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Degradation in the fatigue strength of dentin by cutting, etching and adhesive bonding☆

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ABSTRACT

The processes involved in placing resin composite restorations may degrade the fatigue strength of dentin and increase the likelihood of fractures in restored teeth.

Objective. The objective of this study was to evaluate the relative changes in strength and fatigue behavior of dentin caused by bur preparation, etching and resin bonding procedures using a 3-step system.

Methods. Specimens of dentin were prepared from the crowns of unrestored 3rd molars and subjected to either quasi-static or cyclic flexural loading to failure. Four treated groups were prepared including dentin beams subjected to a bur treatment only with a conventional straight-sided bur, or etching treatment only. An additional treated group received both bur and etching treatments, and the last was treated by bur treatment and etching, followed by application of a commercial resin adhesive. The control group consisted of "as sectioned" dentin specimens.

Results. Under quasi-static loading to failure there was no significant difference between the strength of the control group and treated groups. Dentin beams receiving only etching or bur cutting treatments exhibited fatigue strengths that were significantly lower ($p \le 0.0001$) than the control; there was no significant difference in the fatigue resistance of these two groups. Similarly, the dentin receiving bur and etching treatments exhibited significantly lower ($p \le 0.0001$) fatigue strength than that of the control, regardless of whether an adhesive was applied.

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Significance. The individual steps involved in the placement of bonded resin composite restorations significantly decrease the fatigue strength of dentin, and application of a bonding agent does not increase the fatigue strength of dentin.

1. Introduction

Resin composites are now the primary material for tooth cavity restorations [1]. But there is growing concern that bonded composite restorations have higher failure rates than their predecessors [e.g., 2,3]. The three most common forms of failure are reportedly secondary caries, marginal degradation and fracture (including either the restorative material, the supporting tooth tissues or both) [4,5]. Although not the most common form of failure, tooth fracture is potentially the most detrimental as it more commonly results in complete tooth loss. Teeth without restorations generally do not fail by fracture, which raises an important question. Does tooth fracture occur due to an increase in stress within restored teeth, or from defects introduced within the hard tissue foundation by the restorative process and subsequent fatigue?

In comparison to materials of the past, the placement of composite restoratives is complex [6]. As such, there are a number of steps that could inadvertently cause the introduction of defects within the tooth structure. For example, the excavation of demineralized tissue involves material removal, and an interaction between the cutting tools and hard tissue under dynamic conditions. Surface defects introduced during machining/grinding of brittle materials are extremely detrimental, and often lead to a reduction in strength [7–9]. The introduction of defects within hard tissues could diminish their structural integrity [10], thereby reducing durability of the restoration and increasing the likelihood of tooth fracture.

Past investigations have evaluated the material removal processes in cutting of hard tissues and the resulting surface integrity [11–14]. For instance, carbide and diamond abrasive bur preparations were found to introduce cracks during cutting of enamel, whereas the same processes were not found to cause damage while cutting dentin [14]. Similarly, though cracks were not found to result from bur treatments in dentin, Banerjee et al. [15] reported that sono-abrasion and Carisolv gels introduced flaws. One could perceive that the flaws introduced by cutting are small, and that other aspects of the restorative process serve to enlarge the cracks resulting from cutting. Sehy and Drummond [16] introduced Class I or Class II MOD preparations in molars using either coarse diamond burs or an Er:YAG laser. The preparations were followed by placement of a resin composite, bulk curing to maximize interfacial stresses, and then evaluation of the tooth-composite interface via microscopy. Neither of the two cutting processes and subsequent steps resulted in visible microcracks in dentin.

Using measures of strength to assess the presence of damage, Staninec et al. [17] showed that cracks exceeding 100 μm in length were introduced within the dentin by laser preparations under some treatment conditions. That could suggest that flaws introduced with dental burs are too small to see in direct evaluations (i.e., microscopy), but they certainly alter the natural flaw population and distribution within the tissue. As dentin is susceptible to degradation by fatigue [18,19] small flaws may propagate and facilitate fracture by fatigue crack growth [20,21]. Indeed, Majd et al. [22] reported that while there was no influence of burs or airjet surface treatments on the strength of dentin under quasi-static loading, both preparations caused a degradation of strength when assessed by cyclic loading. That study did not consider other steps used in the placement of composite restorations (e.g., etching or adhesive bonding), or that flaws introduced by cutting operations may be removed by subsequent etching. Despite the importance of this topic to restored tooth integrity, this area of investigation has received limited attention.

The primary objective of this investigation was to evaluate the reduction in quasi-static strength and fatigue resistance of dentin resulting from the steps involved in preparing cavities and placement of resin-composite restorations. The null-hypothesis to be tested was that etching and application of a resin adhesive in the use of 3-step (etch-and-rinse) bonding systems, has no influence on the fatigue strength of dentin, regardless of whether or not the tissue has been prepared by bur cutting.

2. Materials and methods

Caries-free third molars were obtained from participating dental practices in Maryland according to a protocol approved by the Institutional Review Board of the University of Maryland Baltimore County (Approval Y04DA23151). All teeth were from donors between 18 ≤ age ≤ 25 years old. The teeth were maintained in Hanks Balanced Salt Solution (HBSS) with 0.2% sodium azide as an antimicrobial agent at 4 °C, then cast in a polyester resin foundation and sectioned using a highspeed grinder (Chevalier Smart-H818II, Chevalier Machinery, Santa Fe Springs, CA, USA) and diamond abrasive slicing wheels (#320 mesh abrasives) with water-based coolant bath. Primary sections were made in the bucco-lingual plane, and secondary sectioning was performed to obtain beams as shown in Fig. 1(a). The beams were prepared with width of 1.5 mm and thickness of either 0.5 or 0.65 mm, depending on whether a bur treatment was performed. Each of the beams was inspected; those with pulp horn intrusions, enamel end-caps or other non-uniformities were discarded.

Five different groups of beams were prepared including a nominally "flaw-free" control group that was evaluated directly as-sectioned, and a total of four treatment groups. Two of the treated groups received a single surface preparation, and two additional treated groups received a combination of preparations. One of the treated groups was subjected to a