Abstract The aim of this study was to evaluate the effect of a rapid photopolymerization method on the marginal integrity of composite fillings. Ninety two-surface cavities were prepared in extracted human molars using the SonicSys preparation system. All cavities were bonded with one bonding agent (Syntac) and filled with a microfilled composite (Herculite XRV), a heavy filled composite (Z100 MP), and an Ormocer (Definite) in two increments. Each increment had a thickness of approximately 1.5 mm and was polymerized using either halogen light or the plasma light of Apollo 95 E. In this process, six trial groups each containing 15 fillings were created. After replicas were made, the test teeth were subjected to a thermocycling process of 2000 temperature cycles (5°C/55°C) followed by a wear simulation of 50,000 stress cycles each with 50 N. This was followed by the creation of a second set of replicas, quantitative margin analysis, and dye penetration. A significant ($P<0.05$) influence of the thermomechanical stress and a significant ($P<0.05$) influence of the factor “material” were shown for the margin criterion “continuous margin” using MANOVA. The factor “light source” produced no significant influence ($P=0.57$) on the amount of continuous margin. During the dye penetration, no significant differences between the polymerization methods could be established with the materials Herculite XRV and Z100 MP (H-test according to Kruskall and Wallis). Only with the material Definite was a significantly higher dye penetration observed at the occlusal measuring point in the plasma light group. A rapid polymerization with high light intensity had no adverse effects on the margin quality within the limitations of this in vitro study. However the marginal integrity might have been influenced by the chosen adhesive system/composite resin combination, which does not represent the respective product line. Additionally, further studies ought to show which exposure time is necessary for a sufficient degree of conversion.

Key words Composite resins · Polymerization · Marginal adaptation · Light intensity

Introduction

Composite materials shrink during polymerization in the cavity [24]. The size of the free shrinkage depends directly on the volume percentage of the monomer system, the degree of conversion, and the concentration of the methacrylate groups related to the molecular size of the monomers [34].

Shrinkage that occurs in a cavity before the gel point as the monomer–polymer is still fluid can be compensated for by flow of composite material from the free surface of the filling [33]. After the gelation in the beginning elastic phase [7], stress begins to be built up. This stress leads, in many cases, to the composite material pulling away from the cavity wall (adhesive failure), to voids, or to microcracks in either the composite material or in the tooth hard tissue (cohesive failure) [24]. Such clefts lead to microleakage and thus to the penetration of microorganisms, which consequently leads to the development of secondary caries.

In the course of polymerization, hardness, stiffness, and tensile strength increase with the degree of conversion. Simultaneously, the toxicologically important percentage of residual monomer with reactive double bonds sinks [1, 34]. Using light polymerization, a good degree
of conversion can be reached in composite materials as long as the light is present in adequate intensity and can completely penetrate the material. The degree of conversion depends in this case on the light intensity, the curing time, and the thermal energy in the system [34]. Additional factors are the correct wavelength of the light as well as the color, consistency, and composition of the composite [16]. The polymerization depth increases with the logarithm of the product of radiation output and exposure time [5].

For the practical use of halogen light sources, it is recommended that composite layers of maximally 2-mm thickness should be polymerized at least 40 s, optimally 60 s [28]. During polymerization with low light intensity, the viscous phase can be extended up to the gel point to give the material the possibility to better compensate for the shrinkage caused by polymerization. A reduction of the marginal gap development is hereby achieved [8, 31, 32]. The polymerization with high light intensity, which directly follows, then enables an optimal degree of conversion to be reached. The so-called “softstart” polymerization produces a better marginal adaptation [9, 18, 31], as well as lower polymerization stress. A worsening of the flexural strength could not be found after “softstart” polymerization, and the elastic modulus of the samples also remained unaffected by the employed polymerization type.

To increase the light intensity, the application of laser light has been suggested. Higher degrees of conversion [30], better mechanical values of the composite [12], and constant [2] or lower polymerization contraction [30] were so reached. To increase the intensity of light in conventional light instruments, Sutalo et al. [29] recommended the use of an indium high-pressure light. Duret [6] reports on a polymerization instrument with a plasma lamp; the light intensity is reported as 1320 mW/cm² [6]. The emission spectrum of the plasma light is reportedly substantially better adjusted to the absorption spectrum of the camphoroquinone photo initiator [6]. At an exposure time of only 3 s using selected composite materials, Duret could measure higher Knoop hardness on the surface and at 1 mm and 2 mm depth than with conventional polymerization. Polymerization depths of 2.2 mm after 1 s, 2.6 mm after 2 s, and 2.9 mm after 3 s radiation could be measured [21].

Whereas, a light source on the basis of halogen with a polymerization time of approximately 40 s was until now the norm, new methods with higher light intensity and therefore lower polymerization times raise the question of whether advantages of quicker polymerization and the higher penetration depth are not achieved at the cost of stronger stress development and development of marginal clefts. The objective of this study was to compare the influences of a high-speed polymerization using light from a plasma lamp with the conventional technique. In order to create a reproducible black class-II cavity with a definite form and size, a rough preparation was performed with a cylindrical diamond instrument (Fig.# 836KR.314.014, Komet-Gebr. Brasseler, D-32631 Lemgo). Following this, the occlusal and approximal portion of the cavity was shaped using a sonic point (SonicSys approx. Nr. 3, Vivadent Dental GmbH, D-73471 Ellwangen). The occlusal and approximal size of the preparation totaled 3.5 mm each. The cavity depth was 2 mm for the occlusal and the approximal part. Due to the shape of the preparation instrument, a small bevel was produced at all cavity walls. Attention was given during the preparation so that all preparation borders came to lie circular in the enamel.

### Production of the fillings

The prepared teeth were randomly separated into six groups each with 15 teeth (Table 1). First, the enamel margin was etched with 37% phosphoric acid (Email Preparator blau, Vivadent Dental GmbH, D-73471 Ellwangen) for 60 s. After conditioning of the enamel, the cavity was sprayed for 60 s with water, then dried. Next, the dentin was pretreated with the dentin bonding agent Syntac (Primer and Adhesive, Vivadent Dental GmbH, D-73471 Ellwangen). Enamel and dentin were then moistened with Heliobond (Vivadent Dental GmbH, D-73471 Ellwangen) which was carefully blown thin with air pressure. The bonding was polymerized on all teeth using a brand new conventional halogen polymer-