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Optimization of large MOD restorations: Composite resin inlays vs. short fiber-reinforced direct restorations

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ABSTRACT

Objective. To compare mechanical performance and enamel-crack propensity of direct, semi-direct, and CAD/CAM approaches for large MOD composite-resin restorations.

Methods. 45 extracted maxillary molars underwent standardized slot-type preparation (5-mm depth and bucco-palatal width) including immediate dentin sealing (Optibond FL) for the inlays (30 teeth). Short-fiber reinforced composite-resin (EverX Posterior covered by Gradia Direct Posterior) was used for the direct approach, Gradia Direct Posterior for the semi-direct, and Cerasmart composite resin blocks for CAD/CAM inlays. All inlays were adhesively luted with light-curing composite-resin (preheated Gradia Direct Posterior). Shrinkage-induced enamel cracks were tracked by transillumination photography. Cyclic axial isometric chewing (5-Hz) was simulated, starting with a load of 200 N (5000 cycles), followed by stages of 400, 600, 800, 1000, 1200, and 1400 N (maximum 30,000 cycles each) until fracture or to a maximum of 185,000 cycles. Survived specimens were subjected to cyclic-load-to-failure test at 30-degree angle on the palatal cusp.

Results. Only small shrinkage-induced cracks were found in 47% of the direct restorations compared to 7% and 13% of semi-direct and CAD/CAM inlays, respectively. Survival to accelerated fatigue was similar for all three groups (Kaplan-Meier $p > .05$) and ranged between 87% (direct) and 93% (semi-direct and CAD/CAM). Cyclic-load-to-failure tests did not yield significant differences either (Life Table analysis, $p > .05$) with median values of 1675 N for CAD/CAM inlays, 1775 N for fiber-reinforced direct restorations and 1900 N for semi-direct inlays.

Significance. All three restorative techniques yielded excellent mechanical performance above physiological masticatory loads. Direct restorations performed as good as inlays when a short-fiber reinforced composite-resin base was used.

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1. Introduction

Techniques for restoring anterior or posterior teeth include direct, semi-direct, semi-indirect and indirect restorations [1]. Large direct restorations present several challenges, especially in the posterior dentition. Mastering of shape, contours and occlusal anatomy/function requires particular skills [2,3]. But it also raises the problem of polymerization shrinkage [4,5]. Contraction stresses challenge the dentin–resin hybrid layer and may result in gap formation and/or decreased dentin bond strength [4,6]. However when using strong adhesives, shrinkage will likely cause cuspal deformation and cracking of the enamel at the cuspal base [7,8].

Many methods have been proposed in an attempt to reduce those stresses when choosing direct techniques [9], such as sophisticated layering techniques [10], sandwich approaches with glass ionomer bases [11] and fiber patches [12], pulse delay and slow-start light polymerization protocols [13]. To achieve clinically relevant conversion, the majority of the shrinkage stress is developed during and after the vitrification stage and even in the absence of light (“dark” cure stage), which does not permit stress relaxation on the time scales proposed for those “soft” polymerization protocols [14]. Sandwich restorations may represent the most convenient way to help control part of the shrinkage stresses when used in form of a novel “super-closed” technique [8]. Layering protocols have been demystified by a number of studies showing that layering does not necessarily decrease shrinkage stresses [15,16] but might even make them worse compared to bulk filling [17]. Hence, in the recent years, manufacturers have shifted their attention toward simplification using new materials for bulk filling, with encouraging results (stress reduction, strength) in both flowable and packable form [18–20]. In 2013, a new short fiber-reinforced material (EverX Posterior, GC, Lueven, Belgium) to be used as a bulk dentin replacement was introduced and recommended for high-stress bearing area [21]. It presents a higher fracture toughness and flexural modulus within the family of bulk-fill materials but can be used easily in 4-mm deep increments and can potentially match the toughness of dentin [22,23].

However, when it comes to the ultimate way of controlling polymerization stresses in large MOD restorations, luted inlay techniques have proven to be the most efficient [8,24] because the shrinkage is limited to the very thin layer of luting material. There are at least three techniques for the dentist to fabricate a composite resin inlay [25]: the intraoral inlay (isolating and using the tooth itself as a die) [26], the extraoral inlay (using an alginate impression and a fast-setting silicon model) [25] and the CAD/CAM inlay [27]. Filtek MZ100 (3M-ESPE, St. Paul, MN, USA) was the first composite resin CAD/CAM block introduced in 2001 [27]. It demonstrated outstanding performance, wear properties, color integration and millability in thin layers [28–32]. In a recent accelerated fatigue study, large MOD Filtek MZ100 CAD/CAM inlays showed 100% survival unlike all other direct techniques [8]. The positive outcome of Filtek MZ100 may have triggered the development of new CAD/CAM composite resin blocks such as Lava Ultimate (3M-ESPE, Seefeld, Germany), Cerasmart (GC, Lueven, Belgium),

Katana Avencia (Kuraray Noritake Dental Inc., Tokyo, Japan) and Block HC (Shofu, Kyoto, Japan).

This research assessed the accelerated fatigue strength and cracks propensity of a large MOD short fiber-reinforced direct composite restoration compared to composite resin inlays made with either a new CAD/CAM material or using the intraoral inlay technique. The null hypotheses were that (1) no significant influence would be found in mechanical performance among the restorative technique used, and (2) there would be no difference in enamel crack propensity (induced by shrinkage stress) between three groups.

2. Materials and methods

Upon approval from the Ethical Review Committee of the University of Southern California (Los Angeles, CA) (proposal # HS-16-00544), forty-five caries-free maxillary molars were collected from a large collection of teeth, scaled, pumiced and stored in 0.1% thymol solution (Aqua Solutions Inc, Deer Park, TX, USA). It was chosen teeth which presented few or no cracks.

The roots were embedded up to 3 mm below the cemento-enamel junction (CEJ) using acrylic resin (Palapress vario; Heraeus Kulzer, Armonk, NY, USA) and mounted in a special positioning device. With the aim of “enamel crack tracking” during the experiment, each surface of the tooth was photographed under standardized conditions at 1.5× magnification (Nikon D610 with Nikkor 105 mm macro lens) and using transillumination (IL-88-FOI Microscope Light Source, Scioscope, Chino, CA). After every procedure, a new set of images would be taken to precisely detect existing cracks.

In order to evenly distribute the teeth according to their size and shape, all specimens were organized in groups of three (“triplets”) with similar buccolingual and mesiodistal size and height) and subsequently re-assigned randomly to groups ($n=15$) which received (1) a fiber-reinforced composite resin base (EverX Posterior, GC) layered with direct composite (Gradia Direct posterior, GC, Lueven, Belgium), (2) a semi-direct inlay (Gradia Direct Posterior, GC, Lueven, Belgium) or (3) a CAD/CAM inlay (Cerasmart, GC).

2.1. Specimens preparation

A standardized MOD slot-type tooth preparation was applied with 5-mm bucco-palatal width and 5-mm depth by using tapered diamond burs (Brasseler, Savannah, GA, USA) and continuous water cooling in a high-speed electric handpiece (Fig. 1a and b). For direct restorations only, a 0.5–1 mm 45° bevel at the cervical and proximal angles was created with a spherical shape fine diamond bur (#8801-018, Brasseler). After preparation completion, photographic enamel crack tracking was performed to determine if preparation would have caused any damage to the specimens.

Immediate dentin sealing (IDS) was performed to the freshly cut dentin of the semi-direct and CAD/CAM inlay preparations, using a three-step etch-and-rinse dentin bonding agent (Optibond FL; Kerr, Orange, CA, USA) according to previously published protocol [33]. The adhesive was polymerized for 20 s at 1000 mW/cm² (VALO Curing Light, Ultradent

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