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ORIGINAL ARTICLE

Polishing mechanism of light-initiated dental composite: Geometric optics approach

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Background/Purpose: For light-initiated dental hybrid composites, reinforcing particles are much stiffer than the matrix, which makes the surface rugged after inadequate polish and favors bacterial adhesion and biofilm redevelopment. The aim of the study was to investigate the polishing mechanism via the geometric optics approach.
Methods: We defined the polishing abilities of six instruments using the obtained gloss values through the geometric optics approach (micro-Tri-gloss with 20°, 60°, and 85° measurement angles). The surface texture was validated using a field emission scanning electron microscope (FE-SEM). Based on the gloss values, we sorted polishing tools into three abrasive levels, and proposed polishing sequences to test the hypothesis that similar abrasive levels would leave equivalent gloss levels on dental composites.
Results: The three proposed, tested polishing sequences included: S1, Sof-Lex XT coarse disc, Sof-Lex XT fine disc, and OccluBrush; S2, Sof-Lex XT coarse disc, Prisma Gloss polishing paste, and OccluBrush; and S3, Sof-Lex XT coarse disc, Enhance finishing cups, and OccluBrush. S1 demonstrated significantly higher surface gloss than the other procedures ($p < 0.05$). The surface textures (FE-SEM micrographs) correlated well with the obtained gloss values.
Conclusion: Nominally similar abrasive abilities did not result in equivalent polish levels, indicating that the polishing tools must be evaluated and cannot be judged based on their compositions or abrasive sizes. The geometric optic approach is an efficient and nondestructive method to characterize the polished surface of dental composites.
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Introduction

Because of esthetic demand, hybrid dental composites are popular for many dental applications. Inadequate polishing of composites can increase surface roughness and plaque accumulation.[1,2] The disinfected composite surface favors secondary bacterial adhesion and biofilm redevelopment even though the plaque was removed.[3] Furthermore, polymerization shrinkage of light-initiated dental composites will cause intrinsic stress within the tooth cavity.[4,5] Inadequately polishing the composite surface can damage the margin, and the intrinsic stress can cause marginal gap formation, which, consequently, will increase the risk not only of recurrent caries but also of periodontal disease.[2] Therefore, optimal surface polishing of a hybrid dental composite is important for the longevity of the restoration and for healthy adjacent tissues.

To appropriately perform polishing procedures, the characteristics of the polishing instruments that are often used and the mechanisms of rubbing on resin composite surfaces must be explored. Surface quality is an essential parameter that represents the effects of the finishing and polishing procedures of dental restorations.[6] The surface quality of dental composites can be managed using various techniques. In the early 1970s, the original geometric optics assessment of gloss surface was developed by Budde at the National Research Council of Canada (NRC),[7] and it is currently maintained by the National Institute for Standards and Technology (NIST) and NRC.[8,9] According to the standard measuring methods of the American Society for Testing and Materials (ASTM) D523 and the International Organization for Standards (ISO) 2813, this standard gloss measurement defines three illumination angles (i.e., 20°, 60°, and 85°) to measure the surfaces of specimens.[10,11]

Gloss, similar to surface roughness, is considered to be a useful surface quality parameter and is obtained using the specular reflectance of incident light. Surface gloss is represented by the amount of incident light that is reflected at the specular reflectance angle of the mean of that surface.[11] Therefore, specular gloss is proportional to the reflectance of the surface, which can be expressed by the Fresnel equation, as follows[12]:

$$R_s = \frac{I_r}{I_0},$$

$$R_s = \frac{1}{2}\left[\left(\frac{\cos i - \sqrt{m^2 - \sin^2 i}}{\cos i + \sqrt{m^2 - \sin^2 i}}\right)^2 + \left(\frac{m^2 \cos i - \sqrt{m^2 - \sin^2 i}}{m^2 \cos i + \sqrt{m^2 - \sin^2 i}}\right)^2\right]$$

where R_s is the specular reflectance; I_0 is the intensity of the incident unpolarized light; i is the angle of incidence; I_r is the intensity of the specular reflection of the beam of light, and m is the refractive index of the surface specimen.

The main factors that affect gloss are the topography of the specimen surface, the angle of incident light, and the refractive index of the material. To characterize the surface properties of dental composites, current studies commonly employ methods such as atomic force microscopy, scanning electron microscope/field emission scanning electron microscope (SEM/FE-SEM), profilometry, and glossmeters.[6,13,14] Atomic force microscopy and profilometry can detect the surface in three dimensions but at a different resolution level. Using the atomic force microscopy, only surface areas in the order of magnitude of 100 μm^2 are possible. With such a small area, important details outside of this area might be missed. In addition, a hydrate film on the sample surface can obscure structures, whereas coarse scratches or holes from filler plucking can introduce measurement errors or even damage the Atomic-force microscopy (AFM) tip in a worst-case scenario. By contrast, the profilometer uses a diamond tip with a tip radius no smaller than 5 μm; sometimes, even larger tip radii are used. The tip of a profilometer works like a long-pass filter, which only allows the evaluation of surface details larger than the tip radius. In addition, depending on the applied load, the diamond tip can change the surface during the measurement process.[15,16]

Many researchers have studied the polishability of different finishing and polishing systems on the surfaces of various commercial dental composites. Usually, the polishing systems have been evaluated according to the manufacturers' recommendations. However, the manufacturers rarely support their recommendations with objective investigations that have proven the suggested protocol to be superior to others. Sometimes, the number of steps in such a sequence is rather complicated and does not satisfy the clinical demands for efficacy and cost effectiveness. Therefore, it would be helpful to propose efficient polish sequences for clinical use and to supply quantitative proof for the suggested procedure. Combining the use of a glossmeter with three measurement angles using the geometric optics approach and FE-SEM micrographs to interpret surface textures on the resin composites could supply the data necessary to perform quantitative evaluations and to identify the abrasive mechanism. The objectives of this study were: (1) to determine the surface quality and explore the polish mechanism that could be achieved by common polishing instruments with the aid of both a specular glossmeter and FE-SEM; and (2) to test the hypothesis that different polishing sequences with similar abrasiveness would achieve the same gloss level on a dental hybrid composite surface.

Methods

Specimen preparation

A light-cured dimethacrylate-based nanohybrid composite (Tetric EvoCeram, Ivoclar Vivadent, GmbH, Schaan, Liechtenstein) was used in this study because this material has been commercially successful in Europe. In addition, the composition of this material has challenged the polishing sequence (Table 1). By mixing the inorganic fillers into the organic matrix, Tetric EvoCeram includes part of the fillers as ground, prepolymerized hybrid composite filler particles. Square blocks of Tetric EvoCeram nanohybrid composite measuring 24 mm in length, 12 mm in width, and 2.5 mm in thickness were prepared. All specimens were irradiated using a light-curing unit (Dentacolor XS, Kulzer & Co., GmbH, Wehrheim, Germany) through Mylar strips for 180 seconds. To obtain an optimally polished surface as a control, the composite block surface was polished with 320-

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