Fatigue Resistance of Teeth Restored with Cuspal-Coverage Composite Restorations

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Purpose: This study assessed the influence of palatal cuspal coverage on the in vitro fatigue resistance and failure mode of Class II resin composite restorations including replacement of the buccal cusp in premolars. ***Materials and Methods:*** A master model was made of a maxillary premolar with an MOD amalgam cavity and a simulated fracture of the buccal cusp from the isthmus floor to the CEJ. Using a copy-milling machine, this preparation was copied to 20 extracted human maxillary premolars (group A). Subsequently, the palatal cusp was reduced by 1.5 mm; this modified preparation was copied to 20 additional maxillary premolars (group B). Direct resin composite restorations were made in all teeth. Cyclic load (5 Hz) was applied, starting with a load of 200 N (10,000 cycles), followed by stages of 400, 600, 800, and 1,000 N at a maximum of 50,000 cycles each. Samples were loaded until fracture or to a maximum of 210,000 cycles. ***Results:*** Of the restored premolars of group A, 20% withstood all 210,000 loading cycles; in group B, this figure was 55%. In group A, 19% of the fractures ended below the CEJ; in group B, 78% did. ***Conclusion:*** Palatal cuspal coverage increased the fatigue resistance of Class II resin composite restorations with replacement of the buccal cusp in premolars. However, fractures of restorations with cuspal coverage led to more dramatic failures that made restoration virtually impossible. This suggests caution in lowering remaining cusps for these adhesive restorations in the clinical situation. *Int J Prosthodont 2004;17:313–317.*

Complete cusp fracture of posterior teeth with Class II restorations is a common phenomenon in dental practice, with incidence rates varying from 20.5[1] to 71[2] per 1,000 person years at risk. In the former study, more than 91% of the fractures in teeth without endodontic treatment ended supragingivally, which indicates that teeth with a fractured cusp can be restored relatively easily. For the treatment of a tooth with a Class II restoration and a fractured cusp, several options are available. The traditional treatment is to restore the teeth with artificial crowns. A disadvantage of the crown is the required removal of additional sound tooth tissue. In molars, cusp-replacing amalgam restorations have been shown to be a viable alternative that does not require extensive tissue removal. A survival rate of 88% after 8.3 years has been published.[3] In premolars with a fractured cusp, tooth-colored adhesive restorations may be a minimally invasive and esthetic alternative for crowns.[4] However, no clinical data are available on performance and longevity of cusp-replacing adhesive restorations. In vitro research reveals similar fracture strengths for amalgam and resin composite cusp-replacing restorations.[5–7]

Few aspects of restorative procedures for cusp-replacing adhesive restorations have been studied in vitro. In vitro load tests indicate that retention pins weaken rather than

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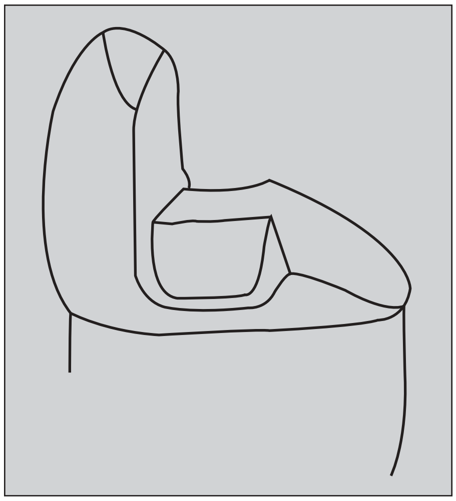

Fig 1a Maxillary premolar with MOD amalgam cavity and simulated buccal cusp fracture: no additional preparation (group A).

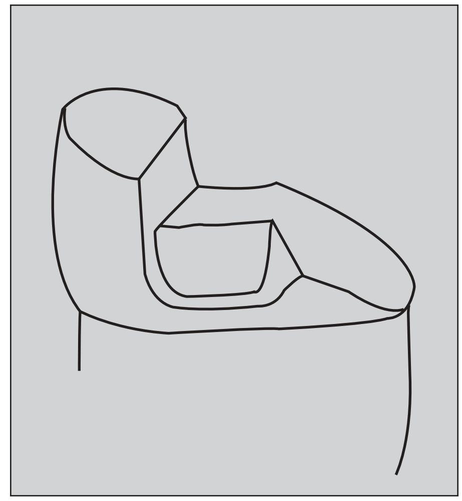

Fig 1b Maxillary premolar with MOD amalgam cavity and simulated buccal cusp fracture: palatal cusp reduced in height (group B).

reinforce the restorative material.[6] Another in vitro study suggests that an additional cervical shoulder preparation does not improve the fracture strength of cusp-replacing direct resin composite restorations.[8] An unknown aspect of adhesive cusp-replacing restorations is whether lowering of the remaining sound cusp, to create cuspal coverage, is beneficial to the quality of the restoration. For mesio-occlusodistal (MOD) amalgam restorations in premolars, in vitro research reveals higher fracture strengths for teeth with cuspal coverage compared to those without.[9] Cuspal coverage can also be considered to improve the strength of a tooth with an inlay-type adhesive restoration and protect the cusps from fracture.[10,11] A disadvantage of cuspal coverage is that sound tooth tissue has to be removed.

The aim of the present study was to assess the influence of palatal cuspal coverage on the in vitro fatigue resistance and failure mode of Class II resin composite restorations that included the replacement of the buccal cusp in premolars. The hypothesis was that palatal cuspal coverage would contribute to greater fatigue resistance and have a beneficial influence on the failure mode in case of fracture.

Materials and Methods

The same sound human maxillary premolar that previously served in finite element simulations was used.[12,13] The dimensions of this premolar were: crown height 7.5 mm, buccolingual width 9.4 mm, and mesiodistal width 7.2 mm. A silicone impression of this sound premolar was made before any experiment to obtain identical restorations after cavity preparation. This impression served as a mold to copy the external shape of the original sound premolar to all the restorations of the premolars in this study.

Cavity Preparation

In the sound premolar, an MOD cavity was ground and a fracture of the buccal cusp from the isthmus floor to the cementoenamel junction (CEJ) was simulated (Fig 1a). A cast-gold copy of this premolar served as a master model. Forty extracted sound human maxillary premolars of comparable size (similar to or slightly larger than the original sound premolar) were selected. After extraction, the teeth were stored in 1% chlorine amine for a minimum of 24 hours. In between the steps for the preparation of the experiment, the teeth were stored in water at room temperature.

The premolars were randomly divided into two groups of 20 premolars each. All premolars were mounted on metal inserts, and the preparation of the master model was copy milled (Celay, Microna) to the first 20 premolars (group A) according to Kuijs et al.[8] After completion of group A, the palatal cusp of the original premolar was reduced in height by 1.5 mm (Fig 1b). Again, a cast-gold copy was made, which served as a second master model. Subsequently, this master model was copied to the remaining 20 premolars (group B).

Restoration

All restorative materials were the same as used in an earlier study.[8] Each specimen was etched for 20 seconds using a 37% phosphoric acid etch gel (Ultra Etch). Subsequently, the cavity surface was rinsed thoroughly and gently air dried. Primer and adhesive were applied according to the manufacturer's instructions (SA primer and Clearfil Photobond, Kuraray). Using the silicone mold, each premolar was restored with a commonly used highly filled hybrid composite (Clearfil Photo Posterior US, Kuraray). For this purpose, the mold was cut longitudinally into four parts to enable light curing of the restorative material. First, the boxes and step (isthmus) of the MOD cavity were restored using two parts of the mold; subsequently, the cervical part and tip of the cusp were restored using the other two parts. Restorations were built up in layers of 2 mm maximum using an injection technique. Each layer was light cured for 40 seconds (Translux CL, Heraeus Kulzer); intensity of the unit was 420 mW/cm^2, as measured before and after the experiment using a curing radiometer. After restoration, premolars were separated from the metal inserts and finished with polishing disks (Sof-Lex, 3M).

Fatigue Test

One restored premolar was embedded in acrylic in a metal cylinder with the occlusal surface horizontally. Subsequently, a silicone relocation jig was made to embed all specimens in an identical position. Cyclic load was applied to the restored premolars using a servohydraulic materials testing machine (MTS), with a 4-mm-diameter cylindric bar of stainless steel (Fig 2). With this diameter, both cusps were loaded halfway up the slope, and, for the specimens without cuspal coverage, the tooth-restoration interface was loaded. The fatigue load was applied at a frequency of 5 Hz. In the first stage, a load of 200 N was applied, with a maximum of 10,000 cycles, as a kind of preconditioning phase of the experiment to ensure good positioning of the cylinder on the specimen. This stage was followed by stages of 400, 600, 800, and 1,000 N at a maximum of 50,000 cycles each. During the experiment, the specimens were kept in water at 37°C. Samples were loaded until fracture, or to a maximum of 210,000 cycles if they did not fail. The number of cycles endured was registered for each specimen. In case of fracture, the failure mode was recorded; a distinction was made between fractures above and below the CEJ. Classification was based on two-examiner agreement.

Statistical Analysis

For comparison of the fatigue resistance of groups A and B, a survival scatter plot was made and a Wilcoxon rank test was used at a significance level of 5%. The influence of cuspal coverage on the failure mode was analyzed by using the chi-square test at a significance level of 5%. The analyses were performed with SPSS/PC, version 4.0 (SPSS).

Results

In group A, 4 (20%) of the restored premolars withstood all 210,000 loading cycles; in group B, this figure was 11 (55%) (Fig 3). Survival of group B was significantly higher than that of group A ($P < .002$).

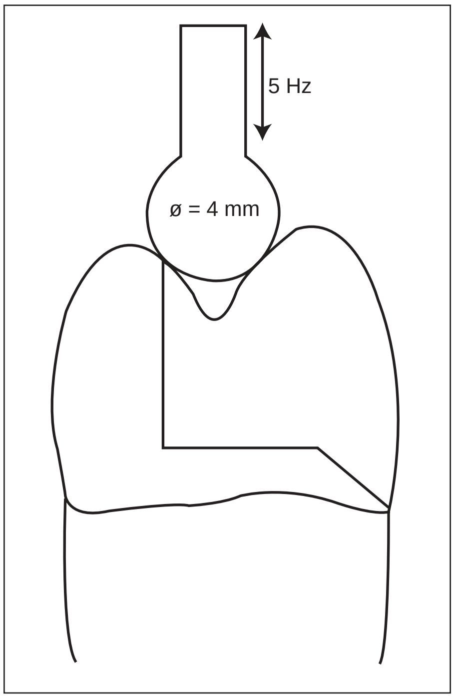

Fig 2 Fatigue test.

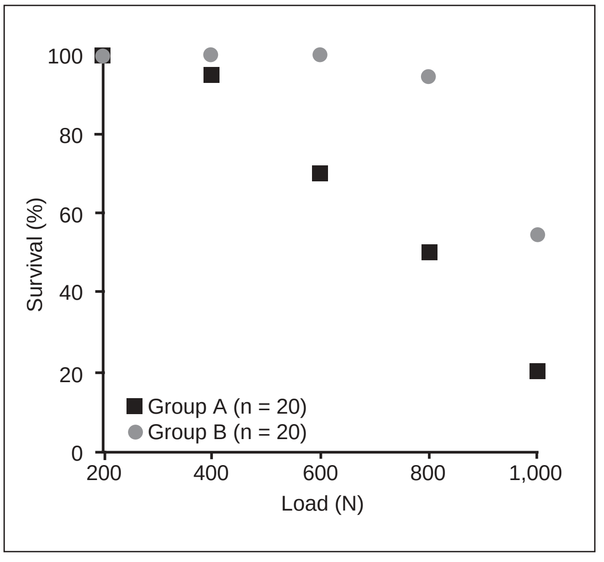

Fig 3 Survival scatter plot of specimens after the different stages of the fatigue test.

Different failure modes were observed (Fig 4 and Table 1). The majority of fractures (all 16 fractures in group A and 6 of 9 in group B) showed failure of the tooth-restoration interface along the palatal cavity surface. In group A this interface failure was combined with a fractured palatal cusp in 14 of the 16 specimens, while in group B this figure was 4 of 6 interface failures. The remaining interface

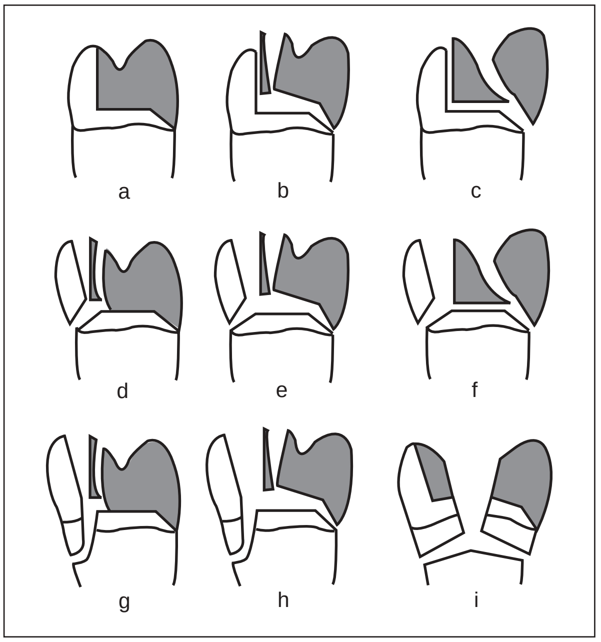

Fig 4 Types of failure modes for groups A and B (see Table 1 for number of each type of failure).

Table 1 No. of Failures of Each Type*

Group	Intact specimen (a)	Fracture above CEJ, intact palatal cusp (b, c)	Fracture above CEJ, fractured palatal cusp (d, e, f)	Fracture below CEJ, fractured palatal cusp (g, h, i)
A (n = 20)	4	2 (1 b, 1 c)	11 (7 d, 3 e, 1 f)	3 (1 g, 2 h)
B (n = 20)	11	2 (1 b, 1 c)	–	7 (4 g, 3 i)

*See Fig 4 for illustration of failure types.
Group A = no additional preparation; group B = reduced palatal cusp.

failures (2 specimens for each group) comprised complete debonding of the restoration without fracture of tooth material. A vertical fracture through the restoration and tooth was registered for the remaining 3 specimens of group B. For group A, 19% (3 of 16 failures) of the fractures ended below the CEJ; for group B, this figure was 78% (7 of 9 failures). This difference in proportions was statistically significant ($P = .040$).

Discussion

Extracted human maxillary premolars were used in this study. Because of natural size differences, results of experimental tests may vary. Therefore, using standardized specimens can be advantageous in several ways. With the copy-milling procedure, it was possible to grind standard preparations in the premolars. The copy-milling procedure is accurate when there are only minor differences in uncut forms of the teeth; therefore, the selection of teeth is important. With molds made from the original sound premolar, identical restorations could be made and a standard positioning of the restored premolars in the materials testing machine could be achieved. Differences in the internal geometry of the premolars (pulp chamber), as with differences in the remaining enamel thickness at the CEJ, could not be controlled with this procedure. This may be an explanation for variation in failure loads within the groups. To avoid bias, the premolars were randomly allocated to the two groups.

The results of this study indicate that palatal cuspal coverage increased the fatigue resistance of Class II resin composite restorations with replacement of the buccal cusp in premolars. After assessment of the fracture patterns, it appeared that in all but three fractures the tooth-restoration interface was involved. This suggests that this interface in a cusp-replacing situation is most prone to failure when occlusal load is applied. This is in accordance with the simulation of the polymerization process in a previous finite element study, indicating that failure at the interface is more probable than failure in the composite material.[13] With cuspal coverage of the remaining cusp, the tooth-restoration interface is not located at the occlusal surface, which may explain the higher resistance to occlusal loads.

In the clinical situation, however, the prognosis of a tooth in case of failure is also important. This is mainly determined by the possibility to restore the tooth; this depends, among other things, on the location of the fracture. A tooth with a fracture below the CEJ is difficult to restore. Restoration may even be impossible. With cuspal coverage the majority of fractures ended below the CEJ, while for the restorations without cuspal coverage fewer than one fifth of fractures ended below the CEJ. Thus, fractures of restorations with cuspal coverage seem to result in a higher share of unrestorable teeth.

The results of this study seem to be conflicting. On one hand, there is the higher fracture resistance for the restorations with cuspal coverage. On the other hand, there is the more dramatic mode of fracture in case of failure of these restorations with cuspal coverage. This obstructs the drawing of a firm conclusion. The inference to clinical practice of course also depends on the chosen simulation. The cyclic load applied to the specimens in this study should cover the repeated occlusal loads found in vivo. Whether the fracture loads and number of cycles found were representative of nature may be discussed. If these loads were higher than are found in the mouth, cuspal coverage is the treatment of choice, protecting the tooth from fracture at best. However, if the simulated conditions are realistic, the dramatic results after failure should be the basis for not applying cuspal coverage. The higher risk of debonding should be taken in favor of the unrestorable teeth remaining after fracture.

The results of the present study indicate that palatal cuspal coverage increased the fatigue resistance of Class II resin composite restorations with replacement of the buccal cusp in premolars. However, fractures of restorations with cuspal coverage led to more dramatic failures that made restoration virtually impossible. This suggests that caution should be exercised before lowering remaining cusps for these adhesive restorations in the clinical situation.

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