International Endodontic Journal

doi:10.1111/j.1365-2591.2011.01859.x

Influence of cusp coverage on the fracture resistance of premolars with endodontic access cavities

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Abstract

ElAyouti A, Serry MI, Geis-Gerstorfer J, Löst C. Influence of cusp coverage on the fracture resistance of premolars with endodontic access cavities. *International Endodontic Journal*, **44**, 543–549, 2011.

Aim To assess the influence of cusp reduction and coverage with composite resin on the fracture resistance of premolars with prepared access cavities.

Methodology Endodontic access cavities were prepared in 60 premolar teeth that were divided into four test groups: R1, R2, R3 and NR (n = 15). In all test groups, MOD cavities were prepared and extended towards one of the cusps. The remaining cusp-wall thickness was: 1–1.5 mm in R1, 1.5–2 mm in R2 and 2–3 mm in both R3 and NR groups. In addition, in group R1, R2 and R3 the same cusp was reduced in height to 3.5 mm. Cuspal coverage and MOD restorations were performed using composite resin. Ten intact premolars served as positive controls and another ten MOD-prepared unrestored premolars as negative controls. Teeth were submitted to cyclic fatigue of 1.2 million cycles. A compressive load was applied 30° to the long axis of the teeth until fracture. Fracture loads were recorded and the means and the Confidence Intervals were compared.

Results The mean fracture resistance of each of the cusp-reduced groups R1, R2 and R3 (603, 712 and 697 N, respectively) was significantly higher than the non-reduced cusp group (305 N) and was comparable to the intact-premolar group (653 N).

Conclusions Cusp reduction and coverage with composite resin significantly increased the fracture resistance of premolar teeth with MOD and endodontic access cavities.

Keywords: composite, cusp reduction, fracture resistance, MOD, premolars, root canal treatment.

Received 12 May 2010; accepted 19 December 2010

Introduction

Restoration of root filled teeth is a complicated and challenging procedure (Smith & Schuman 1997). They are more susceptible to fracture than intact teeth, especially premolars with MOD restorations due to loss of tooth structure (Wendt *et al.* 1987, Wagnild & Mueller 2002). Premolars are weakened more by MOD-preparation than by endodontic access preparation alone (Reeh *et al.* 1989, Steele & Johnson 1999). Loss of tooth structure as result of caries, trauma, or restorative and endodontic procedures increases the risk of cusp fracture. In such cases cusp protection with indirect restorations has been indicated (Cheung 2005). Restoration of the remaining tooth structure with adhesive techniques rather than post-core techniques can successfully restore the fracture resistance (Krejci *et al.* 2003, Fokkinga *et al.* 2005). Composite resin has been suggested as an alternative to time-consuming and expensive cast restorations, especially for the restoration of premolars with MOD and access cavities (Gelb *et al.* 1986, Trope *et al.* 1986, Oliveira *et al.* 1987).

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Several authors suggest cusp coverage to restore weak posterior teeth (Mondelli *et al.* 1998, Stappert *et al.* 2006). Amalgam cusp-coverage significantly increased the fracture resistance compared with amalgam restoration without cusp coverage (Mondelli *et al.* 1998). Lately, clinical trials showed promising results of this alternative method for the restoration of compromised posterior teeth (Deliperi & Bardwell 2006, 2006). Although composite onlays did not significantly increase the fracture strength of posterior teeth (Krejci *et al.* 2003), cusp coverage with direct composite increased the fracture resistance significantly (Mondelli *et al.* 2009). However, limited data are available on the effect of composite coverage on the fracture resistance of premolar teeth when the remaining wall thickness is less than 3 mm.

The aim of the present study was to evaluate the influence of cusp reduction and composite coverage on the fracture resistance of premolar teeth with different dentine-wall thickness. The null hypothesis is: there is no difference between the fracture resistance of reduced cusp and non-reduced cusp premolars with access cavities and MOD preparations restored with composite.

Materials and methods

Tooth selection

Eighty sound human premolar teeth were collected. Fully developed maxillary and mandibular premolars (except mandibular first premolars) free of caries and cracks were used. The premolars were classified according to size to be either small or large. The small premolars had a bucco-lingual dimension of 7.5–8.5 mm and mesio-distal dimension of 6–6.75 mm. The large premolars were approximately 1 mm larger in both dimensions. Premolars were divided into four test groups (n = 15) and two control groups (n = 10) by stratifying the teeth according to crown dimensions and to tooth type. Block randomization was used to perform study protocol in a weighted sequence between the groups.

Tooth preparation

In all groups, except the positive control group, standardized endodontic access cavities were prepared using a cylindrical diamond bur of 1 mm diameter. The pulp chamber was irrigated with 10 mL of a 1% sodium hypochlorite solution. MOD cavities were prepared so that the mesial and distal margins were located 1 mm above the cemento-enamel junction (CEJ). The cavity floor was prepared without a gingival step (no axial walls). Zinc phosphate cement (Harvard©, Richter and Hoffmann, Berlin, Germany) was placed in the canal orifice to the level of cavity floor.

In the three test groups (R1, R2 and R3) the centric cusps (mandibular buccal cusps and maxillary palatal cusps) were reduced to a height 3.5 mm from the cavity floor. The cusp reduction was parallel to the occlusal plane and without bevels. Additionally, the same cusp was reduced in thickness. Figure 1 shows wall thickness and height for each group. All measurements were checked at three reference points (at the mesial, distal and mid of the cusp wall) using a digital calliper (Mitutoyo Corp., Kawasaki, Japan).

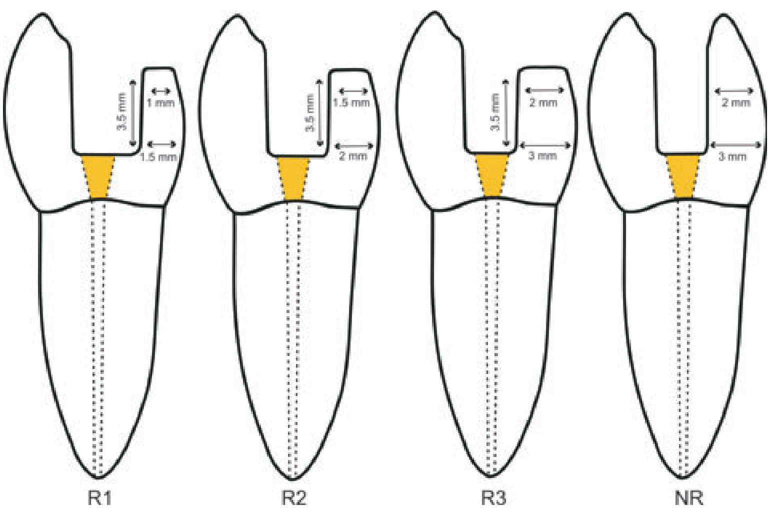

Figure 1 Preparation form with wall thickness and height in the four test groups.

The positive control group included ten sound premolars and the negative control group included ten MOD-prepared premolars that were endodontically accessed. The MOD preparation of the negative control group was similar to that of group NR, but without composite restoration.

Composite restoration

The four test groups were restored as follows:

The prepared surfaces were selectively etched (enamel for 30 s, dentine for 10 s) with 35% phosphoric acid (Ultraetch®, Ultradent, South Jordan, UT, USA). Optibond FL® primer (Kerr, Orange, CA, USA) was applied to dentine for 30 s then thinned with gentle air stream from an air syringe located 2–3 cm away from the cavity. Optibond FL® adhesive was applied with a micro-brush and excess material was removed, then light cured for 60 s. Tetric® EvoCeram (Ivoclar Vivadent, Lichtenstein) was applied in 2 mm increments to the buccal and the lingual walls forming oblique layers. Each layer was light cured for 60s (Bluephase®, Ivoclar Vivadent, Schaan, Liechtenstein).

For R1, R2 and R3, the reduced cusps were restored with composite resin. Restorations were finished and polished using fine diamond burs (Komet Dental, Gebr. Brassler, Lemgo, Germany), Sof-Lex polishing discs (3M Espe, Seefeld, Germany) and rotary brushes (Occlubrush, Kerr, Orange, CA, USA).

Mechanical loading and fracture test

Teeth were mounted in brass rings with their roots embedded up to 2 mm below the CEJ using self-curing acrylic resin (Pattern resin LS, GC America Inc., Alsip, IL, USA). Specimens of the four study groups were submitted to 1.2 million cycles with 45–60 Newton loading forces in a mastication simulation machine (Irmler Konstruktion GmbH, Stuttgart, Germany). The load was applied to the centre of the occlusal surface in contact with both cusp inclines using a ceramic antagonist 6 mm in diameter (Steatite, Hoechst CeramTec AG, Wunsiedel, Germany). Dynamic loading was exerted in the form of axial force following an ellipsoidal curve. The specimens were kept humid throughout.

Specimens that survived the mastication simulation were mounted in a fracture-test machine (Zwicki 1120, Zwick GmbH, Ulm, Germany) so that the angle between the long axis of the tooth and the vertical plane was 30 degrees. Compressive load was conducted until fracture using a steel ball 3 mm in diameter. The load was applied to the triangular ridge of the cusp (mandibular buccal cusps and maxillary palatal cusps) at 0.5 mm min^{-1} cross-head speed (Fig. 3).

The force necessary to fracture each tooth was recorded in Newton (N). The mean and the corresponding 95% confidence interval of the fracture load for each group were calculated and compared. In addition, the Tukey–Kramer test was used to compare the means. Fractures were identified as either restorable ending above the CEJ or non-restorable ending below the CEJ (Uyehara *et al.* 1999).

Results

All, but three specimens in the non-reduced group (NR), survived the 1.2 million cycles of dynamic loading in the mastication–simulation–machine.

The mean and the corresponding 95% confidence interval (CI) of the fracture load for each group are presented in Table 1. Box-and-whisker plots of the fracture load of each tooth are shown in Fig. 2 and the quantiles are summarized in Table 1.

The 95% CI and the Tukey–Kramer test indicated a statistically significant difference between the fracture resistance of the non-reduced cusp group NR (305 N) and the three reduced cusp groups R1, R2 and R3 (603, 712 and 697 N). No significant difference was found between each of the reduced cusp groups (R1, R2 and R3) and the intact teeth group (653 N).

Table 1 Fracture loads of each group in newton (N)

Group	Mean (95% CI)	Median	Minimum	Maximum	Significance	*n*
R1	603 (475–731)	545	299	1036	A	15
R2	712 (591–833)	707	344	1152	A	15
R3	697 (583–812)	615	438	1101	A	15
NR	305 (264–347)	299	202	407	B	12
Non-restored	117 (62–172)	92	24	251	C	10
Intact	653 (507–799)	676	277	941	A	10

Groups not connected by the same letter are statistically significantly different.

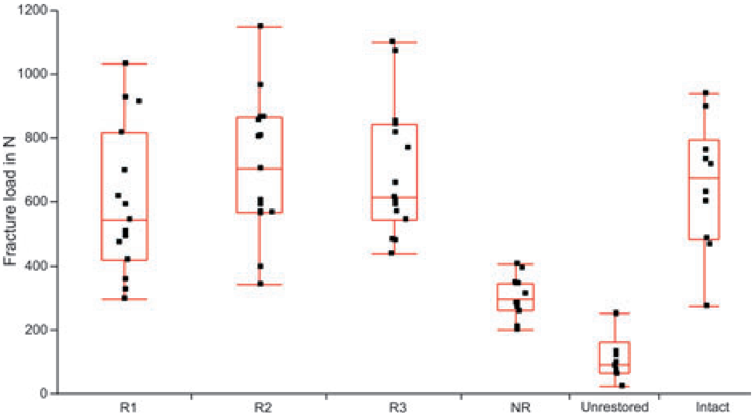

Figure 2 Box-and-whisker-plots of the fracture load for each group in Newtons.

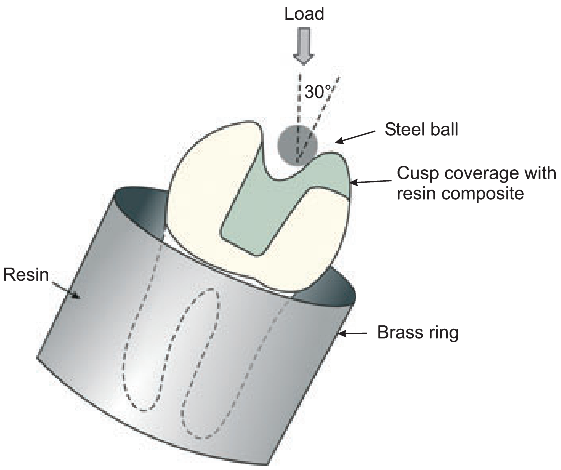

Figure 3 Specimen embedded in resin in brass ring for the fracture test.

Discussion

The majority of teeth fractured obliquely starting from the occlusal surface to the base of the buccal or the palatal cusp. In the cusp-reduction groups (R1, R2 and R3) the oblique fracture started at the middle of the occlusal surface of the restoration (Fig. 4a,b), whilst in the non-reduced group (NR), the oblique fracture started near the junction between the tooth and the filling (Fig. 4c,d) and ended below the CEJ; this coincides with the clinical findings of Hansen (1988). Restorable fractures were observed in only six premolars (Table 2).

The prognosis of restored teeth is difficult to evaluate. Influencing factors include type of post, cement, adhesive and core material. An important factor that has been rarely studied is the amount of remaining tooth structure before the final restoration (Robbins 2002). When cusp thickness is 2 mm or less after caries removal, crown preparation will further weaken the tooth. Post-core techniques were proposed to restore these weak teeth but post dislodgement and root fracture were the main causes of failure (Sorensen & Martinoff 1984). Other authors suggested cusp coverage to restore the fracture resistance (Aquilino & Caplan 2002) because they protect cusps from the outward deflection (McLean 1998, Cheung 2005). Aquilino & Caplan (2002) reported that root filled teeth without crowns were lost at a six times greater rate than teeth with crowns.

The drawbacks of indirect full or partial coverage are the high cost of the laboratory procedure and the considerable amount of sound tooth structure that often has to be sacrificed (Sornkul & Stannard 1992).

Direct composite restorations have been shown to increase the fracture resistance of root filled premolars with MOD cavities in comparison with amalgam (Trope *et al.* 1986), glass–ionomer (Trope & Tronstad 1991) and ormocer (Hurmuzlu *et al.* 2003a). This alternative therapy significantly increased the fracture resistance of premolars with MOD cavities when the remaining wall thickness was 3 mm (Trope *et al.* 1986, Oliveira *et al.* 1987, Trope & Tronstad 1991, Hurmuzlu *et al.* 2003b). Contrary to this, when the wall thickness was 2.25 mm or less, composite failed to restore fracture resistance (Macpherson & Smith 1995). Modifications, e.g. fibre reinforced composite restoration failed to improve the facture resistance, but resulted in a more favourable fracture mode above the cemento-enamel junction (Sengun *et al.* 2008).

The present study showed that when remaining wall thickness was 3 mm, composite restoration with cusp coverage significantly increased the fracture resistance

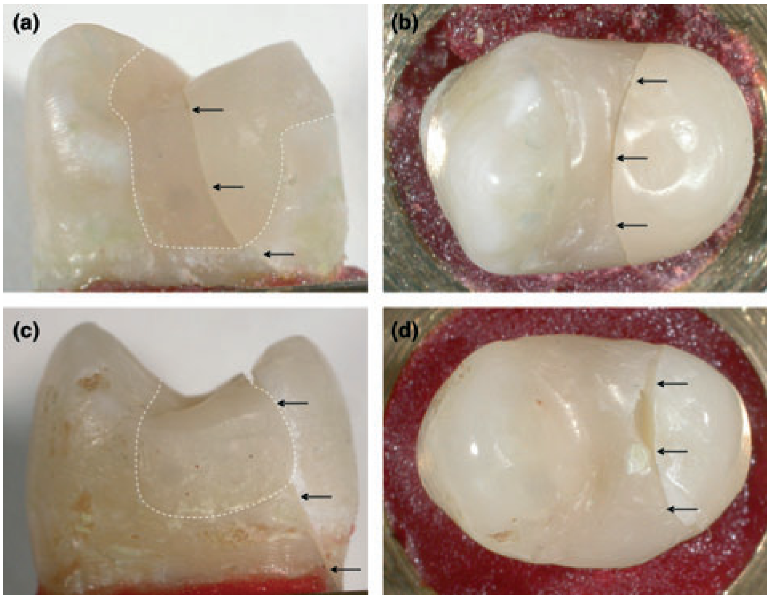

Figure 4 Fracture pattern in group R2 with cusp coverage (a, b); arrows show the oblique fracture starting in the middle of the occlusal surface of the restoration and extending to the cusp base; dotted line shows the restoration margins. (c, d) Fracture pattern in group NR (no cusp reduction); arrows show the fracture starting at the junction between the tooth and composite and ending below the CEJ.

Table 2 Classification of specimens in each group based on the fracture mode

Groups	R1	R2	R3	NR	Non-restored	Intact
Restorable fracture	1	2	2	1	0	0
Non-restorable fracture	14	13	13	11	10	10

Restorable fractures ended above the CEJ and non-restorable fractures ended below the CEJ.

of premolar teeth compared to those restored without cusp coverage. Even when the wall thickness was 1.5 and 2 mm (R1 and R2, respectively), similar results were observed. The adhesive procedure was not solely responsible for this strengthening effect. Reduction of the weak wall may have resulted in lower stresses at the base, thus rendering the tooth more fracture resistant (Mondelli *et al.* 1998).

In the present study, cusp coverage with composite significantly increased the fracture resistance of premolars and the results were comparable to that of intact teeth; similar results were found by Mondelli *et al.* (2009). On the other hand, cusp coverage did not strengthen premolars restored with composite onlays (Krejci *et al.* 2003) or molars restored with ceramic restorations (Stappert *et al.* 2006). This may be due to the axial direction of the compressive load used in these studies, which would lead to different results when the load is applied at 30 degrees to the long axis of the tooth (Uyehara *et al.* 1999).

Moreover, comparing the results of R1, R2 and R3 groups the mean fracture force did not decrease with the decrease of the cusp thickness. This may indicate that the thickness of remaining dentine walls is not relevant to fracture resistance. However, the height may be more relevant than the thickness as shown by the higher fracture resistance of reduced cups groups (R1, R2 and R3) in comparison with the non-reduced group (NR). The high micro-tensile bond strength of dentine-bonding adhesives stabilizes the tooth and may explain the minimal differences in the fracture strength of different cusp thickness (Hernandez *et al.* 1994).

In the present study premolars were used because these teeth are prone to fracture (Hansen 1988). Mandibular first premolars were excluded due to the anatomical differences between the crown and root axis and the higher resistance to fracture compared to other premolars (Salis *et al.* 1987).

Mastication forces can exceed 49 N on the posterior dentition; therefore, an occlusal load of 45 to 60N was applied using a mastication-simulation-machine at speed of 120 cycles per minute. Each cycle followed an ellipsoidal path in which the load was applied in a half-sinus curve (Krejci *et al.* 1990). Cyclic fatigue may have more drastic effect on the fracture resistance than maximal loads due to the initiation and propagation of cracks within tooth structure and restorations. In order to simulate a service time of 5 years, 1.2 million cycles were applied on each tooth (Stappert *et al.* 2006).

Teeth are most vulnerable to fracture when eccentric forces are applied and the failure point can be reached at lower loads for larger loading angles (Christian *et al.* 1981, Plasmans *et al.* 1986). The 30 degrees angle used (Fig. 3) resulted in fracture at lower loads when compared with the axial fracture loads of other studies (Reel & Mitchell 1989, Eakle *et al.* 1992, Burke *et al.* 1994, Steele & Johnson 1999, de Freitas *et al.* 2002, Ortega *et al.* 2004). Using a small steel ball of 3 mm diameter allowed the application of load on one cusp ridge (Fig. 3). Several laboratory studies used different loading elements such as rods (Wendt *et al.* 1987), wedges (de Freitas *et al.* 2002) and balls with large diameters (Eakle 1986), resulting in different values of the load to fracture. Therefore, the differences between study and control groups are more relevant than the actual values of the fracture loads, which depend on the set-up and circumstances of the study. For that reason, care was taken to obtain similar study and control groups in respect to tooth dimensions and type.

Conclusions

Cusp reduction and coverage with direct composite restored the fracture resistance of endodontically accessed premolars; the fracture loads were comparable to that of intact teeth.

The remaining cusp height inversely influenced the fracture resistance of composite-restored premolars.

After cusp reduction, remaining wall thickness (1, 2 or 3 mm) did not influence the fracture resistance of premolars restored with composite.

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