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Effects of fiber-glass-reinforced composite restorations on fracture resistance and failure mode of endodontically treated molars

Scotti Nicola[a,*], Forniglia Alberto[a], Michelotto Tempesta Riccardo[a], Comba Allegra[a], Saratti Carlo Massimo[b], Pasqualini Damiano[a], Alovisi Mario[a], Berutti Elio[a]

[a] Department of Surgical Sciences, Dental School Lingotto, University of Turin, Via Nizza 230, Turin, Italy
[b] Division of Cariology and Endodontology, School of Dentistry, University of Geneva, Rue Barthèlemy-Menn, Geneva, Switzerland

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ABSTRACT

Objectives: The study evaluated the fracture resistance and fracture patterns of endodontically treated mandibular first molars restored with glass-fiber-reinforced direct composite restorations.
Methods: In total, 60 extracted intact first molars were treated endodontically; a mesio-occluso-distal (MOD) cavity was prepared and specimens were then divided into six groups: sound teeth (G1), no restoration (G2), direct composite restoration (G3), fiber-post-supported direct composite restoration (G4), direct composite reinforced with horizontal mesio-distal glass-fibers (G5), and buccal-palatal glass-fibers (G6). Specimens were subjected to 5000 thermocycles and 20,000 cycles of 45° oblique loading force at 1.3 Hz and 50 N; they were then loaded until fracture. The maximum fracture loads were recorded in Newtons (N) and data were analyzed with one-way ANOVA and *post-hoc* Tukey tests ($p < 0.05$). Fractured specimens were analyzed with a scanning electron microscope (SEM).
Results: The mean static loads (in Newtons) were: G1, 831.83; G2, 282.86; G3, 364.18; G4, 502.93; G5, 499.26; and G6, 582.22. Fracture resistance did not differ among G4, G5, and G6, but was significantly higher than G3 ($p = 0.001$). All specimens fractured in a catastrophic way. In G6, glass fibers inducted a partial deflection of the fracture, although they were not able to stop crack propagation.
Conclusions: For the direct restoration of endodontically treated molars, reinforcement of composite resins with glass-fibers or fiber posts can enhance fracture resistance. The SEM analysis showed a low ability of horizontal glass-fibers to deviate the fracture, but this effect was not sufficient to lead to more favorable fracture patterns above the cement-enamel junction (CEJ).
Clinical significance: The fracture resistance of endodontically treated molars restored with direct composite restorations seems to be increased by reinforcement with fibers, even if it is insufficient to restore sound molar fracture resistance and cannot avoid vertical fractures.

1. Introduction

Providing fracture resistance to occlusal load in endodontically treated posterior teeth represents one of the main goals of post-endodontic restorations, because they are generally more susceptible to fractures than vital teeth due to the loss of a large amount of tissue as a consequence of carious lesions or coronal fracture [1,2]. Recent studies have reported that the longevity of endodontically treated teeth depends directly on the amount of remaining tooth structure and the efficacy of the restorative procedures in replacing fracture structural integrity [3]. These factors show the importance of highly conservative endodontic and restorative procedures preserving a sound structure as much as possible. The clinical outcomes of direct resin composite restorations, which represent a less invasive approach to restoring endodontic posterior teeth, are variable in the literature, ranging from catastrophic to acceptable [4–6]. More recently, the insertion of fiber posts within direct composite restorations has been tested with the intention of providing increased fracture resistance [7–9]. Indeed, within the radicular dentin, the fiber post serves as a distributor of stresses and loads applied to the composite restoration [10], providing reinforcement even in the presence of sufficient residual coronal dentin [11,12]. Moreover, post and core should have similar elastic moduli to root dentin to better absorb the forces concentrated along the root and, consequently, decrease the probability of fracture [13,14]. However, fiber post insertion presents some limitations: the post-space preparation tends to weaken the radicular structure, because some dentin tissue should be removed

* Corresponding author at: Via Nizza 230, 10100, Turin, Italy.
E-mail address: nicola.scotti@unito.it (S. Nicola).

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[1,2]. Moreover, several studies have reported poor bond strength in the deeper areas of the post space [15,16].

An alternative method to increase the fracture resistance of endodontically treated teeth is by the insertion of fibers, which are increasingly being used for the reinforcement of polymer-based dental materials. In particular, ultra-high-molecular-weight polyethylene fiber (PWT), which has an ultra-high elastic modulus, has been tested recently [17,18]. The woven network allows fiber wetting and the infusion of the bonding resin; this enhances the transfer of forces acting on the PWT. Previous studies showed that this network changed the stress dynamics at the enamel-composite material interface [19], but the effect on fracture resistance of endodontically treated teeth remains controversial [20,21].

Recently, UDMA-TEGDMA pre-impregnated parallel glass-fibers were introduced, but as yet there is limited knowledge about their effect on fracture resistance when used together with an extensive composite restoration on endodontically treated posterior teeth. Thus, the aim of this *in vitro* study was to evaluate the fracture resistance and failure patterns of endodontically treated mandibular first molars restored with glass-fiber reinforced composite. The null hypothesis was that glass-fibers do not increase the fracture resistance of direct composite restorations in endodontically treated teeth.

2. Materials and methods

In total, 60 non-carious mandibular first molars, extracted for periodontal reasons, were selected. The inclusion criteria were as follows: sound teeth, with nearly similar crown sizes and no cracks under transillumination and magnification, extracted within 1 month. A hand scaling instrument was used for surface debridement, followed by cleaning with a rubber cup and slurry of pumice. The specimens were disinfected in 0.5% chloramine for 48 h and then stored in 4% thymol solution at room temperature until use.

Endodontic treatment was carried out in all specimens. Specimens were endodontically instrumented using Pathfiles (1-2-3) and ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) to the working length, which was set at 1 mm short of the visible apical foramen. Irrigation was with 5% NaOCl (Niclor 5, Ogna, Muggiò, Italy) alternated with 10% EDTA (Tubuliclean, Ogna) using a 2-ml syringe and 25-gauge needle. Specimens were then obturated with gutta-percha (Gutta Percha Points, Medium, Inline; B.M. Dentale Sas Di Bertello G. & Moraes M., Torino, Italy) using the DownPack heat source (Hu-Friedy, Chicago, IL, USA) and endodontic sealer (Pulp Canal Sealer EWT; Kerr, Orange, CA, USA). Backfilling was performed with the Obtura III system (Analytic Technologies, Redmond, WA, USA).

The teeth were stored in distilled water at room temperature for at least 72 h. For the simulation of 0.3-mm-thick periodontal ligament, each root was immersed in melted wax up to the demarcation line 2 mm apical to the cement-enamel junction [18] (CEJ; checked with a digital caliper). A metal cubic mold was used to embed all the specimens in acrylic self-curing resin (StickRESIN; Stick Tech Ltd., Turku, Finland) up to 1 mm apical to the CEJ, their long axes were oriented perpendicular to the horizon using a custom-made parallelometer. Each root was removed from the resin block when primary signs of polymerization were noticed. The wax spacer was removed with hot water and then replaced by a silicone-based impression material (Light Body, Flexitime; Heraeus Kulzer, Hanau, Germany), which was injected into the acrylic resin block prior to reinsertion of the specimen.

After 48 h in distilled water, standardized class II mesio-occluso-distal (MOD) cavities were prepared by the same experienced operator in all specimens except the positive control group. For cavity preparation, cylindrical diamond burs (#806314014; Komet, Schaumburg, IL, USA) under copious air-water cooling were used in a high-speed headpiece (Kavo Dental GmbH, Biberach, Germany). The residual thickness of buccal and lingual cusps at the height of the contour was 2.5 ± 0.2 mm in all specimens, with the medial and distal cervical margin located

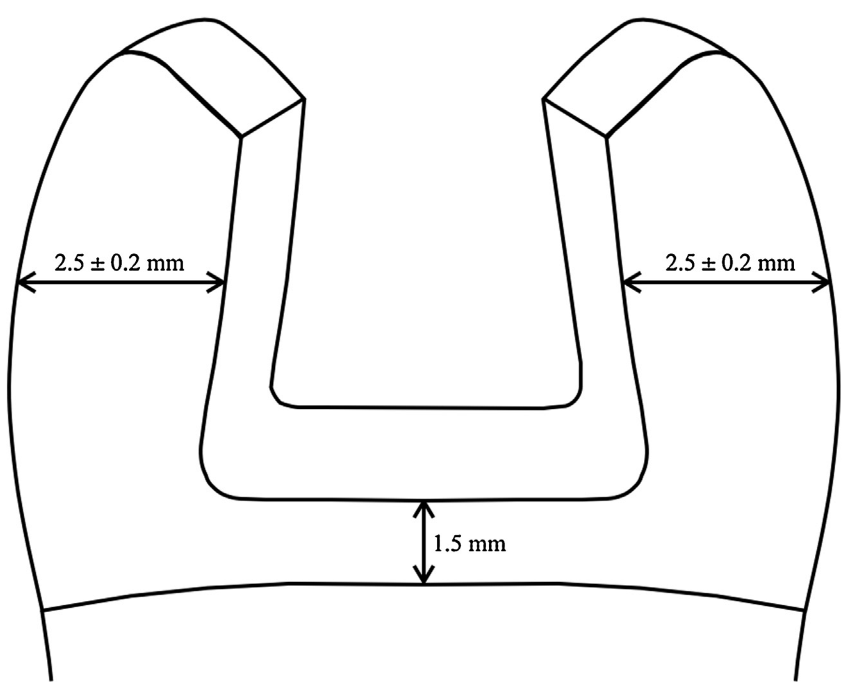

Fig. 1. Schematic representation of the cavity preparation used in this experiment.