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Template assisted surface microstructuring of flowable dental composites and its effect on microbial adhesion properties

Nadja Frenzel[a,1], Stefan Maenz[b,1], Vanesa Sanz Beltrán[b,2], Andrea Völpel[a], Markus Heyder[a], Bernd W. Sigusch[a], Claudia Lüdecke[b,c,1], Klaus D. Jandt[b,c,*,1]

[a] Department of Conservative Dentistry, University Hospital Jena, Friedrich Schiller University, An der alten Post 4, D-07743 Jena, Germany

[b] Otto Schott Institute of Materials Research, Faculty of Physics and Astronomy, Friedrich Schiller University, Löbdergraben 32, D-07743 Jena, Germany

[c] Jena School for Microbial Communication (JSMC), Friedrich Schiller University, Jenergasse 8, D-07743 Jena, Germany

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ABSTRACT

Objectives. Despite their various advantages, such as good esthetic properties, absence of mercury and adhesive bonding to teeth, modern dental composites still have some drawbacks, e.g., a relatively high rate of secondary caries on teeth filled with composite materials. Recent research suggests that microstructured biomaterials surfaces may reduce microbial adhesion to materials due to unfavorable physical material–microbe interactions. The objectives of this study were, therefore, to test the hypotheses that (i) different surface microstructures can be created on composites by a novel straightforward approach potentially suitable for clinical application and (ii) that these surface structures have a statistically significant effect on microbial adhesion properties.

Methods. Six different dental composites were initially tested for their suitability for microstructuring by polydimethylsiloxane (PDMS) templates. Each composite was light-cured between a glass slide and a microstructured PDMS template. The nano-hybrid composite Grandio Flow was the only tested composite with satisfying structurability, and was therefore used for the bacterial adhesion tests. composites samples were structured with four different microstructures (flat, cubes, linear trapezoid structures, flat pyramids) and incubated for 4 h in centrifuged saliva. The bacterial adherence was then characterized by colony forming units (CFUs) and scanning electron microscopy (SEM).

Results. All four microstructures were successfully transferred from the PDMS templates to the composite Grandio Flow. The CFU-test as well as the quantitative analysis of the SEM images showed the lowest bacterial adhesion on the flat composite samples.

* *Corresponding author at*: Otto Schott Institute of Materials Research, Faculty of Physics and Astronomy, Friedrich Schiller University, Löbdergraben 32, D-07743 Jena, Germany Tel.: +49 3641947730; fax: +49 3641947732.
E-mail address: K.Jandt@uni-jena.de (K.D. Jandt).

[1] These authors contributed equally.

[2] Present address: ICFO – The Institute of Photonic Sciences, Mediterranean Technology Park, Av. Carl Friedrich Gauss 3, 08860 Castelldefels (Barcelona), Spain.

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The highest bacterial adhesion was observed on the composite samples with linear trapezoid structures, followed by flat pyramids and cubes. The microstructure of dental composite surfaces statistically significantly influenced the adhesion of oral bacteria.

Significance. Modifying the composite surface structure may be a clinically suitable approach to control the microbial adhesion and thus, to reduce the risk of secondary caries at dental composite restorations. Smaller composite surface structures may be useful for accomplishing this.

1. Introduction

Since the introduction of resin-based dental materials around the middle of the last century, composite restorations in dentistry became indispensable because of the patients' esthetic demands and ease of composite processing [1]. composites are a mixture of organic and/or inorganic fillers surrounded by a monomer matrix which can be set-on-command by photopolymerization e.g. with blue LED lamps [2]. Depending on their filler particles sizes composites can for example be categorized into four different groups: macro-, micro-, hybrid- and nanofiller composites. In addition, they can be categorized according to their rheological properties into flowable and non-flowable composites.

Despite their advantages, such as good esthetic properties, absence of mercury and adhesive bonding to teeth, dental composites still have some drawbacks, such as for example polymerization shrinkage, their tendency to absorb water [3] and the onset of secondary caries caused by microbes on teeth filled with composite materials [4].

A challenge arises through the surface treatment of composites. Inappropriate finishing procedures may result in increased surface roughness [5–7]. An important property in relation to the structural surfaces roughness of dental composites is the adhesion of oral microbes to the composites. Surface roughness influences bacterial colonization [8], particularly on composite materials [5]. Smooth surfaces are preferred clinically, because of their relatively low bacteria adherence [9]. Carlén et al. reported, however, a polished hybrid composite to accumulate more bacteria than the unpolished one [5].

Some investigations showed that microbes adhere stronger on composites surfaces than to the natural tooth covered by a pellicle [10] or in comparison to other dental materials. A threshold level of composite surface roughness of $R_a = 0.2\,\mu\text{m}$ has been discussed, below which no further reduction in microbial accumulation could be expected [11], however, no convincing explanation for this has been given. Although surface roughness seems to be an important factor for microbial accumulation on dental composites, materials properties, such as filler-size [11] shape and content [12], composite surface tension [10], chemical surface composition [13], protein adsorption [5] and others seem to be important factors as well.

It has been predicted that future commercial dental composites will possess antimicrobial properties [14] and the quantity of scientific literature addressing this subject has grown strongly over the last years [15]. Approaches to equip resin based dental materials with antimicrobial properties include silver [16] or zinc oxide nano particles [17], silver-supported antibacterial materials [18], zinc oxide eugenol [19], quaternary ammonium functionalities [20,21], alkylated ammonium chloride derivatives [22], chlorhexidine diacetate (CHXA) [23], carolacton [24] and others. The addition of antimicrobial agents to composites, however, may lead to reduced mechanical properties of the composites and in many cases the antimicrobial effect of the composites is not sustainable [14].

A new and promising approach to reduce the microbial adhesion to different biomaterials surfaces uses specific micro or nano surface topographies or patterns [25–29]. The microbial adhesion reduction mechanisms of these materials surfaces are still an enigma, but some authors assume that an unfavorable physical interaction between microbes and the materials surface is responsible for their antimicrobial effect [28,29].

Reducing microbial adhesion to materials with this approach has a number of advantages since it uses neither antibiotics nor other chemical antimicrobial agents or compounds. Hence these materials cannot lead to antibiotic resistance of microbes or negative side effects of drug release, such as cytotoxicity to body cells.

Based on these findings, the question arises if a surface structuring approach is also feasible for reducing microbial adhesion to dental materials, such as dental composites. Little is known about the interaction of microbes and flowable composites. Due to their rheological properties flowables seem to be, however, the ideal materials for surface patterning.

It was, therefore, the aim of this current study to test the hypotheses that (i) different surface microstructures can be created on composites by a novel straightforward approach potentially suitable for clinical application and (ii) that these surface structures have a statistically significant effect on microbial adhesion properties when compared with flat control samples of the same composite. To the best of our knowledge, neither has been attempted previously and may, if successful, lay the foundations for a new way of functional surface structuring of dental composites.

2. Materials and methods

2.1. *Dental composites*

Six different composites were first tested for their structurability by polydimethylsiloxane (PDMS) templates: the nanohybride composites CLEARFIL MAJESTY Posterior (CMP; Kuraray Europe GmbH, Frankfurt, Germany), Grandio Flow (GF;