Clin Oral Invest
DOI 10.1007/s00784-016-1927-8

ORIGINAL ARTICLE

Influence of proximal box elevation technique on marginal integrity of adhesively luted Cerec inlays

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Received: 18 March 2016 / Accepted: 26 July 2016

Abstract
Objectives This in vitro study evaluated the marginal quality of Lava Ultimate inlays in deep proximal cavities with and without proximal box elevation (PBE) before and after thermomechanical loading (TML).
Materials and methods Mesio-occluso-distal cavities with proximal boxes beneath the cementoenamel junction (CEJ) were prepared in 24 human molars. Then, one of the proximal boxes was elevated with Filtek Supreme above the CEJ. The specimens were divided into three groups ($n = 8$). The inlays of group A were adhesively luted to the cavities with Scotchbond Universal and Rely X Ultimate, the inlays of group B with Monobond Plus, Syntac, and Variolink II, and the inlays of group C with Clearfil Ceramic Primer and Panavia SA Cement. Epoxy resin replicas were taken before and after thermomechanical loading (1,200,000 cycles, 55 °C/5 °C, max. load 50 N). Marginal integrity at the different interfaces tooth/PBE, tooth/dentine, inlay/PBE, inlay/dentine was evaluated with scanning electron microscopy (×200). The percentage of continuous margin (% of total proximal margin length) was compared between the groups before and after TML. Statistics: Mann-Whitney *U* test ($p = 0.05$).
Results No significant differences ($p > 0.05$) before and after TML were found between the three groups for bonding the inlay to dentine or to PBE composite.
Conclusions The marginal integrities of bonding inlays directly to dentine are not different from bonding inlays to a proximal box, which has been elevated by a composite filling material. For deep proximal cavities, the PBE technique could be an alternative technique to conventional methods. Clinical research is needed to confirm.

Keywords Subgingival margins · Proximal box elevation · Marginal quality · Resin nanoceramics

Introduction

The increasing demand for tooth-colored restorations and characteristics such as biocompatibility and esthetics are reasons why dental ceramics have become the preferred material for inlays in recent decades. In extended mesio-occluso-distal (MOD) cavities with loss of proximal contacts and weak remaining tooth structures, ceramic inlays are indicated to restore and stabilize the sound tooth substance [1]. Recently introduced composite resin blocks are gaining popularity. They offer several advantages like fracture resistance and stiffness [2, 3], wear characteristics [4] and cost efficiency.

When the proximal margins extend close or below the cementoenamel junction in extensively decayed teeth, rubber dam application for appropriate moisture control during the luting procedure can be difficult. Furthermore, excess material is hardly detectable and removable just as cavity preparation is challenging at this deep subgingival level. Surgical crown lengthening can be a way to solve this problem by relocating the cavity margin to a supragingival position to create dry conditions during the luting procedure [5]. To avoid surgical intervention and to produce a tooth-colored restoration in a single visit, the relocation of the subgingival proximal margin to a supragingival level [6–8] by using a composite filling material can be a solution.

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Published online: 09 August 2016

Materials and methods

Specimen selection and preparation

Twenty-four carious-free, intact, unrestored human molars were selected for this in vitro test. Between extraction and use, the teeth had been stored in an aqueous solution of 0.5 % chloramine. After removing tissue remnants, standardized non-beveled MOD cavities were prepared using water-cooled diamond burs (80 μm, Cer-Inlay-Set, Intensiv, Viganello-Lugano, Switzerland). Afterwards, the cavities were finished with a 25-μm diamond bur. The mesial and distal proximal boxes were located 2 mm beneath the cementoenamel junction (CEJ). Then, one of the margins was elevated with Filtek Supreme XTE (Universal Restorative, A2 Enamel Shade, 3M ESPE, Neuss, Germany) in layers of 2 mm, as recommended by the manufacturer being bonded with Scotchbond Universal Etchant and Adhesive (3M ESPE, Neuss, Germany). The cavities were finished again with fine diamond burs and polishing disks (Sof-Lex XT Pop-On, 3M ESPE, Neuss, Germany) with descending roughness. During the time being unrestored, the teeth received temporaries (Clip, Voco, Cuxhaven, Germany). The specimens were then divided into three groups (n = 8) (Table 1).

In group A, the whole cavities were etched (Scotchbond Universal Etchant, 3M ESPE) for 15 s, rinsed with air-water spray, and gently dried. Scotchbond Universal Adhesive (3M ESPE) was applied for 20 s and thinned for 5 s with air. The internal surfaces of the inlays were sandblasted (50 μm) and cleaned meticulously. Then the bonding system (Scotchbond Universal Adhesive, 3M ESPE, Neuss, Germany) was applied for 20 s and also thinned for 5 s with air. The inlays were luted with Rely X Ultimate (3M ESPE).

In group B, the whole cavities were also etched (Total Etch, Ivoclar Vivadent) for 15 s, rinsed with air-water spray, and gently dried. Syntac Primer (Ivoclar Vivadent) was applied for 15 s and thinned with air, then Syntac Adhesive was applied for 10 s and thinned with air. Finally, the cavities were pretreated with Heliobond. The internal surfaces of the inlays were also sandblasted, cleaned carefully, and silanated (Monobond Plus, Ivoclar Vivadent, Schaan, Principality of Liechtenstein). The inlays were luted with Variolink II (Ivoclar Vivadent).

In group C, no pretreatment of the cavities was needed. The inlays were sandblasted, cleaned, and Clearfil Ceramic Primer was applied (Kuraray Noritake Dental Inc., Sakazu, Kurashiki, Okayama, Japan). The inlays were luted with Panavia SA Cement (Kuraray Noritake Dental Inc.).

In all groups, the inlays were manufactured using composite resin blocks (Lava Ultimate, 3M ESPE) and using a CAD CAM system (CEREC 3, Sirona).

After applying the luting composite to the inlays and placing the restoration on the teeth, adhesives and luting resin composites were polymerized (Satelec Mini L.E.D., KaVo, Biberach/Riß, Germany) for 2 to 5 s. Excess luting material was removed under continuous pressure. The entire surface was then cured from the mesial, distal, buccal, lingual, and occlusal directions for 20 s each. The margins were finished with fine diamond burs and polishing disks (Sof-Lex XT Pop-On, 3M ESPE, Neuss, Germany). The teeth were stored in distilled water for 24 h at 37 °C. After impression taking (Permadyne, ESPE, Seefeld, Germany), epoxy resin replicas (RenCast CW 2215 and Ren HY 5162 Härter, Gößl-Pfaff,

Table 1 Tested agents and surface conditioning

Luting composite	Surface	Surface conditioning
A: Rely X Ultimate (3 M ESPE, Neuss, Germany)	Cavity	• Scotchbond Universal Etchant
		• Scotchbond Universal Adhesive
	Inlay	• Sandblasting
		• Scotchbond Universal Adhesive
B: Variolink II (Ivoclar Vivadent, Schaan, Principality of Liechtenstein)	Cavity	• Total Etch
		• Syntac Primer
		• Syntac Adhesive
		• Heliobond
	Inlay	• Sandblasting
		• Monobond Plus
C: Panavia SA Cement (Kuraray Noritake Dental Inc., Sakazu, Kurashiki, Okayama, Japan)	Cavity	No pretreatment needed
	Inlay	• Sandblasting
		• Clearfil Ceramic Primer

Karlskron, Germany) were made for scanning electron microscopy evaluation (Phenom, FEI Company, Eindhoven, Netherlands).

Thermomechanical loading

For the simulation of a periodontal ligament, the roots of all teeth were coated with Impregum (ESPE, Seefeld, Germany) and then embedded in self-curing acrylic resin (Palapress Vario Transparent, Heraeus Kulzer, Wehrheim, Germany). Each specimen was placed in one chamber of the chewing simulator (Fig. 1) and loaded with thermal and mechanical stress for 1.2 Mio cycles with 50 N at 1.6 Hz using a ceramic ball (10 mm in diameter) as an antagonist occluding the crown center. Thermal stress was simultaneously applied during 6000 cycles between 5 and 55 °C by filling the chambers with water for 2 min in each temperature. This procedure is considered to simulate a clinical wear of 5 years [9].

Analysis of marginal quality

After TML, teeth impressions were taken again and replicas were fabricated. The replicas were fixed on aluminum stubs, sputter-coated with platin (Sputter Coater SCD 500, BAL-TEC, Balzers, Liechtenstein) and examined under SEM at ×200 magnification. The marginal integrity was evaluated at the mesial and distal box of each tooth and at four different interfaces (Fig. 2): inlay-luting composite (dentine), inlay/luting composite (PBE), luting composite/dentine, luting composite/PBE. All interfaces were classified according to the criteria "continuous margin," "marginal gap," "mistakes in material processing," and "not judgeable." Then, the percentage of continuous margin in relation to the judgeable margin was calculated.

Fig. 1 Chewing simulator

Statistical analysis

Statistical appraisal was performed using SPSS, version 15 (SPSS Inc., Chicago, IL, USA), for Windows [10]. The level of significance was set at $p = 0.05$.

Results

As the marginal integrity is adequately described by the criterion "perfect margin," the evaluation was limited to this respect. The results are presented in Fig. 3a–b and in Table 2. After TML, a deterioration of the marginal integrity can be detected in all groups in comparison to the data before TML, but the Mann-Whitney *U* test revealed no statistical relevance ($p \leq 0.05$).

Discussion

The aim of this study was to investigate the marginal quality of adhesively luted MOD composite resin inlays using three different kinds of luting composites after elevating one of the proximal cavities with a composite (PBE).

All specimens were installed in a chewing masticator as a well-established method to simulate clinical wear conditions [11, 12]. With the chosen parameters of TML, stress is kept standardized and a 5-year period of clinical wear can be simulated [9]. By covering the teeth roots with a polyether layer as an artificial periodontium, the physiological teeth movement inside the alveole could be simulated [13, 14]. However, clinical wear conditions are influenced by several factors like force, force profile, contact time, sliding movement, clearance of worn material, etc. which cannot be controlled during the whole mastication simulation [15] so that the in vitro data are not transferable one to one to in vivo investigations [16]. For this reason, marginal quality was investigated as a determining factor for clinical success [17].

Scanning electron microscopy (SEM) was used to examine the deterioration of the adhesive gap after TML of the different luting composites; the advantage of this technique is to non-invasively investigate the influence of oral stress to the same margins at two different times (before and after TML) [18]. To avoid errors of the marginal analysis, the evaluation criteria were defined precisely and the evaluation was performed by one and the same operator.

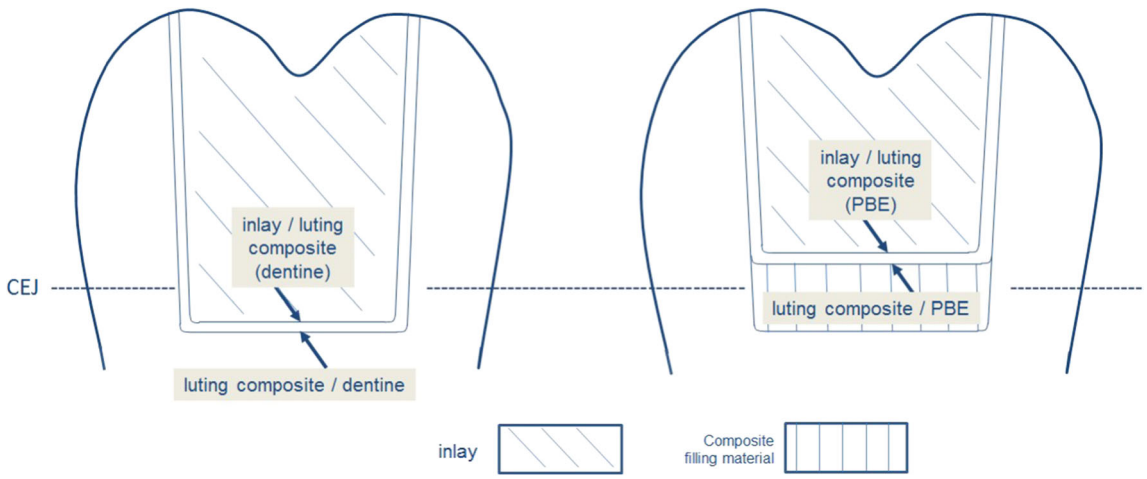

Fig. 2 Interfaces evaluated for marginal integrity

Dietschi et al. first introduced the technique of a proximal box elevation to facilitate the luting procedure [6]. The choice of the material for PBE is discussed controversially; Dietschi et al. published promising results for flowable composites [19], which on the other hand could result in excess material in the deep proximal cavities because of their lower viscosity [20]. Higher filled composites however may be challenging to insert and adapt because of their higher viscosity. Rocca et al. found that marginal adaption was not influenced significantly by the composite type [21]. A study by Frankenberger et al. reported that self-adhesive luting composites were not indicated for PBE and that the marginal quality to dentine was substantially influenced by a meticulous layering technique [7].

The promising advantages of using the proximal box elevation technique can be seen in facilitating and easing the following procedures during the luting of the indirect restorations; rubber dam isolation can be performed faster for creating dry conditions just as detecting and removing of excess luting composite after the inlay insertion. Moreover, by elevating the proximal margin to a supragingival level, the size of the inlay can be reduced what may ease the accurate light polymerization of the luting composites [22, 23]. In addition,

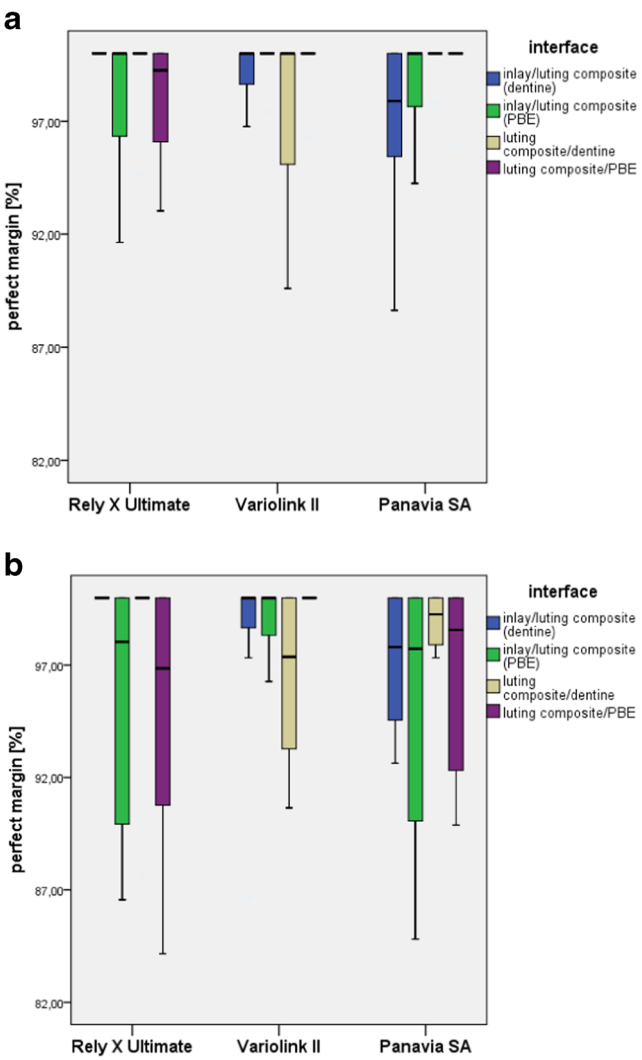

Fig. 3 Marginal integrity at the evaluated interfaces. **a** SEM analysis before TML. **b** SEM analysis after TML

Table 2 Percentage of perfect margins at the different interfaces before and after TML; no significant differences were found

		Perfect margin (%, median)			
		Tooth		Inlay	
		PBE	Dentine	PBE	Dentine
Rely X Ultimate	Before TML	99.25	100.00	100.00	100.00
	After TML	96.85	100.00	98.04	100.00
Variolink II	Before TML	100.00	100.00	100.00	100.00
	After TML	100.00	97.36	100.00	100.00
Panavia SA	Before TML	100.00	100.00	100.00	97.90
	After TML	98.57	99.26	97.73	97.81

impression taking—conventional or optical—is much easier to perform at supragingivally located margins.

The insertion of the resin composite for PBE can also be very difficult facing the permanent contamination hazard in deep cavities resulting in microleakage between composite and tooth structures [24]. Even when a rubber dam cannot be placed, contamination hazard during PBE is still easier to handle than during the luting procedure [25]. Under clinical conditions, finishing and polishing of the filling margins might be challenging because of the reduced access to the proximal aspect. Creating smooth and non-irritating surfaces, however, in combination with excellent oral hygiene are basic requirements to avoid gingival and periodontal inflammation [26, 27].

The PBE technique could be favorable—although the problem of moisture control stays the same—because adapting a well-fitting matrix system and placing the composite increments take less time than a complex luting procedure which in the end reduces the period of contamination hazard. Even though the contamination aspect was not simulated in this study, the reduction of the contamination risk while restoring the proximal cavity—directly or indirectly—seems to be a clinical relevant aspect for dental practitioners.

The present study focused on the material used for the luting of the inlays. All groups showed rates of reduced marginal integrity after TML, even though the reduction was not statistically significant. This confirms the importance of thermomechanical loading in in vitro tests to simulate oral conditions [28]. Furthermore, no significant difference was found for luting the inlays to dentine or to PBE composite. Thus, within the limits of this in vitro study, the PBE technique is performed as a promising solution to ease the adhesive luting procedure in deep proximal cavities. The combination of Syntac and Variolink II was chosen as a clinically approved more-step luting composite to be compared with the faster applicable materials like Rely X Ultimate and Panavia SA Cement. Rely X Ultimate still needs a pretreatment of the cavities, but not as complicated as Variolink II. Panavia SA Cement needs no cavity pretreatment which is attractive for dental practitioners; luting procedures can be eased as well as the contamination hazard can be reduced. Comparing the materials at the different interfaces before and after TML, no significant reduction of marginal integrity was found. Thus, all investigated materials showed promising results for the luting of indirect restorations.

Conclusion

Within the limits of this in vitro study, all materials under evaluation performed well for the luting of the inlays. The proximal box elevation technique can be a promising solution for restoring deep proximal cavities under clinical conditions.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Funding There was no external funding.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent It is not necessary, because no individual participants were included.

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