Thickness of CAD–CAM composite resin overlays influences fatigue resistance of endodontically treated premolars

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\begin{abstract}
Objectives. Evaluate the influence of composite resin CAD–CAM restoration thickness on the in vitro fatigue resistance and failure mode of overlay-type restoration in endodontically treated premolars.

Methods. Thirty extracted premolars received root canal treatment followed by a standardized tooth preparation (1.5-, 2.5- or 3.5-mm cusp reduction, proximal gingival margins located 1.5 mm below the CEJ, glass-ionomer base and immediately sealed dentin with Opti-bond FL). Restorations were milled using Cerec3 and FiltekMZ100 composite blocks. The intaglio surfaces of the overlays were sandblasted and silanated. Tooth preparations were sandblasted and etched before insertion of the restoration. All restorations were luted with Optibond FL and preheated FiltekZ100. A closed-loop servohydraulic unit was used for simulating cyclic isometric chewing at 5 Hz, starting with a load of 200 N (5000 cycles), followed by stages of 400, 600, 800, 1000, 1200 and 1400 N at a maximum of 30,000 cycles each. All samples were loaded until fracture or to a maximum of 185,000 cycles. Groups were compared using the Kaplan–Meier survival curves.

Results. None of the restored premolars with the 1.5-mm cusp overlap restoration withstood all 185,000 loading cycles. With 2.5- and 3.5-mm cusp overlap, the survival rate was 30% and 40%, respectively. The rate of fracture below the CEJ was 60%, 60% and 30% for 1.5, 2.5 and 3.5 mm of cusp overlap, respectively. Survival of restored premolars with 2.5- and 3.5-mm cusp coverage was not significantly different (\( p = .23 \)).

Significance. Thick FiltekMZ100 composite resin onlays showed higher fatigue resistance than thin ones and may be associated with fractures that are less subgingival.

\end{abstract}

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1. Introduction

Endodontically treated posterior teeth present with specific challenges for the restorative dentist and the prosthodontist because of their more brittle behavior when compared to vital teeth. This difference is not explained by their moisture content but rather the structural defect generated during tooth preparation [1,2]. The clinical diagnosis generally requires extracoronal strengthening by cuspal coverage. Traditionally, full coverage cast restorations have been used, even though adhesively placed restorations with total cuspal coverage (overlays) have been proposed as a more conservative alternative [3]. The significant advantage of adhesive restorations is their ability to mimic the natural behavior
of enamel and dentin (biomimetic principle) and simultaneously reduce the need for root canal treatment (RCT) and unreasonable destruction of remaining tooth substance [3–5]. As margins of adhesive restorations are not required to be placed subgingivally, they are associated with less gingival inflammation and secondary caries [6]. Teeth (with or without RCTs) restored with adhesive onlay restorations demonstrated superior fatigue resistance when composite resin restorations were used instead of porcelain [7–9]. Three-millimeter thick resin overlays [9], either generated by CAD/CAM or hand-layered, also demonstrated a reduced risk of subgingival catastrophic failure. An area which requires further investigation is whether the amount of cuspal coverage might influence the performance of the tooth-restoration complex. The usual cuspal reduction varies between 1.5 and 2.0 mm [10–12] but limited scientific evidence is available to support this recommendation.

Therefore, the aim of this study is to determine the influence of material thickness on the in vitro fatigue resistance and failure mode of overlay-type restoration of endodontically treated premolars. The null hypothesis is that there is no difference between thin and thick CAD/CAM composite resin overlays.

2. Materials and methods

Upon approval from the University of Southern California Institutional Review Board, 30 freshly extracted, sound human maxillary premolars were collected and stored in a solution saturated with thymol. Each tooth was mounted in a special positioning device using acrylic resin (Palapress, Haereus Kulzer, Armonk, NY, USA) embedding the root up to 3.0 mm below the cementoenamel junction (CEJ).

2.1 Specimen preparation

First, all specimens were prepared in a standardized way (Fig. 1), starting with occlusal reduction generating either 1.5-, 2.5- or 3.5-mm clearance for the overlay. This was followed by a 2.5-mm wide mesio-occluso-distal slot preparation with rounded internal line angles and proximal margins 1.5 mm below the cementoenamel junction. Second, a standard access opening was prepared to simulate root canal treatment. Following shaping with the stepback technique (maximum file size 35–40), the root canals were filled with a thermoplasticized gutta percha delivery system (ObturaII, Obtura/Spartan, Fenton, MO, USA). Third, a base was applied to the pulp chamber in the form of a 2.0–3.0-mm thick glass-ionomer barrier (Ketac Molar, 3M-ESPE, St. Paul, MN, USA). A coarse round diamond bur was used at 1500 rpm to refresh the dentin surface before the application of a 4th generation etch-and-rinse dentin bonding agent (Optibond FL, Kerr, Orange, CA, USA). This immediate dentin sealing was followed by the application of an air-blocking barrier (K-Y Jelly, Personal Products Company, Skillman, NJ, USA) and 10 s of additional light exposure (light unit Allegro, Den-Mat, Santa Maria, CA, USA) to polymerize the oxygen-inhibition layer. Excess adhesive resin was carefully removed from all enamel margins with a coarse round diamond at 1500 rpm.

2.2 Restoration design and manufacturing

Standardized overlays were generated with the Cerec3 CAD/CAM system (Cerec software v. 3.03, Sirona Dental Systems GmbH, Bensheim, Germany). All specimens were fitted with the anatomy of a first maxillary premolar (Lee Culp Youth database, Crown Master Mode) with cusp tips parallel to the preparation surface and the central groove aligned with the mesio-occluso-distal slot. All restorations were milled using the composite resin Paradigm MZ100 blocks (3M-ESPE, St. Paul, MN, USA) using the Endo mode with the sprue located at the distal surface, then polished mechanically using a commercial polishing kit (Dialite, Ultra Polishers; Brasseler, Savannah, GA, USA).

2.3 Adhesive placement of restoration

Surface conditioning of milled restorations included airborne-particle abrasion with 50-μm aluminum oxide at 30 psi, followed by cleaning using 37.5% phosphoric acid (Ultradent, Ultradent, South Jordan, UT, USA) with a gentle brushing motion for 1 min and rinsing with water for 20 s. After final cleaning by immersion in distilled water kept in an ultrasonic bath for 2.5 min followed by oil-free air-drying, intaglio surfaces were silanated (Silane, Ultradent, South Jordan, UT, USA) and dried for 5 min.

Tooth preparations were treated by airborne-particle abrasion with 50-μm aluminum oxide at 30 psi and 30 s etching with 37.5% phosphoric acid. They were rinsed with water and dried. Both intaglio surfaces (restoration and tooth) were coated with adhesive resin (Optibond FL, bottle 2; Kerr, Orange CA, USA) left unpolymerized until the application of the luting material. The composite resin luting materials (Z100; 3M-ESPE, St. Paul, MN, USA) was preheated for 5 min (Calset; Addent, Danbury, CT, USA), applied onto the prepared tooth surface and the restoration was inserted. After careful removal of all excesses of uncured composite resin, each surface was light-polymerized for 60 s (Allegro; Den-Mat, Santa Maria, CA, USA). All margins were covered with an air-blocking barrier for the final polymerization cycle.