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Resin composites: Modulus of elasticity and marginal quality

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ABSTRACT

Objective: To investigate how the modulus of elasticity of resin composites influences marginal quality in restorations submitted to thermocyclic and mechanical loading.

Methods: Charisma, Filtek Supreme XTE and Grandio were selected as they were found to possess different moduli of elasticity but quite similar polymerization contraction. MOD cavities ($n = 30$) were prepared in extracted premolars, restored and then subjected to thermocyclic and mechanical loading. Marginal quality of the restorations before and after loading was analyzed on epoxy replicas under a scanning electron microscope. The percentage of gap-free margins and occurrence of paramarginal fractures were registered. Modulus of elasticity and polymerization contraction were analyzed with parametric and margins with nonparametric ANOVA and *post hoc* Tukey HSD or Wilcoxon rank-sum tests, respectively. The number of paramarginal fractures was analyzed with exact Fisher tests ($\alpha = 0.05$).

Results: Grandio demonstrated significantly more gap-free enamel margins than Charisma and Filtek Supreme XTE, before and after loading ($p < 0.01$), whereas there was no difference between Charisma and Filtek Supreme XTE ($p > 0.05$). No significant effect of resin composite ($p = 0.81$) on the quality of dentine margins was observed, before or after loading. Deterioration of all margins was evident after loading ($p < 0.0001$). More paramarginal enamel fractures were observed after loading in teeth restored with Grandio when compared to Charisma ($p = 0.008$).

Conclusions: The resin composite with the highest modulus of elasticity resulted in the highest number of gap-free enamel margins but with an increased incidence of paramarginal enamel fractures.

Clinical significance: The results from this study suggest that the marginal quality of restorations can be improved by the selection of a resin composite with modulus of elasticity close to that of dentine, although an increase in paramarginal enamel fractures can result as a consequence.

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1. Introduction

The provision of long-term adhesion and a tight seal of resin composite materials to the dental hard tissues are among the main goals of restorative dentistry. Adhesive restorations with improved marginal quality are less inclined to marginal staining, presence of gaps, pulpal irritation, bacterial infiltration with consequent demineralization of the surrounding dental tissues, tooth cracks or fracture, or yet retention loss.[1–5]

However, despite the continual improvements in the performance of dental adhesives and resin composites, it is extremely challenging to produce restorations with perfect margins.[4,6–9] During polymerization, the resin composite contracts and generates stresses at the adhesive interface.[6,10–12] These contraction stresses are accompanied by undesirable consequences, such as deformation of the tooth's cusps, gap formation, and/or paramarginal enamel fractures.[4,10,13–20]

Although the contraction stresses may immediately influence the quality of restoration margins, in longer term the occlusal loading by contact with an opposing cusp during function will induce stresses at the interface between the restoration and the tooth.[16,17,21] Further aggravation of gap formation can therefore be expected by loading of the restorations during masticatory function.[4,7,8,22,23]

For these reasons, gap formation remains as an important limitation for resin composite restorations. Interfacial failure due to cuspal movements as a result of polymerization contraction or occlusal loading[16,17] is particularly concerning in Class II MOD restorations.[21] In Class II restorations, less tooth structure is present to distribute the stresses, which might consequently imply a shorter life expectancy for Class II when compared to Class I restorations.[21] Additionally, Class II cavities often finish in dentine margins, where adhesion is known to be more challenging than in enamel, and gap formation is thus more evident particularly after loading.[4,7,8,22,23]

The use of appropriate restorative techniques or restorative materials has been advocated in order to minimize the development of interfacial stresses and its subsequent side effects.[20,24] Finite element analysis has shown that the modulus of elasticity of the restorative material plays an essential role in the success of a restoration.[16,17,21] Findings indicate that more rigid resin composites suffer lower cuspal movements under occlusal loading but exhibit higher preloading cuspal movement due to polymerization shrinkage stresses.[16,17] The higher cuspal deflection during polymerization of resin composites with a high modulus of elasticity has been confirmed *in vitro*.[19] Therefore, a good restoration has to balance the two opposite effects: a certain degree of initial stress is accepted in order to guarantee sufficient rigidity to the restoration.[16] Further finite element analysis has demonstrated that the properties and thickness of the adhesive layer may also alleviate part of the stresses at the restoration interface,[16] and the association with a resin composite with high modulus of elasticity will minimize marginal deterioration in occlusal restorations.[21] Therefore, premature failure due to stresses arising from polymerization contraction and occlusal loading can be prevented by the proper selection and combination of materials.[16,17,24]

However, these models lack *in vitro* validation on how the modulus of elasticity of the restorative material influences gap formation and how it may optimize the quality of restoration margins. Previous studies have investigated the effect of the modulus of elasticity of adhesive base materials, such as flowable resin composites or glass ionomer cements, on the marginal quality of restorations.[8,14,23–25] However, in these earlier studies the modulus of elasticity was not very distinct among the investigated base materials[8,24,25] nor was the polymerization contraction accounted for,[8,23,24] which in all hamper interpretation of the results. Therefore, the aim of this study was to investigate how the modulus of elasticity of resin composites influences marginal quality in Class II restorations submitted to thermocyclic and mechanical loading. It was hypothesized that increasing modulus of elasticity of the resin composite would result in improved marginal quality of restorations following thermocyclic and mechanical loading.

2. Materials and methods

Since polymerization contraction is known to play an important role in marginal integrity, resin composites with similar contraction but distinct moduli of elasticity were selected in order to investigate the working hypothesis (Table 1). Previous studies have indicated that Charisma (Heraeus Kulzer, Hanau, Germany), Filtek Supreme XTE (3M ESPE, St. Paul, MN, USA), and Grandio (VOCO GmbH, Cuxhaven, Germany) might possess different moduli of elasticity while at the same time quite similar polymerization contraction. These properties were verified in the present study as described below, before the cavities were restored and subjected to thermocyclic and mechanical loading.

2.1. *Modulus of elasticity*

The modulus of elasticity of the resin composites was calculated from three-point flexural strength tests performed according to ISO 4049.[26] Each resin composite was inserted in a mould and light-cured at 850 mW/cm^2 (Optilux 501 Curing Light, Kerr Corporation, Orange, CA, USA) for 20 s per site at 5 overlapping sites, from both the top and bottom surfaces. Six rectangular specimens (25 mm × 2 mm × 2 mm) were fabricated from each resin composite and stored in water at 37 °C for 24 h. The specimens were mounted in a universal testing machine (Instron 5566, High Wycombe, UK) and loaded at a cross-head speed of 0.75 mm/min until fracture. The modulus of elasticity of the resin composites was defined as the slope from their stress–strain curve in the elastic deformation region.

2.2. *Polymerization contraction*

The polymerization contraction of the resin composites was measured using the bonded-disc method adapted from Watts and Cash.[27] Three measurements were conducted for each resin composite. Standard amounts (0.22 ± 0.02 g) of the resin composites were placed on a glass plate attached to a metallic ring. On top of the ring, a thin glass lamina was positioned. The tip of a LVDT (linear variable differential transformer,