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Influence of using different bonding systems and composites on the margin integrity and the mechanical properties of selectively excavated teeth in vitro

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ABSTRACT

Objectives: Selective (incomplete) caries excavation reduces the risk of pulpal complications, but might compromise the properties of teeth or restorations. Different restorative approaches might be required after selective instead of complete excavation. We compared margin integrity, microleakage and fracture resistance of selectively excavated and differently restored premolars in vitro.
Methods: In 72 extracted human premolars, artificial residual lesions were induced on pulpo-axial walls of standardized cavities. Teeth were restored using one of three bonding systems (OptiBond FL, Clearfil SE Bond, G-aenial Bond) and a fibre-enforced (EverX) or standard hybrid composite resin (Filtek Z250). After thermo-mechanical cycling, groups ($n = 12$) were compared regarding their gingivo-cervical margin integrity (proportion of acceptable margins), microleakage depth, and fracture resistance, with statistical evaluation using generalized linear modelling.
Results: Margin integrity was significantly influenced by the bonding system ($p < 0.001$), but not by the composite ($p = 0.105$). Proportions of acceptable margins were increased in teeth restored with OptiBond FL (median [25th/75th percentiles]: 93 [78/100%]) or Clearfil SE (82 [60/94]%) compared with G-aenial Bond (43 [15/74%]; $p < 0.05$). Neither bonding systems nor composites significantly influenced leakage depth in enamel ($p = 0.749/0.569$) or dentine ($p = 0.112/0.909$). Fracture resistance was significantly influenced by bonding system ($p = 0.008$) and composite ($p = 0.001$), and was higher in teeth restored using OptiBond FL (mean [SD]: 1210 [336] N) compared with Clearfil SE (1007 [208] N) or G-aenial Bond (1023 [281] N, $p < 0.05$), and using EverX (1182 [314] N) instead of Filtek Z250 (979 [228] N; $p < 0.01$).
Conclusions: Bonding systems which perform well in completely excavated teeth also yielded good results for selectively excavated teeth in vitro. Using fibre-enforced composites to restore selectively teeth increased fracture resistance.
Clinical significance: Bonding systems which perform well in completely excavated teeth are also suitable for restoring selectively excavated teeth. Using fibre-enforced composites seems suitable for increasing the fracture resistance of selectively teeth and their restorations.

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1. Introduction

Q2 The treatment of cavitated caries lesions usually involves the excavation of carious biomass and restoration of the cavity, and is associated with the risks of pulpal exposure and post-operative pulpal symptoms especially when treating deep lesions. Selective, i.e. partial or incomplete excavation does not remove all carious dentine, but purposively leaves softened caries-affected and (possibly) infected dentine in proximity to the pulp. Thus, the risks of pulpal exposure or symptoms[1,2] and endodontic re-treatment[3] are reduced, which might allow retaining teeth and their vitality for longer at lower cost.[4,5]

Whilst convincing evidence showed that bacteria sealed under a sufficient restoration inactivate due to nutritional deprivation, doubts remain regarding the mechanical properties of selectively excavated teeth.[6] Softer, demineralized dentin[7] is feared to not sufficiently support the restoration, and might further reduce the bond between the adhesive restoration and the tooth.[8] Whilst sealed dentine remineralizes and rehardens to a certain degree, it is unclear if this affects the mechanical stability of the tooth. It seems further unlikely that bond strengths are affected by this post hoc alterations of dentine. Both compromised stability of the tooth and reduced bond strengths might affect the margin integrity of the placed restorations and increase the cuspal deflection during mastication. This, in turn, might further accelerate margin deterioration, which could subsequently lead to microleakage. For teeth with sealed caries lesions, microleakage of carbohydrates might then impede the attempted lesion arrest.

Whilst one early experimental study found selective excavation of occlusal lesions in molars to decrease their fracture resistance,[6] more recent studies could not confirm significantly decreased mechanical properties or disadvantageous margin integrity and leakage behaviour of restorations placed in selectively compared with completely excavated premolars in vitro.[9,10] Moreover, clinical evidence also supports the assumption that the risk of restorative failures does not significantly differ between selectively and completely excavated teeth.[4] Nevertheless, selectively excavated teeth do differ with regards to the pulpo-proximal substrate for adhesive restorations: Compared with completely excavated teeth, different restorative approaches might help to improve the mechanical properties of selectively excavated teeth, and the quality of therein placed restorations. Different bonding systems might have differential suitability for bonding to caries-affected dentine.[8,11] Composite resins differing in their flexural resistance might be differently suitable for restoring selectively excavated teeth. We aimed to compare the effects of using different bonding systems and resin composites on the mechanical properties of selectively excavated teeth and the marginal integrity and microleakage of restorations placed in such teeth in vitro.

2. Materials and methods

2.1. Study design

Within this study, selectively excavated teeth were adhesively restored using

(a) three different bonding systems, i.e. the 3-step etch-and-rinse adhesive OptiBond FL (Kerr, Bioggio, Switzerland), the 2-step self-etching adhesive Clearfil SE Bond (Kuraray, Hattersheim, Germany) and the 1-step self-etching adhesive G-aenial Bond (GC, Bad Homburg, Germany),
(b) two different resin composites, i.e. the fibre-enforced EverX (GC) and the standard hybrid composite Filtek Z250 (3M ESPE, St. Paul, USA),

resulting in six experimental groups, which were analysed regarding the integrity of gingivo-cervical margins, marginal leakage, cuspal deflection, and fracture resistance.

2.2. Specimen preparation

A sample size of 12 teeth per group had been determined a priori based on a previous study using a similar design.[9] Seventy-two extracted human upper second premolars obtained with informed consent under an ethics-approved protocol (D444/10) were selected according to their mesial-distal (mean [range] = 7.40 [7.25/7.55] mm) and buccal-oral width (9.78 [9.63/9.93] mm) width, with a maximal deviation of 0.25 mm from the means in each dimension set as limit. Teeth were cleaned, controlled for cracks, etc. and embedded (Technovit 4071, Heraeus Kulzer, Hanau, Germany) in chromed brass tubes (∅15 mm; Richter, Kiel, Germany) 1 mm below the cementum–enamel-junction using a gauge. Standardized cavities were prepared using water-cooled copy-milling (Celay, Mikrona, Spreitenbach, Switzerland), minor adjustments were performed with rotating instruments. Cavity surfaces were controlled for cracks or abnormalities using a stereomicroscope (Stemi Zoom, Zeiss, Oberkochen, Germany). Teeth were then covered with nail varnish (High Gloss, Rossmann, Burgwedel, Germany), with two windows (2 mm × 3 mm) left unprotected on the mesial and distal pulpal-axial walls (Fig. 1).

Teeth were submitted to an established protocol to induce artificial residual caries lesions, resembling those remaining after selective excavation using the criterion of leathery dentine remaining in proximity to the pulp.[12] Briefly, teeth were exposed to an acetic acid solution containing 50 mM acetic acid, 3 mM $CaCl_2 \times 2H_2O$, 3 mM KH_2PO_4 and 6 μM methylhydroxy-diphosphonate (pH 5.30, 37 °C) for 2 weeks. Analysis of created lesions was performed after the mechanical analyses using microradiography (see below). The nail varnish was then mechanically removed and surfaces checked again. Cavities were treated according to one of three protocols:

- *OptiBond FL*. Etching with 37% phosphoric acid (3M Espe, St. Paul, USA) for 30 s and 15 s in enamel and dentine, respectively; blow-drying until the surface was not wet anymore, but slightly moist; application of OptiBond FL Primer for 15 s; evaporation of the solvent; followed by OptiBond FL adhesive for 20 s; and light-curing (see below).
- *Clearfil SE Bond*. Conditioning using Primer for 20 s; evaporation of the solvent; application of Bond; and light-curing.
- *G-aenial Bond*. Enamel etching for 10 s using G-aenial Etch (40% phosphoric acid); application of G-aenial Bond for 10 s;