Fracture Resistance of Maxillary Premolars Restored with Direct and Indirect Adhesive Techniques

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ABSTRACT

Objective: To evaluate the fracture resistance of teeth restored using 2 intracoronal direct and indirect adhesive techniques.

Methods: Forty maxillary premolars were divided randomly into 4 groups of 10: group 1, intact teeth; group 2, mesio-occlusodistal (MOD) cavity preparation associated with endodontic therapy (unrestored); group 3, MOD cavity preparation and restoration with direct composite resin (Z100, 3M ESPE); and group 4, MOD cavity preparation and restoration with indirect ceramic inlay (IPS Empress, Ivoclar-Vivadent). Specimens were subsequently submitted to an axial compression test, using an 8-mm diameter steel ball at a loading speed of 0.5 mm per minute, until their fracture.

Results: The average compression force causing cuspal fracture in the 4 experimental groups was group 1, 138.4 kg; group 2, 49.0 kg; group 3, 105.4 kg; and group 4, 82.7 kg. ANOVA analysis and Tukey tests showed that cavity preparation significantly weakened the remaining tooth structure. The fracture resistance of teeth restored using direct composite resin was not significantly different from that of teeth restored with ceramic inlays ($p > 0.05$). None of the materials tested was able to restore completely the fracture resistance lost during cavity preparation.

Conclusions: Cavity preparation significantly weakens the remaining tooth structure. Direct and indirect intracoronal adhesive restorations can partly restore fracture resistance of teeth weakened by wide cavity preparation.

MeSH Key Words: bicuspid; composite resins; dental cavity preparation/adverse effects; dental porcelain

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Over the last few decades, the development of new materials and advances in restorative techniques in adhesive dentistry have made possible reinforcement of weakened dental structure.[1–3] The strengthening effects of adhesive restorations have been examined in several studies.[2–11] Teeth with wide mesio-occlusodistal (MOD) cavities restored with amalgam have frequently shown cusp failure due to the inability of this material to strengthen weakened cusps.[10,12] Bell and others[13] showed that large MOD cavities restored with amalgam frequently develop cusp failure because cracks are propagated under constant functional occlusal forces. Thus, teeth with large cavities are usually restored with onlays instead of inlays,[4,5] because when a significant amount of the tooth structure is lost, there is an increase in the fragility and susceptibility to fracture of the cusps.[3,14,15] Although the onlay restoration procedure provides a tooth-strengthening effect, it also requires the removal of additional tooth structure and, therefore, sometimes allows exposure of the metal.

Society's increasing emphasis on appearance allied with advanced adhesive techniques has expanded the range of possibilities for esthetic restorative procedures. Diverse adhesive restorative techniques that meet the need for esthetics and tooth strengthening have been proposed; among them, composite resin and ceramic inlays are the most frequently used. Several studies have attributed an additional reinforcement function to the direct composite resin method, compared with nonadhesive methods.[5,7,10,12]

Composite resins have been used in posterior teeth since the 1960s; however, the first generation of these materials showed great alteration in colour, low wear resistance and postoperative sensitivity.[16] Currently, these drawbacks have been minimized with the introduction of dentin adhesive systems with high bond strength and composite resins with improved physical properties and wear resistance as a result of a reduction in the size of filler particles and high inorganic load content.[16–18] However, polymerization shrinkage, marginal leakage, postoperative sensitivity and difficulty in obtaining proximal contact may still occur.[8,16]

Indirect restorations, such as ceramic inlays, have become popular, not only because of improved esthetics, but also because they provide tooth strength and allow for a reduction in the volume of composite resin, which is used only as a luting agent.[2,6] Ceramic inlays are known for their biocompatibility, chemical durability and optical properties. Although ceramics were first used in dentistry more than 100 years ago, the lack of adequate adhesion between ceramic and tooth made their performance clinically unacceptable.[19] Today, with recent advances in dentin adhesives and resin luting agents, ceramic inlays have become more useful. New types of ceramics with improved esthetic features and durability have been released in the last few years as alternatives to the traditional feldspathic porcelain.[20,21]

The aim of this in vitro study was to evaluate the effect of 2 adhesive techniques on the fracture resistance of premolars with deep MOD cavities extending into the pulp chamber. We tested the hypothesis that restoration of maxillary premolars with direct composite resin or with indirect ceramic inlays would confer a fracture resistance comparable with that of intact teeth.

Materials and Methods

Forty noncarious maxillary premolars extracted for orthodontic reasons were selected for this study. The inclusion criteria were that the teeth had similar buccolingual and mesiodistal width and no visible cracks. The teeth were thoroughly rinsed in running water, and excess tissue was removed. The teeth were stored in distilled water at 4°C until the experiment started.

Each tooth was vertically positioned and its root was embedded in a plastic cylinder of self-curing acrylic resin (30 mm in height and 20 mm in diameter) up to 1.0 mm below the cementoenamel junction. Each tooth was carefully positioned to maintain the occlusal surface parallel to the cylinder's base to permit correct alignment and prevent oblique forces during the axial compression test.

The 40 teeth were randomly divided into 4 experimental groups of 10 and treated as follows.

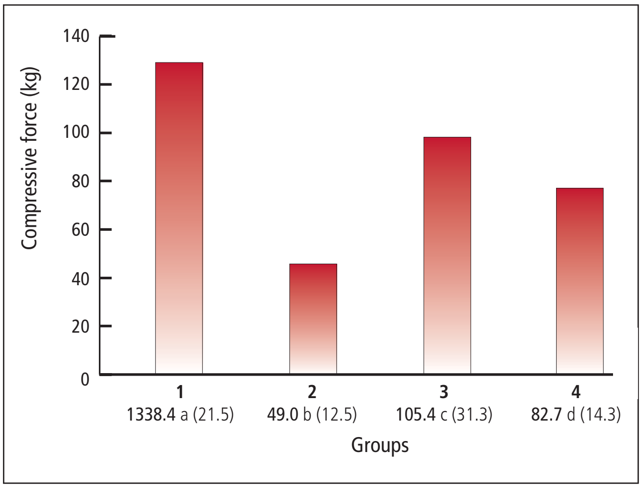
Group 1 — Intact teeth, no treatment.

Group 2 — Class II MOD cavities were prepared with the gingival cavosurface margin located 1.0 mm above the cementoenamel junction. The buccolingual width of each cavity, measured with a digital caliper (Mitutoyo Corp., Kawasaki, Japan), was half the intercuspal distance and extended into the pulp chamber. The depth of the cavities was 4.0 mm, without axial walls. Buccal and lingual walls diverged about 15 degrees. The cavities were prepared using a conical diamond bur (#3131 FG, KG Sorensen Ind. Com. Ltda, São Paulo, Brazil) with abundant air–water spray. Subsequently, access was obtained using a round diamond bur and the pulp chamber was filled with resin-modified glass ionomer cement (Vitremer, 3M ESPE, St. Paul, Minn.). These teeth were not restored.

Group 3 — Teeth were prepared in the same manner as those in group 2, then restored with composite resin (Z100, 3M ESPE). The entire cavity was etched with 35% phosphoric acid and thoroughly rinsed and dried, avoiding dehydration. Primer and bonding adhesive were applied according to the manufacturer's instructions (Scotchbond Multi-Purpose System, 3M ESPE) and light-cured for 10 seconds. The composite resin was placed into the cavity using the incremental insertion technique. The first increment was placed against the lingual wall and gingival seat of the proximal boxes and polymerized. Then, composite resin was placed against the facial wall and polymerized. This procedure was repeated for the occlusal portion of the preparation. The restoration was progressively built up with polymerization following each 2.0-mm increment. Each increment was light-cured for 40 seconds using a visible-light curing unit (XL2500, 3M; light intensity, 580 mW/cm^2). All restorations were finished with a fine diamond bur (#1190 F, KG Sorensen) under air–water spray and finishing discs (Sof-Lex XT, 3M ESPE), 48 hours after the restoration procedure.

Group 4 — Teeth were prepared in the same manner as those in group 2, then restored with ceramic inlays (IPS Empress, Ivoclar-Vivadent, Schaan, Leichtenstein). Following cavity preparation, a polyvinyl siloxane impression (Express, 3M ESPE) was made to produce a hard stone master model for each sample. The prepared teeth were stored in distilled water at 37°C until cementation of the inlays. The reinforced glass–ceramic IPS Empress system was fabricated by the heat-pressing technique, according to the manufacturer's instructions. The internal surface of each inlay was sandblasted with 50-µm aluminum oxide particles at a pressure of 87 psi (Optiblast, Buffalo Dental Mfg., Inc., Syosset, N.Y.). Subsequently, the internal surface was treated with

Figure 1. Mean compressive force (kg [standard deviation]) required for cuspal fracture in the 4 experimental groups. Means followed by the same letter are not significantly different ($p > 0.05$).



10% hydrofluoric acid (Dentsply International Inc., York, Penn.) for one minute. After rinsing, the internal surface was also silanized (Scotchbond Multi-Purpose System, 3M ESPE).

The entire cavity was etched with 35% phosphoric acid, rinsed and dried, avoiding dehydration. The dentin adhesive system (activator, primer and catalyst) was applied according to the manufacturer's instructions (Scotchbond Multi-Purpose System, 3M ESPE).

The resin luting agent (RelyX Adhesive Resin Cement, 3M ESPE) was mixed at a 1:1 ratio and applied to the internal surface of the inlay. While maintaining pressure with a ball burnisher, excess cement was carefully removed from the margins using a probe and a small brush. A visible-light curing unit (XL2500, 3M; light intensity, 580 mW/cm^2) was applied to each restoration surface for 40 seconds, for a total of 120 seconds. All samples were stored in distilled water at 37°C for 72 hours before testing.

Axial Compression Test

The samples were positioned to maintain the occlusal surface perpendicular to the loading axis. All specimens were submitted to axial compression in an Instron universal testing maching (model 4301, Canton, Mass.) using an 8-mm diameter steel ball at a loading speed of 0.5 mm per minute until their fracture. The steel ball contacted the buccal and lingual inclined cuspal planes, but not the restoration.

Analysis of variance (ANOVA) and Tukey tests were carried out on fracture resistance data.

Results

All samples failed with a buccal or lingual cuspal fracture after compression. Mean values of the compression force required for cuspal fracture (kg) and standard deviations for each experimental group are shown in **Fig. 1**. Statistical analysis revealed that the mean fracture load for group 1 (intact teeth) was significantly higher than that of the other groups ($p < 0.05$). Group 2 (prepared and not restored) exhibited significantly lower resistance to fracture than all other groups in this study. Groups 3 and 4 (restored teeth) had fracture loads that were not statistically different from each other.

Discussion

The effect of adhesive restorations for large MOD cavities in increasing fracture resistance has been extensively studied.[1–5,7,9–12,22] In our study, the fracture resistance of group 2 teeth (prepared, not restored) was significantly lower than that of group 1 (intact teeth). These data are consistent with those of Vale,[14] Mondelli and others,[15] Ausiello and others[1] and Dalpino and others,[3] whose studies pointed out the weakening effect of cavity preparation procedures. Hood[23] analyzed the biomechanics of the intact, prepared and restored tooth and considered that the degree of cuspal deflection increases with the depth of the preparation. According to Mondelli and others,[15] teeth with large MOD cavities are severely weakened due to the loss of reinforcing structures, such as the marginal edging, and become more susceptible to fractures; they suggested that cast restorations with cuspal protection should be indicated for preparations in which the width of the occlusal isthmus is half or more of the intercuspal distance.

According to Mackenzie,[5] however, the traditional method of providing reinforcement for weak teeth by using cuspal coverage, although ideal in some circumstances, has many drawbacks, such as poor esthetics, high cost and the removal of large amounts of dentin and enamel. Moscovich and others[24] showed that significant dental structure is removed to change a direct restoration into an indirect one. In recent years, acid etching has been used to bond various materials to the tooth and has been shown to strengthen the remaining dental structure. Several studies[4,5,25] have shown that MOD adhesive restorations can reduce fracture of endodontically treated premolars. Costa and others[25] verified that the fracture resistance of endodontically treated premolars was increased by MOD inlay cast restoration bonded with Panavia Ex resin (Kuraray Co., Ltd., Kurashiki, Japan).

In the current study, to fracture group 3 teeth (direct restoration with composite resin) an average load of 105.4 kg was needed, whereas a mean load of 82.7 kg was needed for group 4 teeth (restored with ceramic inlays). These results were not significantly different. Although direct composite resin and ceramic inlays restored fracture resistance to 76.2% and 59.8%, respectively, these materials did not restore all of the fracture resistance lost during cavity preparation, probably because of the large cavity preparations used in this study. These results are in accordance with those of Reel and Mitchell[22] and Watts and others,[26] who verified partial reinforcement of teeth restored with composite resin compared with intact teeth. Boyer and Roth[12] found that even though the use of dentin bonding agents had strengthened weakened cusps, the fracture resistance of teeth restored with composite resin was not fully recovered. However, other studies have shown different results: Jensen and others,[27] Ausiello and others,[1] Dalpino and others[3] and de Freitas and others[9] reported no significant difference in fracture resistance between intact teeth and teeth restored with composite resin.

De Freitas and others[9] investigated the effect of various adhesive restorative techniques on fracture resistance of maxillary premolars. The results showed that fracture resistance of the teeth restored with direct composite resin was not statistically different from that of intact teeth. However, the author of this study used samples with smaller cavity preparations than in the present study. The discrepancy between the results of our study and those of Redford and Jensen,[6] Jensen and others,[27] Ausiello and others,[1] Dalpino and others[3] and de Freitas and others[9] probably lies in differences in experimental conditions. In these other studies, smaller preparations and more conservative restorative procedures were used. In our study, diverse factors with potential to weaken the remaining dental structure were employed, i.e., large MOD cavities, no axial walls and endodontic access to simulate a clinical situation in which teeth are weakened by endodontic therapy.

With the development of dentin adhesive systems with high bond strength and the introduction of resin luting cements, the all-ceramic inlay became another restorative option for posterior teeth. According to Nasedkin,[8] Rosenblum and Schulman[20] and Peutzfeldt,[21] all-ceramic inlays are superior in terms of esthetics, biocompatibility, colour stability, shrinkage and wear resistance. However, they have some disadvantages, such as fragility, the need for a specialized laboratory, high cost and wear on the antagonistic tooth. Several studies have shown that the all-ceramic restorative procedure can provide a tooth-strengthening effect.[2,6] In the current study, we found that the mean fracture resistance of teeth restored with all-ceramic inlays was greater than that of unrestored teeth.

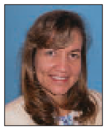
Differences between the 2 methods of intracoronal restoration were not statistically significant. Consequently, in choosing between these treatment options, other factors, such as wear potential, accuracy in fitting, marginal leakage, cost and number of dental appointments should be considered.

Conclusions

Based on the results obtained under in vitro experimental conditions and taking account of the limitations of this study, the following conclusions can be reached:

- Cavity preparation significantly reduced the fracture resistance of maxillary premolars.
- The hypothesis that direct composite resin and ceramic inlay restorations would increase fracture resistance to a level comparable with that of intact teeth was rejected.
- In terms of fracture resistance, there was no significant difference between direct composite resin restorations and ceramic inlays.

THE AUTHORS



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References

1. Ausiello P, De Gee AJ, Rengo S, Davidson CL. Fracture resistance of endodontically-treated premolars adhesively restored. *Am J Dent* 1997; 10(5):237–41.

2. Cotert HS, Sen BH, Balkan M. In vitro comparison of cuspal fracture resistances of posterior teeth restored with various adhesive restorations. *Int J Prosthodont* 2001; 14(4):374–8.

3. Dalpino PH, Francischone CE, Ishikiriama A, Franco EB. Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic material. *Am J Dent* 2002; 15(6):389–94.

4. Morin D, DeLong R, Douglas WH. Cusp reinforcement by the acid-etch technique. *J Dent Res* 1984; 63(8):1075–84.

5. Mackenzie DF. The reinforcing effect of mesio-occlusodistal acid-etch composite restorations on weakened posterior teeth. *Br Dent J* 1986; 161(11):410–4.

6. Redford DA, Jensen ME. Etched porcelain resin-bonded posterior restorations: cuspal flexure, strength, microleakage. *J Dent Res* 1986; 65(Abstr 1573):344.

7. Oliveira FC, Denehy GE, Boyer DB. Fracture resistance of endodontically prepared teeth using various restorative materials. *J Am Dent Assoc* 1987; 115(1):57–60.

8. Nasedkin JN. Porcelain posterior resin-bonded restorations: current perspectives on esthetic restorative dentistry; Part II. *J Can Dent Assoc* 1988; 54(7):499–506.

9. de Freitas CR, Miranda ML, Andrade MF, Flores VH, Vaz LG, Guimaraes C. Resistance to maxillary premolar fractures after restoration on class II preparations with resin composite or ceromer. *Quintessence Int* 2002; 33(8):589–94.

10. Hurmuzlu F, Kiremitci A, Serper A, Altundasar E, Siso SH. Fracture resistance of endodontically treated premolars restored with ormorcer and packable composite. *J Endod* 2003; 29(12):838–40.

11. Soares CJ, Martins LR, Pfeifer JM, Giannini M. Fracture resistance of teeth restored with indirect-composite resin and ceramic inlay systems. *Quintessence Int* 2004; 35(4):281–6.

12. Boyer DB, Roth L. Fracture resistance of teeth with bonded amalgams. *Am J Dent* 1994; 7(2):91–4.

13. Bell JG, Smith MC, du Pont JJ. Cuspal failures of MOD restored teeth. *Aust Dent J* 1982; 27(5):283–7.

14. Vale WA. Cavity preparation. *Irish Dent Rev* 1956; 33–41.

15. Mondelli J, Steagall L, Ishikiriama A, de Lima Navarro MF, Soares FB. Fracture strength of human teeth with cavity preparations. *J Prosthet Dent* 1980; 43(4):419–22.

16. Christensen GJ. Buonocore Memorial Lecture. Tooth-colored posterior restorations, 1997. *Oper Dent* 1997; 22(4):146–8.

17. Leinfelder KF. Using composite resin as a posterior restorative material. *J Am Dent Assoc* 1991; 122(4):65–70.

18. Leinfelder KF. Posterior composite resins: the materials and their clinical performance. *J Am Dent Assoc* 1995; 126(5):663–4, 667–8, 671–2.

19. Qualtrough AJ, Wilson, NH, Smith GA. Porcelain inlay: a historical view. *Oper Dent* 1990; 15(2):61–70.

20. Rosenblum MA, Schulman A. A review of all-ceramic restorations. *J Am Dent Assoc* 1997; 128(3):297–307.

21. Peutzfeldt A. Indirect resin and ceramic systems. *Oper Dent* 2001; (Suppl 6):153–76.

22. Reel DC, Mitchell RJ. Fracture resistance of teeth restored with Class II composite restorations. *J Prosthet Dent* 1989; 61(2):177–80.

23. Hood JA. Biomechanics of the intact, prepared and restored tooth: some clinical implications. *Int Dent J* 1991; 41(1):25–32.

24. Moscovich H, Creugers NH, De Kanter RJ, Roeters FJ. Loss of sound tooth structure when replacing amalgam restorations by adhesive inlays. *Oper Dent* 1998; 23(6):327–31.

25. Costa LC, Pegoraro LF, Bonfante G. Influence of different metal restorations bonded with resin on fracture resistance of endodontically treated maxillary premolars. *J Prosthet Dent* 1997; 77(4):365–9.

26. Watts DC, Wilson NH, Burke FJ. Indirect composite preparation width and depth and tooth fracture resistance. *Am J Dent* 1995; 8(1):15–9.

27. Jensen ME, Redford DA, Williams BT, Gardner F. Posterior etched-porcelain restorations: an in vitro study. *Compendium* 1987; 8(8):615–7, 620–2.