspal splinting. Use of dentin bonding agents in composite resin restorations can enhance this effect (17,19).

Several studies conducted on bonded restorations have proved that combined enamel- and dentin-bonded composite resins are significantly more resistant to fracture than

enamel-bonded resins (17).

Hernandez in his study in 1994 showed improved cuspal fracture resistance in premolars with MOD cavities restored with a combination of glass ionomer cement and composite resin (20).

Wendt et al, in 1997 studied MOD cavities in maxillary premolars restored with different restorative materials and revealed that composite restorations along with bonding agents have the greatest fracture resistance. However, no statistically significant difference was detected between the cavities restored with composite resin and those restored with a combination of glass ionomer and composite resin (21).

In another study by Ausiello in 1997, fracture resistance of molars with large deep MOD cavities restored with adhesive systems was assessed. Cuspal fracture resistance of composite restorations with dentin bonding agents was significantly higher than that of bonded amalgam restorations (4).

Some other studies by Burke (1994) and Trope (1991) also confirmed increased cuspal fracture resistance in teeth etched and bonded to resin restorations (18, 22). On the other hand, Ruyter (1992) reported that direct composite restorations had a better bonding with tooth compared to indirect restorations because in direct inlays more free radicals are present to react with cement (23). Based on this theory, for small enamel caries we can easily ignore the indirect technique which is difficult, time consuming and costly. Ghasemi et al, in 1997 in their study concluded that for enamel carious lesions above the CEJ, direct technique is superior to indirect method (24).

Lopes et al, in their study in 1991 on maxillary premolars found that indirect composite restorations in large MOD cavities can improve tooth stiffness as much as that of sound teeth. They attribute this to the high level of polymerization and high bond strength between the tooth and inlay (25). Cubas et al, in their study in 2010 concluded that indirect composite resin restorations offer better performance than ceramic restorations, regardless of the cavity design (26).

Based on the results of the present study, restoring teeth with composite inlays has a smaller effect on tooth reinforcement compared

to direct restorations. However, this difference was not statistically significant. This finding is in accord with the results of Camacho and colleagues in 2007 who demonstrated that direct and indirect composite restorations are similar but inferior to the control group in terms of fracture resistance (8). However, Dalpino et al, in 2002 failed to find a significant difference between intact teeth and those restored with direct or indirect restorations ($P=0.05$)(3).

In contrast to the present study results, Sun and colleagues in 2008 showed that teeth restored with direct composite restorations had a significantly higher fracture resistance than those with composite inlays (9).

Furthermore, in the present study, unrestored teeth were significantly weaker than those with direct and indirect composite restorations which is in accord with Bezerra and Santos study in 2005 and Sun et al, study in 2008 (1,9).

Considering the difference in stiffness and bond strength (which are both among the important and effective factors on increasing the fracture resistance of tooth after restoring with composite resin) of teeth restored with direct composite resin and composite inlays, it seems that increased fracture resistance of teeth after restoration with composite inlay has a different pattern than the reinforcement mechanism when direct restoration with composite resin is used. Number of studies conducted on this particular subject is scarce. Thus, the authors decided to evaluate and compare the fracture resistance of two aforementioned restoration techniques. Based on the obtained results, teeth restored with composite inlays have a lower fracture resistance compared to those restored with direct composite resin. However, this difference was not statistically significant. To justify this difference, the following reasons may be mentioned:

1- The bond between the tooth and the composite inlay is weaker than the bond between the tooth and direct composite restoration which is due to the higher polymerization of composite resin in inlays. One of the main problems during the cementation of composite inlays is the absence of adequate number of double bonds at the surface to bond with the luting cement and the tooth structure. As a result,

the bond strength between the tooth and inlay is lower than that of tooth and direct composite restoration. Since the reinforcement of remaining tooth structure in a restored tooth depends on the bond strength, the abovementioned outcome is predictable.

- 2- The second reason may be the higher stiffness of inlay compared to direct restoration. The stiffness of composite resin depends on its degree of polymerization which is higher for inlays. Therefore, when occlusal loads are applied a greater wedging effect is exerted on the tooth and teeth with inlay restorations would be more fragile and susceptible to fracture than teeth with direct composite restorations.
- 3- The C factor (configuration factor) during the curing of inlay is much more than that of direct composite restoration and consequently greater tension is applied to the bonding area. This tension may cause micro-cracks to develop in the tooth structure and when loaded in Instron machine, crack propagation results in earlier tooth fracture.
- 4- In direct composite restorations, the polymerization shrinkage of the composite resin increments results in cuspal flexure towards each other and the tooth is subjected to compressive forces. Therefore, greater tensile forces are required for tooth fracture because parts of this force are used to neutralize the mentioned compressive forces.
- 5- The bond between the composite resin, bonding agent and tooth in the direct restoration group is more uniform compared to the indirect restoration group. Thus, uniformity of teeth in the direct restoration group is more similar to the healthy teeth group.

Conclusion:

Based on the current study results, direct and indirect composite restorations increase the fracture resistance of teeth and therefore, could be an ideal option for restoring teeth weakened by wide cavity preparation. Although, the

mechanical properties of indirect restorations are superior to direct ones, no statistically significant difference was detected in fracture

resistance between the two groups. Therefore, no superiority was observed in this respect for the indirect restorations over the direct ones.

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