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Cuspal deflection, strain and microleakage of endodontically treated premolar teeth restored with direct resin composites

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ABSTRACT

Objectives: To measure cuspal deflection and tooth strain, plus marginal leakage and gap formation caused by polymerization shrinkage during direct resin composite restoration of root-filled premolars.

Methods: Thirty-two first and second maxillary premolars were divided into four groups ($n = 8$). Group 1 had standardised mesio-occlusal-distal (MOD) cavities and served as the control group. Group 2 had endodontic access and root canal treatment through the occlusal floor of the MOD cavity, leaving the axial dentine intact. Group 3 had endodontic access and root canal treatment with the mesial and distal axial dentine removed. Group 4 had endodontic access and root canal treatment with axial dentine removed and a glass ionomer base (GIC). All groups were restored incrementally using a low shrink resin composite. Cuspal deflection was measured using direct current differential transformers (DCDTs), and buccal and palatal strain was measured using strain gauges. Teeth were immersed in 2% methylene blue for 24 h, sectioned and scored for leakage and gap formation under light and scanning electron microscopy.

Results: Total cuspal deflection was 4.9 ± 1.3 μm for the MOD cavity (group 1), 7.8 ± 3.3 μm for endodontic access with intact axial dentine (group 2), 12.2 ± 2.6 μm for endodontic access without axial dentine (group 3), and 11.1 ± 3.8 μm for endodontic access with a GIC base (group 4). Maximum buccal strain was 134 ± 56, 139 ± 61, 251 ± 125, and 183 ± 63 μstrain for groups 1–4 respectively, while the maximum palatal strain was 256 ± 215, 184 ± 149, 561 ± 123, 264 ± 87 μstrain respectively. All groups showed marginal leakage; however placement of GIC base significantly improved the seal ($p = 0.007$).

Conclusion: Cusp deflection and strain increased significantly when axial dentine was removed as part of the endodontic access. Placement of a glass ionomer base significantly reduced tooth strain and marginal leakage. Therefore, a conservative endodontic access and placement of a glass ionomer base are recommended if endodontically treated teeth undergo direct restoration with resin composite.

1. Introduction

Root-filled teeth are weakened by loss of strategic tooth structure through restorative procedures and caries, rather than by the endodontic procedures.[1] In this context, the importance of a restoration which provides cuspal coverage has been highlighted in both ex vivo[2,3] and retrospective clinical studies.[4–8] Removal of tooth structure for this purpose

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can be considerable in addition to the high cost of the restoration. This may lead the patient to choose alternative treatment options, and direct restoration using resin composite materials has been advocated.[9,10]

Prospective clinical studies comparing the outcome of different types of restorations of endodontically treated teeth are scarce. Mannocci et al.[10] found fibre posts and direct composite restorations to be more effective than amalgam in preventing root fractures, but not secondary caries, of root-filled premolars. In another prospective study[9] similar survival rates of endodontically treated premolars restored with fibre posts plus direct composite restoration vs. full coverage with metal ceramic crowns were observed over a 3-year period.

Resin composites provide a potential alternative restorative technique based on their ability to bond to tooth structure. One important drawback of composites is polymerization shrinkage and consequently, significant stresses in the tooth itself and at the tooth–restoration interface. While composites flow and relieve the stresses within the tooth structure during the pregel phase, this flow ceases after gelation and cannot compensate for the stresses created at the tooth–restoration interface.[11] Cuspal deflection is the result of interaction between the polymerization shrinkage stress of composite and the compliance of the cavity wall.[12] This may compromise the bond at the tooth–restoration interface, possibly leading to bacterial microleakage and recurrent caries. Cuspal deflection has been reported between 4 and 45 μm depending on the measurement method, cavity size and extent of resin composite shrinkage.[13–15]

Cuspal deflection increases with increasing cavity dimension,[12] and the larger the restoration, the higher the stress in the tooth, while the stress is lower within the restoration and at the tooth–restoration interface. This stress distribution incurs the risk of tooth fracture.[16] Many methods have been used to measure cusp deflection, including microscopy,[14] strain gauges,[17] DCDTs,[18] linear variable differential transformers (LVDTs),[13] and a twin channel deflection measuring gauge.[19,20] Jantarat et al.[17] concluded that the use of strain gauges and DCDTs simultaneously provides the best insights into patterns of cusp deformation.

Low shrink resin based composites have been introduced, aiming at reducing the polymerization shrinkage, and therefore cuspal deflection and stress at the tooth–restoration interface. Palin et al.[19] reported a decrease in total cusp displacement in MOD cavities restored with low shrink oxirane and silorane resin based composites. In addition incremental placement of composites is recommended by most manufacturers to maximize curing, to minimize polymerization shrinkage and to reduce gap formation and cusp deflection,[12,21–23] despite doubts about the efficacy of this technique reported by other authors.[16,18,24] Furthermore flowable composites and resin modified glass ionomer cements have been recommended as liners under resin composites to reduce potential microleakage, gap formation and recurrent caries.[14,25–27]

In this study we have investigated the extent to which endodontic access influences cuspal deformation and strain during direct restoration with a low shrink resin composite. Endodontic access was either confined within the occlusal floor of an MOD cavity or (as is common clinically) with the axial walls of dentine removed. Use of a glass ionomer cement (GIC) to seal the canal orifices and to reproduce the floor of the standard MOD cavity was also investigated, with regard to its effect on cuspal deflection and strain.

The hypothesis of this study was that leaving the axial dentine of an endodontic access cavity intact and the placement of a GIC base under the resin composite restoration of endodontically treated maxillary premolars results in reduced cuspal deflection, reduced strain and less marginal leakage. The overall aim of the study was to evaluate alternate restoration techniques, which preserve tooth structure and utilize the technology available in dental materials.

2. Materials and methods

2.1. Teeth selection and cavity preparation

Thirty-two intact, caries free human maxillary first and second premolars extracted for orthodontic reasons were used. The teeth were selected by measuring the inter-cuspal width in millimetres using a digital caliper; the measured width varied between 5.3 and 6.1 mm, with a maximum deviation of not more than 10% from the determined mean. The teeth were then ranked in descending order of inter-cuspal width and distributed into four groups each of eight teeth. The project was approved by the Ethics in Human Research Committee of the University of Melbourne. The teeth were stored in 1% chloramine T solution in distilled water (pH 7.8) (Sigma–Aldrich Co., St. Louis, MO, USA).

The teeth were mounted in the centre of nylon mounting rings using a jig to maintain vertical orientation in all directions. The teeth were mounted using dental stone covering the roots to within 2 mm of the cement–enamel junction (CEJ), to approximate the support of alveolar bone in a healthy tooth. It was not considered necessary to simulate the periodontal ligament since the teeth were not subjected to any form of occlusal loading; the small extent of cuspal movement is not likely to be affected by terminating the mounting 2 mm below the CEJ.

Standardised mesio-occlusal-distal (MOD) cavities were prepared as described below in all specimens, using a tungsten carbide round-ended fissure bur (Komet H21R, Brasseler, Lemgo, Germany) in a high speed handpiece with water coolant. The cavosurface margins were prepared at 90° and all internal angles were rounded. Four types of preparation were carried out (Fig. 1).

Group 1 (*control*): extensive MOD cavity preparation; occlusal depth of 3 mm, isthmus width of 1/3 inter-cuspal distance, and proximally to 1 mm above the CEJ. Consistency in cavity preparation was ensured by parallel preparation of the facial and palatal walls of the cavity.

Group 2: endodontic access cavity confined within the occlusal floor of the MOD cavity; root canals were prepared using rotary nickel–titanium instruments and obturated using a warm vertical condensation technique and AH26 resin sealer (De Trey, Dentsply, Konstanz, Germany); gutta-percha was removed to 2 mm below the CEJ. Excess sealer was removed with a cotton pellet moistened with alcohol.