Effect of Restoration Method on Fracture Resistance of Endodontically Treated Maxillary Premolars

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Purpose: The aim of the present study was to compare the fracture resistance of endodontically treated maxillary premolars with mesio-occlusodistal (MOD) cavities restored using various restorative materials and luting agents. **Materials and Methods:** Eighty extracted human maxillary premolars satisfying certain predetermined criteria were subjected to seven different restoration methods (10 premolars per method). After endodontic treatment, an MOD cavity was prepared in each specimen, and restoration was carried out by one of the following methods: group 1 = control (intact premolars); groups 2 and 3 = restoration using a photo-cure resin composite with and without bonding, respectively; groups 4 and 5 = restoration using a cast-metal inlay with zinc phosphate and adhesive resin cements, respectively; groups 6 and 7 = restoration using a cast-metal onlay with zinc phosphate and adhesive resin cements, respectively; and group 8 = restoration using a hybrid resin onlay. A fracture test was conducted to determine the fracture resistance and fracture mode of each specimen. **Results:** Fracture resistance was greatest for teeth restored using a cast-metal onlay cemented with adhesive resin cement, but those fractures that did occur were generally unrestorable. Fracture resistance of teeth restored using a cast-metal inlay was also high. Fracture resistance for teeth restored using a resin composite was significantly lower, but the majority of these fractures were restorable. **Conclusion:** Endodontically treated maxillary premolars with MOD cavities could be successfully restored by cast onlay and inlay restorations luted with adhesive resin cement, but their failure mode was often unfavorable. *Int J Prosthodont 2004;17:94–98.*

Fracture of endodontically treated premolars is a common problem encountered in the clinical setting, and numerous reports have documented a high incidence of fracture for endodontically treated maxillary premolars.[1–6] To improve the strength of endodontically treated teeth, the post-core technique has been used, but long-term follow-up studies have shown that dislodgment and root fractures still occur.[7,8] With the recent advances in adhesive restorations, a concept of minimal intervention dentistry has been introduced to conserve the tooth structure as much as possible.[9,10] Several studies have shown that, provided most of its tooth structure remains, an endodontically treated tooth can be successfully restored by partial coverage using an adhesive, without the need for the post-core technique and a complete-coverage crown.[11–14] However, it is not clear which type of partial coverage is appropriate to provide sufficient strength.

The aim of the present study was to compare the fracture resistance of endodontically treated maxillary premolars with mesio-occlusodistal (MOD) cavities restored using various restorative materials and luting agents.

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Materials and Methods

Specimen Selection

A total of 496 extracted human maxillary premolars, free of caries, restorations, and fractures, were collected and stored in distilled water at 4°C. Each tooth was radiographed from two directions (buccolingual and mesiodistal). Subsequently, each radiograph was magnified 50 times using a profile projector (model V-16, Nikon), and eight measurements of tooth length and width were made. From the initial 496 premolars, 196 teeth with eight measurements within mean and 1 standard deviation were selected. From this sample, 80 premolars were then randomly selected and divided into eight groups of 10.

Cavity Preparations

In group 1, no cavities were prepared, and the 10 intact premolars thus served as a control. In groups 2 through 8, a 3.0 mm × 2.0 mm access cavity was prepared in each specimen for endodontic treatment. According to conventional methods, the root canal in each specimen was expanded to the No. 70 K file, and root canal filling was performed. In an aluminum cylinder (external diameter 20.0 mm, height 20.0 mm, thickness 1.0 mm), the root of all specimens was embedded up to 2.0 mm below the cemento-enamel junction (CEJ) using a self-curing acrylic resin (Unifast II, GC) (Fig 1). In the root region, additive silicone rubber impression material (Duplicone, Shofu) was applied to a thickness of 200 to 400 µm to act as an artificial periodontal membrane. In groups 2 through 5, root canal filling material was removed to a depth of 8.0 mm from the occlusal surface, and the canal was cleaned and primed for 20 seconds (ED Primer II, Kuraray). Each specimen was air dried. After applying a bonding agent (Photo Bond, Kuraray) and light curing for 10 seconds (Quick Light model VL-1, Kuraray), each canal was filled using a resin composite (DC Core, Kuraray) and light cured for 40 seconds (Quick Light). MOD cavities were subsequently prepared using an air turbine handpiece and a diamond high-speed bur while continuously spraying water. The buccolingual width on the occlusal surface of each cavity was 3.0 mm, the height of the axial wall was 2.0 mm, and the width and depth of the gingival wall were 4.0 mm and 1.5 mm, respectively (Fig 1). A finish line was set 1.0 mm above the CEJ. Additionally, in groups 6 through 8, an onlay cavity was formed in each specimen by eliminating 1.5 mm from the occlusal surface. A marginal bevel was not placed in any of the specimens.

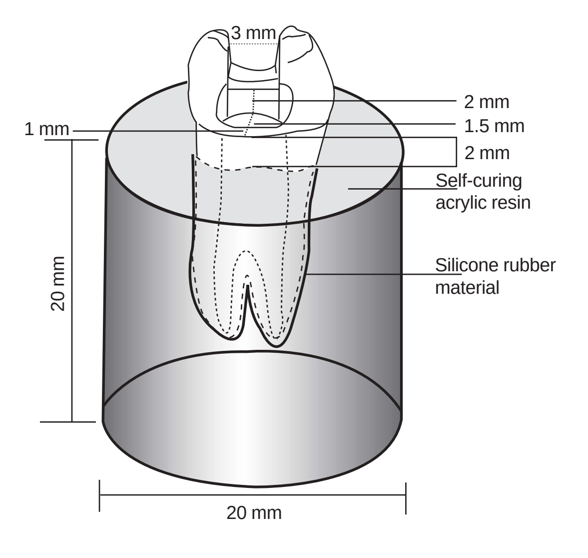

Fig 1 Embedded tooth and MOD cavity preparation.

Restoration Methods

The following restoration methods were employed:

- Group 1 = no restoration
- Group 2 = resin composite filling with bonding system
- Group 3 = resin composite filling without bonding system
- Group 4 = cast-metal inlay with adhesive resin cement
- Group 5 = cast-metal inlay with zinc phosphate cement
- Group 6 = cast-metal onlay with adhesive resin cement
- Group 7 = cast-metal onlay with zinc phosphate cement
- Group 8 = hybrid resin composite onlay with adhesive resin cement

In group 2, cavities were restored using a photo-cure resin composite (Clearfil AP-X, Kuraray), prior to which a bonding system (MEGA Bond System, Kuraray) was applied according to the manufacturer's instructions. The restoration was performed in layers, and each layer was photoirradiated for 30 seconds. In group 3, the photo-cure resin composite (Clearfil AP-X) was applied and cured in the same method described for group 2, but the bonding system was omitted. In group 4, a cast-metal inlay with a primed (Alloy Primer, Kuraray) internal surface was cemented in place with an adhesive resin cement (Panavia Fluoro Cement, Kuraray). In group 5, the procedure was as for group 4, except a zinc phosphate cement (Elite Cement 100, GC) was used instead of the adhesive resin cement. In group 6, a cast-metal onlay with a primed (Alloy Primer) internal surface was cemented with an adhesive resin cement (Panavia Fluoro Cement). In group 7, the procedure was as for

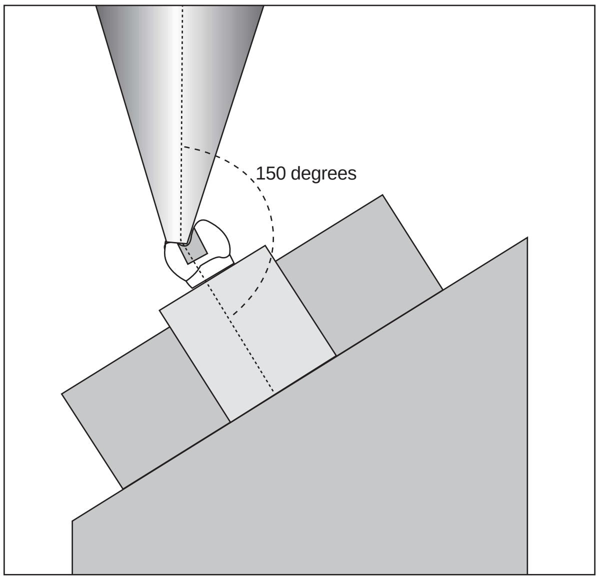

Fig 2 Fracture test.

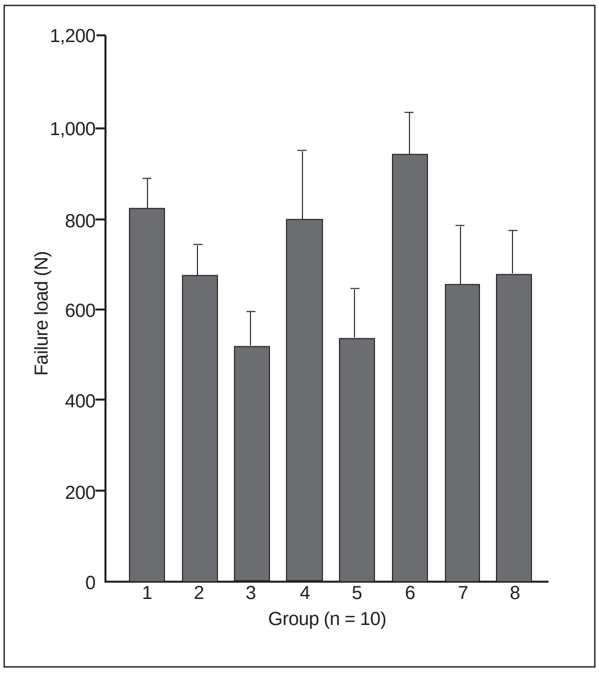

Fig 3 Fracture resistance for each group.

group 6, except a zinc phosphate cement (Elite Cement 100) was used instead of the adhesive resin cement. In group 8, a hybrid resin composite (Estenia, Kuraray) onlay was cemented using the adhesive resin cement (Panavia Fluoro Cement). This onlay was made by photopolymerization (αLight II, Kuraray) and heat polymerization (KL-310, Kuraray). After polishing, the internal surface of each resin onlay was sandblasted using 50-μm aluminum oxide particles and then treated with 37% phosphoric acid (K-Etchant gel, Kuraray). Subsequently, the resin onlay was subjected to a silane coupling treatment (Clearfil MEGA bond primer and Clearfil porcelain Bond Activator, Kuraray) and cemented.

For groups 4 through 7, casts were made using the indirect method. For each specimen, an abutment tray was used to take an impression using an additive silicone rubber impression material (Exafine, GC). This was used to prepare a working cast (New Fujirock, GC). Following wax-up, casting was performed using a gold alloy (Castwell MC, GC) and a vacuum-pressure casting machine (KDF-CASCOM, Denken). After adjusting and polishing, the internal surface of all cast-metal inlays and onlays was subjected to sandblasting using 50-μm aluminum oxide particles. For specimens in groups 2 through 8, an impression of the crown was taken prior to cavity preparation using a putty-type hydrophilic polyvinyl siloxane impression material (Exafine) to act as a guide to the shape of the crown on restoration.

Fracture Test

Following restoration, all specimens were stored in distilled water at 37°C for 24 hours prior to the fracture testing. Subsequently, an Autograph (AGS-5kND, Shimazu) was used to conduct a fracture test at a cross-head speed of 0.75 mm/min (Fig 2). The lingual cusp of each specimen was loaded at an angle of 150 degrees to its longitudinal axis. Compressive loading, up to failure, was converted using an A/D converter (RDM-200A, Kyowa), and a load-time curve was drawn for each specimen. Fracture resistance was defined as the amount of loading at the peak of the load-time curve. To compare fracture resistance between any two groups, a nonparametric analysis of variance (ANOVA; Kruskal-Wallis) and the Mann-Whitney *U* test were performed. Fractures were divided into two groups based on the extent of each fracture[15]: *(1)* restorable fractures = fractures stopping higher than 1 mm below the embedding resin surface; and *(2)* unrestorable fractures = fractures stopping lower than 1 mm below the embedding resin surface.

Results

The fracture resistance for group 6 was 943 N and greater than for all other groups ($P < .01$; Fig 3). The mean fracture resistance for group 1 (control) was 825 N, which did not differ from group 4 and was greater than for other groups (groups 2, 3, 5, 7, and 8; $P < .05$). As to the mode of fracture, more than 90% of

Table 1 Classification of Specimens from Each Group Based on Fracture Mode*

	Group							
Fracture mode	1	2	3	4	5	6	7	8
Restorable	6	9	10	5	9	1	6	6
Unrestorable	4	1	0	5	1	9	4	4

*Unit = teeth.

the fractures for groups 2, 3, and 5 were restorable. However, only 10% of the fractures for group 6 (onlays) were restorable, compared to 50% for group 4 (inlays). For groups 1, 7, and 8, 60% of fractures were restorable (Table 1).

Discussion

In the present study, maxillary premolars were used to determine the appropriateness of different restoration methods, since these teeth have been reported to show a high incidence of fractures in the clinical setting.[3,4,6] Many studies have addressed the fracture resistance of endodontically treated teeth.[12–14,16–19] In these studies, specimens were loaded at an angle of 180 degrees to their longitudinal axes, and fracture resistance was defined as fracture-inducing load. In the present study, however, specimens were loaded at an angle of 150 degrees[20,21] to their longitudinal axes, simulating the direction of occlusal forces during chewing movements. Furthermore, the method of loading might be controversial because the compressive static loading used in the present study is different from the dynamic loading in the mouth. Therefore, findings from this in vitro study should be interpreted with caution. Long-term clinical studies are necessary.

In the control teeth (group 1), only 60% of the fractures were restorable. Since the continuity of the tooth structure was maintained in this group of intact premolars, the loading stress did not concentrate in any particular area, thus resulting in this mix of fracture modes.[11] There was a significant difference of fracture resistance between groups 2 and 3, suggesting that the bonding system is useful for improving fracture resistance, as previously reported.[22,23] In addition, in group 2, 90% of the fractures were restorable. Most fractures occurred within the resin, not at the adhesion interface, thus suggesting a high degree of adhesion between the resin and tooth structure. However, the fracture resistance for group 2 was 82% of that for group 1, which cannot be estimated as sufficient for clinical use. A similar study documented that the fracture resistance for premolars restored using a photo-cure resin composite is 53% that of intact premolars,[19] while other studies found no significant differences in fracture resistance between intact premolars and premolars restored using a photo-cure resin composite.[24,25] These differences in results could reflect differences in restorative materials and loading methods used.

In the zinc phosphate–cemented groups, the fracture resistance of the onlay group (group 7) was significantly greater than that of the inlay group (group 5). As previously reported, this is most likely because compressive stress tends to concentrate in the case of inlays, while it tends to disperse in the case of onlays.[26–28] The fracture resistance for the zinc phosphate cement groups was significantly lower than that for the corresponding resin cement groups (groups 4 and 6). These results are in support of previous findings, which documented the effectiveness of adhesive resin cements for improving fracture resistance.[17,18] Others[18] compared the fracture resistance of inlays cemented using adhesive resin cements and onlays cemented using zinc phosphate cements and found that the fracture resistance for the latter is greater. That report is in conflict with the results of the present study. The difference may be caused by the prepared form of lingual cusps (cuspal coverage vs cuspal overlay) and luting agents (with vs without dentin bonding).

Although the percentage of unrestorable fractures varied depending on cements and restorative materials used, the risk of having unrestorable fractures appears to be high for onlay restorations. Cast-metal onlays luted with adhesive resin cement (group 6) showed the highest fracture load, but 90% of the fractures were unrestorable. In this situation, the clinical application of this restoration should be strictly confined. Furthermore, there must be some way to resolve this problem because this restoration does not have any posts in the root.

In group 8, restorations were performed using onlays made of a hybrid resin composite with a filler content of 87.7 wt% to 88.2 wt%. Several studies have reported the fracture resistance of premolars restored using a resin composite onlay and an adhesive resin cement to be comparable to that of intact premolars,[12,14] but in the present study, the fracture resistance for group 8 was significantly lower than that for group 1. In preparation for onlay placement in the present study, the buccal and palatal cusps were reduced at

1.5 mm, just like in cast-metal restorations. The cusp should probably be more reduced for the hybrid resin composite, since Burke et al[12] reported that the thickness needs to be at least 2.0 mm.

This study has revealed that endodontically treated maxillary premolars with MOD cavities could be successfully restored by cast onlay and inlay restorations, but their failure mode was often unfavorable.

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