Fracture resistance of root filled premolar teeth restored with direct composite resin with or without cusp coverage

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Abstract

Introduction: *This in vitro study compared fracture resistance of endodontically treated maxillary premolars with mesio-occlusal cavity preparation restored with different designs of direct composite resin restoration.*

Methods: *One hundred extracted sound human maxillary first premolars were randomly divided into 5 groups. Group 1 was unaltered premolars (negative control). Conventional endodontic treatment with mesial-occlusal cavity was performed on premolars in group 2 to 5. In group 2, the premolars were restored intra-coronally with direct composite resin (positive control). In group 3, palatal cusp of the premolar was reduced, and the cavity was restored with composite resin covering the palatal cusp (partial coverage). In group 4, buccal and palatal cusps were reduced; and the cavity and the cusps were restored with composite resin (full coverage). In group 5, buccal and palatal cusps were reduced but the distal marginal ridge was conserved. The cavity and the cusps were restored with composite resin (modified full coverage). All premolars were subjected to a progressive compressive loading parallel to the tooth longitudinal axis until fracture.*

Results: *The mean fracture resistance for group 1 to 5 were 1,131±207N, 904±184N, 927±224N, 1,095±289N and 1,085±243N, respectively (Group 1,4,5 > Group 2,3; P=0.004). Fractured cusp as the failure mode was observed in 20 (100%), 19 (95%), 16 (80%), 8 (40%) and 12(60%) premolars in Group 1 to 5, respectively.*

Conclusions: *When direct composite resin was used to restore endodontically treated maxillary first premolars involving a proximal surface, tooth restored with full coverage designs had an improved fracture resistance.*

Fracture resistance of endodontically treated premolars restored with direct composite resin with or without cusp coverage

Introduction

Extra-coronal restoration such as crown with cuspal protection is recommended for endodontically treated posterior teeth to prevent fractures and minimize coronal leakage (1). Esthetic crown in maxillary first premolar with proper labial emergency profile requires much tooth reduction. Edelhoff *et al.* (2) found that conventional completed crown preparation with 1.4 mm axial reduction facial shoulder and 0.7 mm lingual chamfer removed 75.6% of tooth structure. Remaining coronal tooth structure and functional requirements are important to determine the type of restoration (3). In many cases, the caries attack and subsequent endodontic procedures on this relatively small tooth necessitate post insertion. Mannocci *et al*. (4) suggested using direct composite restoration to restore teeth with endodontic treatment. This is supported by Plotino *et al*. (5) who found similar fracture resistance of endodontically treated teeth with direct or indirect composite restorations. Composite resin restoration conserves both tooth structure and the beauty of buccal surface. The adhesive property of composite resin restoration allows minimal cavity preparation and provides intra-coronal reinforcement.

Studies suggested cusp coverage of composite restoration to minimize tooth fracture (6-9). These studies investigated fracture resistance of premolars with mesial-occlusal-distal (MOD) cavity preparation. Nevertheless, there are circumstances that the cavity preparation involves only one proximal surface, and there is few study investigated premolars with mesio-occlusal (MO) or disto-occlusal (DO) cavity design. Extrapolation of the results on MOD to MO/DO cavity design cannot be justified because the marginal ridge has great influence on tooth strength (10). Thus, it is prudent to study the fracture resistance of endodontically treated premolar with a MO/DO cavity setting. This *in vitro* study was performed to compare the fracture resistance of endodontically treated maxillary premolars with different designs of MO composite resin restoration.

Materials and Methods

Human first maxillary premolars with single fused roots extracted for orthodontic reason on patients below 18 years old were collected. Parents of the patients were informed of the study's purpose and consented to donate the extracted premolars for research purposes. The extracted teeth were cleaned with a curette to remove attached periodontal tissue, calculus and plaque. They were examined under a 10x stereo-microscope and teeth with caries, cracks or significant development defects such as extensive enamel hypoplasia were excluded. Sound teeth with fully developed roots were selected. The root length and the mesio-distal width of the crown were measured with a vernier caliper. They were stored in 0.5% chloramine T solution at 23 ℃ and used for this study within three months.

One hundred stored premolars were chosen and randomly assigned to five groups (n = 20). The roots of the tooth sample were covered with a 0.2 mm layer of vinylpolysiloxane (VPS) impression material (Virtual, Ivaclar Vivadent, Schann, Lichtenstein) and embedded in acrylic resin (Shanghai Medical Instruments Co., Ltd, Shanghai, China) up to 2 mm below cementoenamel junction (CEJ) to simulate periodontal ligament and alveolar bone (11). Group 1 was unaltered sound teeth which served as negative control. Teeth in other four groups (group 2 to 5) underwent conventional root canal treatment. Step back technique was performed using ISO #30 K file (Mani Inc., Tochigi, Japan) as master apical file and ISO #40 K file as the last file in canal preparation. Sodium hypochlorite (5.25%) solution was used as irrigant. The prepared canals were obturated with cold lateral condensation technique using gutta-percha points (Diadent, Chongju City, Korea) and zinc-eugenol based sealer (Endomethasone, Septodont, Saint Maur des Fosses, France).

Slit design of MO cavity preparations without isthmuses (12) were prepared with high speed coarse grit diamond burs (TR12, Mani Inc., Tochigi, Japan) under water coolant. The bucco-lingual width was 4 mm and the proximal gingival margin was 1 mm above CEJ. (Figure 1) Group 2 was MO cavity preparation which served as positive control. Group 3 was MO cavity preparation with 2mm reduction on palatal cusp (partial coverage). Group 4 was MO cavity preparation with 2mm reduction on both buccal and palatal cusps (full coverage). Group 5 was MO cavity preparation with 2mm reduction on both buccal and palatal cusps conserving the distal marginal ridge (modified full coverage).

Gutta-percha was removed to the depth of 1 mm below proximal gingival margin and resin modified glass ionomer cement (Fuji II LC capsule, GC, Tokyo, Japan) was used as base material. An etch-and-rinse three steps adhesive (Scotch Bond Multipurpose, 3M ESPE, St. Paul, MN, USA) was applied. Nano-hybrid composite with low shrinkage and shrinkage stress (Tetric-N Ceram, Ivaclar Vivadent, Schann, Lichtenstein) was used to restore the premolar using layering technique. Proximal contact area and occlusal surface were restored using prefabricated VPS indices. The restoration was finished using super fine diamond point (SF102R, Shofu, Kyoto, Japan) and polished using silicone point (Silicone Midi, Shofu, Kyoto, Japan).

The teeth were stored in distilled water for one week to allow the sealer to set completely. Fracture resistance test described by Reeh *et al.* (13) was used in this study. The tooth was mounted in a customized fixture and subjected to axial compressive loading with crosshead speed of 0.5 mm/min (Model 3367, Instron, Canton, MA, USA). The vertical loading force was applied through a 8 mm diameter stainless steel ball parallel to the tooth axis. The contact point was approximately half way of the cusp triangular ridge. Fracture resistance was recorded at the peak of load-displacement curve. In addition, the failure mode was recorded using a simplified classification of cracked tooth proposed by the American Association of Endodontics (2008) (14). The failure mode recorded could be 1) fractured cusp which may extend to cervical third of the crown and 2) fractured tooth which includes cracked tooth and split tooth. Fracture resistance of premolars in the five groups was compared using one-way analysis of variance or ANOVA; multiple comparisons between groups were carried out using Fisher's LSD test. Failure mode of the five groups was analyzed with chi-square test. Pair wise comparison was performed to calculate the odds ratio. The significance level was set at 0.05.

Results

The results were summarized in Table 1. There was no statistical significant difference between the root length and crown width of premolars among the five groups. The mean fracture resistance for group 1 to 5 were 1,131±207N, 904±184N, 927±224N, 1,095±289N and 1,085±243N, respectively. The fracture resistance of premolars in group 1, 4 and 5 were significantly higher than that of group 2 and 3 (P= 0.004). Fractured cusp as the failure mode was observed in 20 (100%), 19 (95%), 16 (80%), 8 (40%) and 12(60%) premolars in Group 1 to 5, respectively. Multiple comparisons found Group 1 and 2 had more fractured cusp than group 4 and 5; and group 3 was more than group 4 ($P < 0.001$). The odd ratios (confidence interval) of fractured tooth of Group 4 and 5 to Group 2 were 28.5 (3.2-257.5) and 12.7 (1.4-114.4), respectively. In group 2, 18 out of 19 cusp fractures were adhesive failures, 14 of them occurred along the palatal adhesive interface. In group 3, 12 out of 16 cusp fractures were adhesive failures, 10 of them occurred along the buccal adhesive interface.

Discussion

Many factors such as the amount of residual tooth structure, the polymerization stresses of composite resin, the occlusion and opposing dentition, contribute to the achievement of clinical success with direct posterior composite restorations (15). This study allowed standardised assessment of the tooth strength in a laboratory environment. The axial compressive loading applied in this study did not completely mimic the occlusal force during mastication and the intraoral aging factors were not taken into consideration. Similar to all *in vitro* studies, there were limitations and the results should be interpreted with care.

The largest loss in tooth stiffness was related to the loss of marginal ridge integrity, not endodontic treatment (16). Mondelli *et al.* (7) found loss of one and two marginal ridges weakens the tooth by 40% and 60%, respectively. Thus conserving the marginal ridge and proximal wall is imperative to preserve the tooth strength. Shahrbaf *et al.* (10) reported the tooth strength could be substantially maintained when at least 1 mm of the marginal ridge thickness was kept. We also found similar results in this study by saving the distal surface and marginal ridge co-incidentally. As shown by this study, reducing the height of the marginal ridge by 2 mm had no remarkable effect on tooth strength because there is no significant difference in the fracture resistance of the restorations with full and modified full coverage designs.

We found that fracture resistance of premolar restored with full or modified full coverage designs significantly strengthened the teeth, and this is in agreement with other studies (6, 7). This finding suggests that composite resin restoration should cover both buccal and lingual cusps (full coverage) to reinforce endodontically treated premolar. The modified full coverage design is preferred because the distal marginal ridge is conserved with less tooth reduction.

Previous studies reported that fracture resistance MOD restorations could be improved by with full coverage design, but was lower than intact tooth (7-9). In this study, the fracture resistance of the full coverage composite resin restoration was almost the same as intact tooth. This might be attributed to the intact distal surface and marginal ridge because earlier studies reported marginal ridges have great influence on tooth strength (7, 10, 16). Nanostructured dental composites can have superior mechanical properties such as increased elastic modulus, strength, or resistance to fatigue fracture that can easily be tuned by small modifications of their building blocks (17). The new generation of composite resin might also contribute in maintaining the tooth strength by reducing the stress developed in the tooth. This was in agreement previous study (7).

Intra-coronal restorations in this study frequently fractured at the adhesive interface, probably because failure of the tooth-restoration interface is more likely than failure of the composite material. This is in agreement with previous studies (7,18). This study showed most intra-coronal restorations had adhesive failures on palatal cusp. The load on occlusal surface might cause stress concentration in the palatal cusp, and the restoration fractured at its weakest link. Fracture on restorations with partial coverage occurred primarily on buccal cusp, because the buccal adhesive interface was the weak link under loading. In restorations with full cuspal coverage, fractures might occur in other locations where stress was concentrated. Many full coverage composite restorations in this study had tooth fractured, but intact tooth exhibited coronal fracture when they failed with compressive loading. Dejak and Mlotkowski reported full coverage composite restoration demonstrated that stress built up along the tooth under loading (19). This might explain more tooth fracture observed in restoration with full cuspal coverage.

Conclusion

When direct composite resin was used to restore endodontically treated maxillary first premolars involving a proximal surface, tooth restored with full or modified full coverage designs had higher fracture resistance than intra-coronal or partial coverage design. The modified full coverage design is preferred because the distal marginal ridge is conserved with less tooth reduction.

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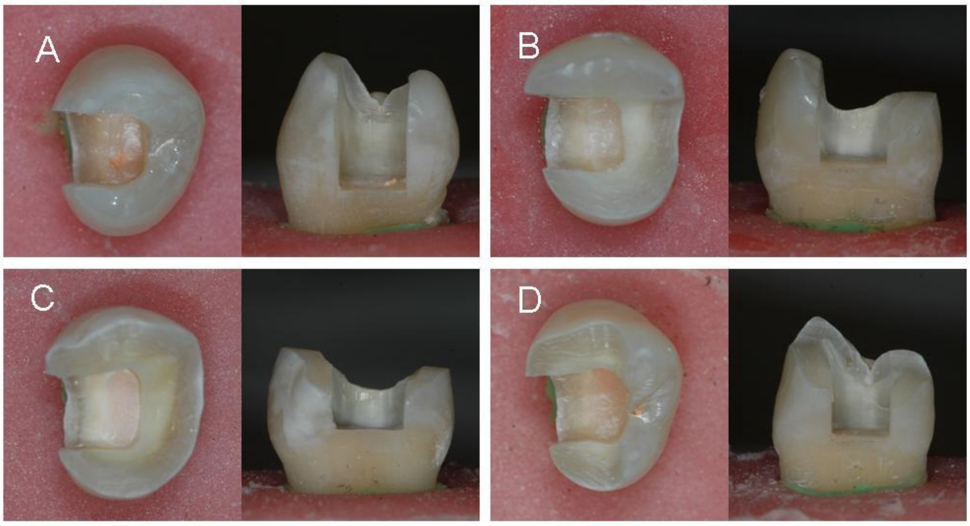
Figure 1 Preparation designs of the endodontically treated premolars



(A) Group 2, conventional intra-coronal MO cavity preparation;
(B) Group 3, MO cavity preparation, partial cusp coverage;
(C) Group 4, MO cavity preparation, full cusp coverage;
(D) Group 5, MO cavity preparation, modified full cusp coverage.

Table 1 Root length, crown width, fracture resistance and fracture type according to treatment group

Group (n=20)	Premolar Treatment	Root length / mm (SD)	Crown width / mm (SD)	Fracture resistance / N(SD)	Fractured cusp / n (%)
1	Unaltered (No restoration)	13.9 (1.3)	7.7 (0.4)	1,131 (207)	20 (100)
2	Conventional intra-coronal MO composite restoration	15.1 (6.6)	7.7 (0.4)	904 (184)	19* (95)
3	MO composite restoration partial cuspal coverage	13.4 (1.4)	7.7 (0.4)	927 (224)	16† (80)
4	MO composite restoration full cuspal coverage	13.5 (0.9)	7.6 (0.3)	1,095 (289)	8 (40)
5	MO composite restoration modified full cuspal coverage	13.1 (1.3)	7.7 (0.4)	1,085 (243)	12 (60)
P value (Multiple Comparison)		0.302	0.690	0.004 (Gp1,4,5>2,3)	<0.001

* 18 were adhesive failures, 14 of them occurred along lingual adhesive interface.

† 12 were adhesive failures, 10 of them occurred along buccal adhesive interface.