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Long-term tensile bond strength of differently cemented nanocomposite CAD/CAM crowns on dentin abutment

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ABSTRACT

Objectives. To test the tensile bond strength of luted composite computer aided design/computer aided manufacturing (CAD/CAM) crowns after use of different adhesive systems combined with different resin composite cements on dentin abutments.

Methods. Human molars ($n = 200$) were embedded in acrylic resin, prepared in a standardized manner and divided into 20 groups ($n = 10$). The crowns were treated as follows: (i) Monobond Plus/Heliobond (MH), (ii) Ambarino P60 (AM), (iii) Visio.link (VL), (iv) VP connect (VP), and (v) non-treated as control groups (CG) and luted with Variolink II (VAR) or Clearfil SA Cement (CSA). Tensile bond strength (TBS) was measured initially (24 h water, 37 °C) and after aging (5000 thermal cycles, 5/55 °C). The failure types were evaluated after debonding. TBS values were analyzed using three-way and one-way ANOVA, followed by post hoc Scheffé-test, and two-sample Student's *t*-tests.

Results. Among VAR and after aging, CG presented significantly higher TBS ($p = 0.007$) than groups treated with MH, AM and VP. Other groups showed no impact of pre-treatment. A decrease of TBS values after thermal aging was observed within CSA: CG ($p = 0.002$), MH ($p < 0.001$), VL ($p < 0.001$), AM ($p = 0.002$), VP ($p < 0.001$) and within VAR: MH ($p = 0.002$) and AM ($p = 0.014$). Groups cemented with VAR showed significantly higher TBS than groups cemented with CSA: non-aged groups: CG ($p < 0.001$), and after thermal aging: CG ($p = 0.003$), MH ($p < 0.001$), VL ($p = 0.005$), VP ($p = 0.010$).

Significance. According to the study results nano-composite CAD/CAM crowns should be cemented with VAR. Pre-treatment is not necessary if the tested resin composite cements are used.

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1. Introduction

In recent years, the demand of non-metallic restorations in dentistry has increased, based on increased esthetic demands

[1]. The combination of these restorations with adequate adhesive techniques allows a more conservative tooth preparation [2]. Hereby insertion, modeling, and light-curing of the direct composite resin restoration takes place directly in the patient's mouth. Indirect resin composites are used for

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single tooth restorations such as inlays, onlays or crowns [3]. In vitro studies reported good physical properties of direct and indirect resin composite materials, such as flexural strength and hardness [4–7] as well as material wear stability and low abrasiveness to antagonist teeth [8,9]. As an alternative to conventional indirect and direct resin composites, computer aided design/computer aided manufacturing (CAD/CAM) composites, which can be processed more rapidly and at lower cost [10,11], have been recently introduced.

Using CAD/CAM blocks, which are prefabricated in controlled conditions by the manufacturer, offers the chance to use materials at their highest obtainable quality. Such blocks are industrially polymerized under standardized parameters at high temperature and pressure. Therefore, the physical and optical (color stability) properties of these blocks are higher compared to conventionally fabricated resin [12–15]. Additionally, composite resins are more fracture resistant than glass–ceramics, especially when the thickness of the restoration is limited [16,17].

Kassem et al. [18] determined the effect of compressive cyclic loading on fatigue resistance and microleakage of CAD/CAM fabricated glass–ceramics and composite crowns. The authors reported that CAD/CAM composite crowns were more fatigue-resistant than glass–ceramic crowns. The microleakage of the composite crowns showed comparable results to glass–ceramic ones. Another in vitro study reported that CAD/CAM composite resins provided better fracture resistance for non-retentive occlusal veneers than for ceramic [19]. Fasbinder et al. [10] investigated the color stability of CAD/CAM milled inlays of composite and glass–ceramic. Composites showed significantly better color-matches after 3 years than glass–ceramic inlays. Several studies have recommended CAD/CAM fabricated composite overlays and crowns for long-term reconstructions [20–22].

Conditioning of the dental hard tissue can take place in a single step before use of etch-and-rinse systems for conventional resin cements (Variolink II). Another possibility that requires no separate conditioning step of the hard dental tissue is the use of self-etch resin composite cement (Clearfil SA Cement). For pre-treatment of the CAD/CAM generated restoration the different methods can be applied according to the material combinations used. For glass–ceramics, hydrofluoric-acid etching should be performed before primer application [23], whereas alloys [24] and zirconia can be pre-treated by air-abrasion [25]. For pre-treatment of polymeric materials, primarily abrasion with airborne-particles is used, which results in a cleaned and increased surface [26]. For alloys, zirconia and polymeric restorations, bonding liquids can be applied [24,26–30]. According to the material composition it was shown that further chemical pretreatment of polymeric materials with different bonding liquids is required to improve bond strength [26,28–30].

In summary, the recently introduced CAD/CAM composites are considered as alternative materials to glass–ceramics. Resin composite cements are the material of choice for the adhesive cementation of glass–ceramic reconstructions [31,32]. However, limited information is available on the bond strength between industrially polymerized anatomic CAD/CAM composite restorations and resin composite cements. Therefore, the purposes of this study were (a) to

test whether the bond strength of resin cements to CAD/CAM composite would improve by surface conditioning methods, and (b) to evaluate the failure types after debonding. The hypothesis tested was that pre-treated, adhesively cemented composite crowns show higher tensile bond strength results than non-treated ones.

2. Material and methods

The study used experimental nano-composite CAD/CAM blocks as basis material for milling the crowns. The CAD/CAM material is composed of different nano-adhesives and a high percentage of filler (approx. 80%). The crowns were cemented using a conventional resin composite cement Variolink II (VAR, Ivoclar Vivadent) or a self-adhesive resin composite cement Clearfil SA Cement (CSA, Kuraray) after following pre-treatments: (i) Monobond Plus/Heliobond (MH, Ivoclar Vivadent), (ii) Ambarino P60 (AM, Creamed), (iii) Visio.link (VL, Bredent), (iv) exp. VP connect (VP, Merz Dental), and (v) non-treated as control groups (CG). Table 1 gives detailed information of all tested materials and manufacturer with their application steps.

Prior to performing this study, power analysis was calculated with R software (R Development Core Team, The R Foundation for Statistical Computing) using data of a previous study [25]. The aim was to find an impact of composite pre-treatment to TBS values. A sample size of 10 in each group will behave 99.9% power to detect the increase by 25% of the mean (difference in means of 0.44 MPa) caused by composite pre-treatment, assuming that the common standard deviation is 0.15 MPa using two group t-test with 0.00082 Bonferroni corrected two-sided significance level. Consequently, 200 specimens were divided into 20 groups of 10 each.

2.1. Preparation of human teeth abutments as well as division in subgroups

For this study 200 caries-free human molars were used. The teeth were cleaned from remnant soft tissue and stored in 0.5% Chloramine T (Sigma Aldrich, Seelze, Germany, lot no. 53110) at room temperature during the first 7 days after extraction. Thereafter, the teeth were stored in distilled water at 5 °C for a maximum of 6 months (ISO 11405). The roots of all teeth were subsequently embedded in a cylindrical base metal form as lower holding device with self-polymerized acrylic resin (ScandiQuick, ScanDia, Hagen, Germany). For constant preparation angle of the teeth under constant water-cooling, a parallelometer and a diamond cutting torpedo (Komet Dental, Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany) were used. To obtain a standardized abutment height, all teeth were cut using a grinding machine (Secotom 50, Struers, Ballerup, Denmark). Sharp angles were rounded with a polishing disc (Sof-Lex 1982C/1982M, 3M ESPE, Seefeld, Germany). In summary, prepared teeth had a height of 3 mm, a flat surface, a conicity of 10°, rounded edges and a shoulder preparation. After preparation, the tooth abutments were scanned with KaVo Everest Scan (KaVo, Biberach, Germany). For each abutment the STL-datasets were imported into inspection

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