JOURNAL OF DENTISTRY 42 (2014) 199–209

Available online at www.sciencedirect.com

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Marginal and internal fit of heat pressed versus CAD/CAM fabricated all-ceramic onlays after exposure to thermo-mechanical fatigue

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ARTICLE INFO

Article history:
Received 18 April 2013
Received in revised form
21 September 2013
Accepted 1 October 2013

Keywords:
Onlay restoration
All-ceramic materials
CAD/CAM
Marginal fit
Internal fit
Thermo-mechanical fatigue

ABSTRACT

Objectives: The aim of the study was to evaluate the marginal and internal fit of heat-pressed and CAD/CAM fabricated all-ceramic onlays before and after luting as well as after thermo-mechanical fatigue.

Materials and methods: Seventy-two caries-free, extracted human mandibular molars were randomly divided into three groups ($n = 24$/group). All teeth received an onlay preparation with a mesio-occlusal–distal inlay cavity and an occlusal reduction of all cusps. Teeth were restored with heat-pressed IPS-e.max-Press* (IP, *Ivoclar-Vivadent) and Vita-PM9 (VP, Vita-Zahnfabrik) as well as CAD/CAM fabricated IPS-e.max-CAD* (IC, Cerec 3D/InLab/Sirona) all-ceramic materials. After cementation with a dual-polymerising resin cement (VariolinkII*), all restorations were subjected to mouth-motion fatigue (98 N, 1.2 million cycles; 5 °C/55 °C). Marginal fit discrepancies were examined on epoxy replicas before and after luting as well as after fatigue at 200× magnification. Internal fit was evaluated by multiple sectioning technique. For the statistical analysis, a linear model was fitted with accounting for repeated measurements.

Results: Adhesive cementation of onlays resulted in significantly increased marginal gap values in all groups, whereas thermo-mechanical fatigue had no effect. Marginal gap values of all test groups were equal after fatigue exposure. Internal discrepancies of CAD/CAM fabricated restorations were significantly higher than both press manufactured onlays.

Conclusions: Mean marginal gap values of the investigated onlays before and after luting as well as after fatigue were within the clinically acceptable range. Marginal fit was not affected by the investigated heat-press versus CAD/CAM fabrication technique. Press fabrication resulted in a superior internal fit of onlays as compared to the CAD/CAM technique.

Clinical relevance: Clinical requirements of 100 μm for marginal fit were fulfilled by the heat-press as well as by the CAD/CAM fabricated all-ceramic onlays. Superior internal fit was observed with the heat-press manufacturing method. The impact of present findings on the clinical long-term behaviour of differently fabricated all-ceramic onlays warrants further investigation.

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http://dx.doi.org/10.1016/j.jdent.2013.10.002

1. Introduction

Patient demands for highly aesthetic restorations and concerns in the use of direct resin composites for rehabilitation of severely compromised posterior teeth have led to an increasing interest in all-ceramic restorations.[1] Adhesively placed all-ceramic restorations with partial or complete coverage of the occlusal surface represent an alternative to the traditional full-coverage crown, as they provide a more conservative approach in restoring weakened or missing tooth structure.[2,3] Over the last few decades, cast gold partial coverage restorations were considered as gold standard for the rehabilitation of posterior teeth due to the favourable long-term clinical data.[4,5] In the meantime, various all-ceramic systems and manufacturing processes have been introduced to the dental market. Pressable ceramics using the lost-wax technique as well as industrially prefabricated machinable ceramics for lab- and chair-side CAD/CAM systems have evolved as an alternative for the conventional powder slurry fabrication technique.[6] With advancements in material sciences and adhesive technologies, all-ceramic onlay restorations have proven to be fatigue resistant enough to fulfil both functional and aesthetic requirements of the oral environment.[7]

However, the adhesive interface between tooth structure, composite cement and all-ceramic material at the restoration margin has been frequently addressed in clinical studies as a susceptible factor for ageing processes.[8,9]

The dimensions of this adhesive interface, the physical properties of the luting material and the tooth substrate available for adhesive bonding determine the clinical long-term success of bonded restorations.[10] Elevated marginal discrepancies are related to increased exposure of the luting material to the oral environment, leading to a higher rate of cement dissolution caused by oral fluids and chemo-mechanical degradation.[11] As a consequence, the longevity of the restored tooth can be compromised by an augmented risk for plaque retention, caries and pulpa pathology.[12] Increased cement wear and the subsequent submargination can also result in microcracks at the marginal edges of the restorative material and/or of the circumjacent tooth structure.[13] A review article has revealed a 5–10 times higher loss of luting resin composite in wider marginal gaps (>150 μm) than in smaller ones (50 μm) and concluded that sufficient marginal fit can significantly reduce the wear of luting resin composites in clinical circumstances.[10]

The internal fit is another key factor for the long-term stability of all-ceramic restorations.[14] The thickness of the cement layer, reflected by the internal fit, as well as the chemical composition and the elastic modulus of the applied cement are important parameters affecting the failure behaviour of monolithic all-ceramic restorations.[15–17] In ceramic failure theory, the cement interface of all-ceramic restorations has been described as a crack initiation area.[17] When a ceramic layer is uniformly supported and bonded to a less stiff material, high tensile stresses develop in the ceramic at the cement interface, in particular, underneath the area where masticatory load is applied.[18] Interfacial stresses arise from different stress or strain behaviours of the all-ceramic system, cement material and underlying tooth structure exacerbated by discrepancies in the modulus of elasticity. Flexural radial cracks originating at the cementation internal surface can propagate upward to the occlusal surface or to the margin, ultimately leading to restoration bulk fracture failure.[17,19–23] Therefore, augmented layers of resin cement result in a significantly reduced reliability of all-ceramic materials.[14,24]

Onlay restorations reveal a high ratio of bonded to unbonded surfaces (high configuration factor), exposing the system to polymerisation shrinkage.[25,26] When these polymerisation forces exceed the adhesion efficacy of the tooth/cement/all-ceramic interface and the plastic or elastic deformation of the system, adhesive or cohesive fracture failures may occur. Therefore, a sufficient three-dimensional fit of the restoration is a prerequisite to receive maximum mechanical support for the all-ceramic material from the underlying tooth structure and cementation composite.[21] Measuring methods for marginal and internal fit evaluation can be classified into invasive with application of a cross-sectioning technique and into noninvasive with the direct-view or impression replica technique.[27]

Limited data is presently available on the marginal and internal fit evaluation of partial coverage all-ceramic restorations with respect to different fabrication techniques.

The aim of this in vitro study was to evaluate the marginal and internal fit of various all-ceramic onlay restorations before and after luting as well as after thermo-mechanical fatigue. The heat press versus CAD/CAM fabrication technique and different all-ceramic materials were compared. The null hypothesis assumed that there is no difference in marginal and internal fit of onlay restorations made from different all-ceramic materials and fabrication techniques, subjected to thermo-mechanical fatigue.

2. Materials and methods

Seventy-two caries-free extracted mandibular molars were cleaned and stored in 0.1% thymol solution at room temperature. The Albert-Ludwig-University of Freiburg Ethics Committee ruled that approval was not needed for the use for research purposes of unidentified and pooled extracted teeth. Twenty-four teeth were randomly allocated to one of the three groups. Roots were covered with an artificial periodontal membrane (Anti-Rutsch Lack, Wenko-Wenselaar GmbH, Hilden, Germany) 2 mm apically of the cemento-enamel junction. All teeth were embedded in a self-polymerising resin (Technovit 4000, Kulzer, Wehrheim, Germany). Two silicon impressions (Twin Duo, Picodent GmbH, Wipperfürth, Germany) were taken from each tooth prior to preparation. One impression was used as a template for the design of the all-ceramic restoration. Depth orientation groves were cut and a sectioned silicone index (Twin Duo, Picodent GmbH, Wipperfürth, Germany) was used to ensure the tooth reduction. All teeth first received a mesio-occlusal–distal box preparation with the geometry of an inlay cavity. The dimension of the isthmus was 3 mm in depth and width. The mesial and distal finishing lines of the rounded boxes were 1 mm above the cemento-enamel junction. Functional and non-functional cusps were then reduced by 2 mm