Influence of cavity type and size of composite restorations on cuspal flexure

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ABSTRACT

Objectives: The present study examines the influence of cavity type, and size of composite restorations on cuspal flexure due to polymerization shrinkage.

Methods: Thirty healthy premolars were selected and divided into two experimental groups. Group 1: Mesial, mesio-distal, and MOD cavities were successively prepared in each tooth by means of the SONICSYS approx system (KaVo ®) using a nº 2 (small) diamond tip. Group 2: The same cavity preparation sequence was followed but a nº 3 (medium) tip was used.

Cavity preparations were performed and afterwards restored using the same adhesive system and resin composite. Cuspal displacement was measured 15 min after completion of each type of restoration.

Results: Under the experimental conditions used, polymerization shrinkage of composite restorations resulted in an inward deflection of the cusps in all the situations evaluated. The Friedman global test found significant differences according to the cavity type and size ($p<0.05$). The Wilcoxon test revealed that deflection was significantly affected by the amount of dental tissue lost, since practically no movement was observed in the case of mesial cavities but extensive displacements were recorded for MOD restorations ($p<0.05$). However, no influence of bucco-lingual width on cuspal flexure was detected by the Student's t test ($p>0.05$).

Conclusions: The present study demonstrates that significantly higher cuspal deflection is observed in MOD restorations, showing that the degree of dental removal influences the cuspal flexure from polymerization shrinkage of composite restorations.

Key words: Cuspal flexure, cuspal deflection, cusp movement, polymerization shrinkage, cavity type.

INTRODUCTION

Current light-cured composite resins offer excellent aesthetics, improved mechanical properties and good bonding to tooth structure, when placed in combination with adhesive systems, accounting for their wide use in contemporary restorative dentistry. However, all resin-based materials undergo contraction inherent to the polymerization reaction, which ranges from 2.7% to 7.1% (1,2).

This shrinkage subjects the tooth structure to mechanical stresses may cause enamel fracture, cracked cusps, cuspal movement, and opening of the restoration margins, which may result in microleakage and postoperative pain (3-6).

The polymerization shrinkage of composites in a cavity generates stress that can be transmitted via the adhesive interface to adjacent dental tissues (3,7), producing dental deformation. According to Versluis et al. (8), tooth deformation offers the closest relationship to shrinkage stresses and can be quantified, whilst many of the other clinical symptoms are substantially subjective. This deformation is often determined by measuring the flexure of cusps (3, 7, 9, 10). Linear displacement of the cusps was previously reported using other devices such as Linear Variable Differential Transformers (LVDTs) and Direct Current Differential Transformers (DCDTs) (11), which are reported to be highly sensitive to the vertical angle of inclination (12). Cuspal deflection has also been measured with a digital micrometer (13) and by using strain gauges to measure strains generated in the deformed cusp (12, 14-16).

Reports on the degree of cuspal deflection range from 6 to 47 μm,(3, 7-10, 17) depending on the size of the restoration (9), cavity design (10), stiffness and flow of composite, bonding system applied, placement technique, light curing lamp intensity, and curing mode (6).

Cusps of teeth with large cavity preparations have been reported to exhibit greater deflection than those of teeth with small cavities (9). Loss of strategic dental structures, namely the marginal ridges, and the increased width of the isthmus region, reduce tooth stiffness and increase cusp flexibility (11, 14-17). Furthermore, a larger volume of composite may result in greater shrinkage forces (7-9). It has also been proposed that repeated functional loading causes fatiguing of the restored tooth and ultimately results in failure (18).

The present study was designed to determine the effects of three cavity designs of small or medium size on the magnitude of cuspal deflection caused by polymerization shrinkage of composite restorations. The null hypothesis was that there is no difference in cuspal deflection among mesial, mesio-distal, and MOD cavity preparations of small and medium size.

MATERIALS AND METHODS

Thirty intact non-carious human maxillary first premolars extracted for orthodontic reasons were used in the present study. The teeth were cleaned and stored in buffered saline plus 0.5% thymol at 4°C until use. Teeth were free of cracks or other defects after visual and stereomicroscopic examination and had regular occlusal anatomy and similar crown sizes.

Each tooth was mounted vertically in a plastic ring with acrylic resin (Ortocryl EQ, Dentautum, Germany), leaving 2 mm of the root surface exposed to mimic the support of alveolar bone in a healthy tooth. Samples were connected to a simulated pulpal pressure system using a previously described method (19), maintaining the tooth under pressure and humidity conditions throughout the preparation and measurement period. Adhesive techniques were then used to fix a 1.5 mm diameter glass ball to each cuspal vertex as reference points for intercuspal distance measurements.

The teeth were randomly divided into two experimental groups (n=15). In the first group, mesial, mesio-distal, and MOD cavities were successively prepared by means of the SONICSYS approx system (KaVo, Biberach, Germany) using a n° 2 (small) diamond tip. In the other group, the same cavity preparation sequence was performed but a n° 3 (medium) tip was used. Cavity preparation types are shown in Figure 1.

In MOD cavity preparations, both proximal boxes were connected with an occlusal extension of approximately one-third of the bucco-lingual width of the tooth and 2 mm in depth. The cavity dimensions are shown in Figure 2.
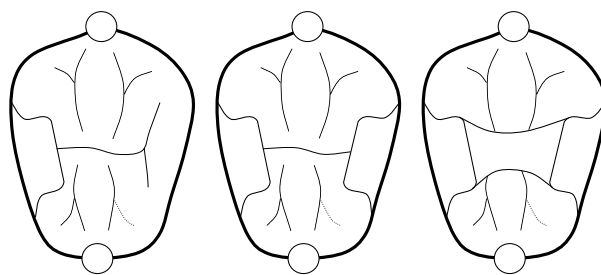

Fig. 1. Mesial, mesio-distal, and MOD cavity preparation designs.

Small cavity preparations   Medium cavity preparations
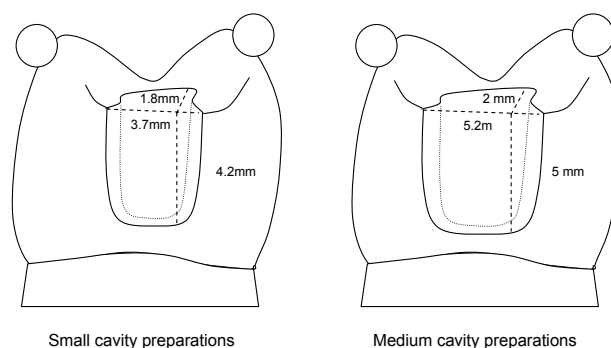
Fig. 2. Dimensions of the two cavity preparation sizes evaluated.

After preparation of each cavity type, the distance between reference balls was measured using a precision micrometer (Mitutoyo, 293-561, Japan) and recorded as the initial distance.

In both experimental groups, mesial cavities were filled and the intercuspal distance was measured 15 min later. Afterwards, mesial composite restorations were removed from each specimen and distal cavities were prepared. After restoration of both cavities, the intercuspal distance was again recorded 15 min after composite polymerization. Finally, both composite restorations were removed and a MOD cavity was performed and filled, followed by measurement of the cuspal displacement 15 min after completion of the restoration

In all cases, the matrix band was placed without using a retainer in order to avoid any tension on the cusps. All cavities were treated with 37% phosphoric acid for 15 s, and the Syntac Single adhesive system (Ivoclar, Schaan, Liechtenstein) was then applied following the manufacturer's recommendations. The same resin composite, Tetric Ceram (Ivoclar, Schaan, Liechtenstein), was used to restore all samples. Cavities were filled with horizontal layers in two increments, the first to one-half the cavity height and the second completing the restoration. In MOD restorations, the first increment filled the lower half of the proximal boxes and the second layer completely filled both boxes and the occlusal preparation. Each increment was light-cured for 40 seconds with the light source (Optilux 401, Demetron Research Corp, Danbury, Conn), which was tested with a radiometer (Cure Rite, Efos Inc, Mississawga; Canada) for a light output = 450 mW/cm2 before each application. The occlusal aspect of the restorations was carved before polymerization to approximate the normal occlusal anatomy of a maxillary premolar tooth.

All measurements were performed by the same operator and ten consecutive measurements were recorded for each specimen and experimental situation and the mean was used for the subsequent statistical analysis.

The Friedman global test was used for the global comparison among the three cavity types (M, MD and MOD) for each cavity size (small and medium). After finding significant differences among the three cavity designs, paired comparisons were made with the Wilcoxon test. Comparison of the cuspal movements recorded in either small or medium cavities was performed by Student's t test. Statistical significance was set in advance at the 0.05 confidence level. All data were analyzed by means of SPSS 11.0 for Windows software (SPSS Inc., Chicago, IL, USA).

RESULTS

The values of cuspal deflection obtained for each cavity type and size are shown in Table 1. Type of cavity significantly influenced cuspal deflection. In small cavity preparations, MOD restoration was related to a significantly greater reduction in intercuspal distance compared with mesial or mesio-distal restorations, whereas no difference in distance reduction was observed between the restoration of mesial

and mesio-distal cavities. In medium restorations, MOD restoration was again associated with a greater reduction in intercuspal distance and there was also a significantly greater reduction in mesio-distal versus mesial cavities.

No influence of cavity size on the inward movement of the cusps was detected, and the small and medium resin composite restorations showed a similar behavior.

Table 1. Mean cuspal displacements and standard deviations (in μm) associated with resin composite polymerization for each type and size of cavity preparation evaluated.

	Small restorations	Sig	Medium restorations
Intercuspal Distance (ID) in unaltered tooth	10084 (403)	NS	9883 (425)
Cuspal displacement in mesial cavity	1.3 (2.4)[a]	NS	0.8 (1.7)[a]
Cuspal displacement in mesio-distal cavity	1.5 (1.4)[a]	NS	4.1 (5.1)[b]
Cuspal displacement in MOD cavity	8.9 (6.6)[b]	NS	8.5 (4.8)[c]

For each column, the means designated by different letters show statistically significant differences ($p < 0.05$). NS: statistically similar inward cuspal displacements for small and medium composite restorations.

DISCUSSION

Polymerization shrinkage of composite restorations resulted in an inward deflection of the cusps for all the experimental groups evaluated, in agreement with previous reports (3, 6, 7, 9). Nevertheless, values of displacements in the present study were lower than other reported values (9, 17), probably because of differences in experimental design. In order to maximize cuspal movement due to polymerization shrinkage of resin composite, large MOD restorations are usually prepared (6, 7, 9). However, the objective of the present study was to evaluate the contribution of different dental structures to tooth stiffness, so that more conservative cavities were prepared, producing less tooth structure removing.

The relative effects of cavity size and sequential cavity restoration were determined by linear displacement of the cusps in a non-destructive testing procedure (20). Composite restorations were inserted, removed, and replaced by more extensive designs. This sequence simulates the clinical situation, where the most common treatment is the replacement of previous failed restorations (21, 22). This approach allowed each tooth to be used as its own control (15), minimizing the effect of variations in morphology or

stiffness among teeth, which have been reported to increase after cavity preparation (12). Accordingly, only a small sample size is required to achieve statistical significance, improving the efficiency of the experimental design and statistical analysis (11, 15, 20).

The results are given in the table in absolute values of cuspal displacement as they are easier to grasp in this manner and the dispersion was minimal. The type of cavity preparation significantly influenced the extent of cuspal flexure (10, 15). Movement of the cusps when mesial cavity preparations were restored was minimal, practically non-existent (1 µm). The presence of the distal marginal ridge and the preservation of the occlusal enamel and dentin connecting the cusps may have prevented greater cusp displacement (15, 23). Thus, the elimination and subsequent restoration of the distal marginal ridge increased cuspal deflection only in larger restorations (4.1 µm). Nevertheless, the reductions in cuspal distance recorded were very small and may not be clinically relevant.

Significantly higher cuspal deflection was observed in MOD restorations (9 µm). The degree of cuspal flexure is known to be directly related to loss of dental structure. Larger cavity preparations cause a reduction in tooth stiffness (10, 11, 24, 25) and require more composite resin when restored, producing greater contraction forces (9).

In the present study, the cuspal displacements recorded for small and medium restorations were statistically similar. This finding contrasts with other studies (7, 9) that reported a greater cuspal deflection in teeth with large cavities than in those with small cavities. One possible reason is that, in those studies, there was a marked size difference between the small and large cavities. Moreover, the preservation of other strategic structures, such as the remaining dentin above the pulp chamber and the distal marginal ridge, seems to play a more important role in avoiding tooth weakening (23).

The inward deflection of the cusps is an expression of the polymerization kinetics and may be affected by many factors. It has been reported that cusps recover their original position after inward deflection because of shrinkage of composite restorations and that this recovery is strongly influenced by tooth hydration conditions and cavity size (9). To minimize these effects, intercuspal distances were measured 15 min after polymerization, because the majority of cusp movement is reported to occur within this time period (9, 24) and the teeth were fully hydrated. These study conditions may have influenced the low values of cuspal movement observed. Other factors that may affect cuspal deflection are the composite system and corresponding bonding system (6). The chemical curing of composites takes longer, showing lower resulting stress versus light-curing (26). Only one type of system was evaluated in the present study, and other systems, including different light curing sources or filling techniques, may produce different effects on cuspal movement (6, 8). The layering of resin composite has been proposed to reduce the composite mass to be polymerized and the resulting shrinkage stress (27), although Versluis et al. (28) reported that incremental techniques may produce higher stresses at the restorative interface in comparison with bulk filling. On the other hand, other in vitro studies reported no clear differences between these approaches (13, 29).

The present study demonstrates that the degree of dental removal influences the cuspal flexure from polymerization shrinkage of composite restorations. Cuspal movement indicates residual stresses in the tooth structure (8), which may cause failure during composite curing or act as a preloading, facilitating tooth fracture under occlusal loads (7, 18, 30). Conservative cavity designs are recommended for resin composites in order to reduce these stresses, avoiding classic designs for amalgam.

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