Background — Although attritive and abrasive wear of recent composite resins has been substantially reduced, in vitro wear testing with reasonably simulating devices and quantitative determination of resulting wear is still needed. Three-dimensional scanning methods are frequently used for this purpose. The aim of this trial was to compare maximum depth of wear and volume loss of composite samples, evaluated with a contact profilometer and a non-contact CCD camera imaging system, respectively.

Method — Twenty-three random composite specimens with wear traces produced in a ball-on-disc sliding device, using poppy seed slurry and PMMA suspension as third-body media, were evaluated with the contact profilometer (TalyScan 150, Taylor Hobson LTD, Leicester, UK) and with the digital CCD microscope (VHX1000, KEYENCE, Osaka, Japan). The target parameters were maximum depth of the wear and volume loss. Results — The individual time of measurement needed with the non-contact CCD method was almost three hours less than that with the contact method. Both, maximum depth of wear and volume loss data, recorded with the two methods were linearly correlated (r^2 > 0.97; p< 0.01).

Conclusion — The contact scanning method and the non-contact CCD method are equally suitable for determination of maximum depth of wear and volume loss of abraded composite resins.

Key words: Composite resin, Wear, Profilometry, CCD-imaging

Introduction

During recent years numerous composite resins, indicated for restoration of all cavity classes, were introduced to the dental market, differing from previous brands in monomer composition, yet particularly in reduced filler size. It is likely that the size of filler particles might affect clinical performance, as smaller particles result in less interparticle spacing and thus better protection of the surrounding polymer matrix. It is however questionable whether or not the common concept of combining nano-sized particles with more conventional fillers, as in several of the current nanohybrid composites, is an adequate means to prevent plucking of the larger filler particles. Filler refinement is considered the main reason for reduced abrasive wear. Long-term clinical trials have shown that filler refined composites perform satisfactorily when used in standard class I/II cavities; unacceptably high wear was only observed in occlusal contact areas of patients with severe bruxism. In spite of such encouraging results, especially in vivo, yet also...
in vitro wear studies are still needed\(^7\), although in vitro models cannot satisfactorily simulate the complex clinical conditions\(^8\). Apart from the question how to simulate wear, it is important to decide how to measure wear. Among the numerous methods of measuring wear three-dimensional (3-D) scanning is probably the most adequate approach, since quantitative data may be generated, including volume loss, depth and area of wear\(^9\). Three-dimensional scanners are operating either in contact or in non-contact mode. With contact scanners the target surface is recorded by a number of parallel line traces that are finally put together to digitize the surface. Non-contact profilers, in contrast, digitize the surface by a light-source or microscope focused on the surface.

The purpose of the present study was to investigate and compare wear traces on flat composite resin specimens that were produced with a zirconia ball-sliding wear testing device, using contact profilometry and 3D imaging with a digital charge coupled device (CCD) microscope for determination of maximum depth of wear and volume loss. The research hypothesis was that wear data determined with the two evaluation methods would not yield significantly different results.

### Materials and Methods

From an ongoing investigation on wear characteristics of microfilled (DUR), nano-hybrid (MFL) and micro-hybrid (APX) composite resins 23 abraded specimens were randomly selected for comparative measurements of wear traces, produced with a custom-made sliding ball wear testing device\(^10\). The composite resins used in the present study are shown in Table I. Disc-shaped specimens, 8 mm in diameter and 2 mm thick, were produced in aluminum molds, light-activated using the halogen curing unit XL 3000 (3M ESPE, MN, USA; output >500 mW cm\(^{-2}\)) for 40 seconds, and stored in 37 °C deionized water for 7 days and consecutively polished with SiC paper to the final grit #4000. A zirconia ball (4-mm in diameter) served as antagonist, loading the composite specimen at 15° angulation for a 3.7 mm long slide path (50 N load, 1.2 Hz, 10,000 cycles). During loading the specimens were immersed in third-body media, either aqueous slurry of slightly preground poppy seeds (33 mass%) or aqueous suspension of PMMA beads (30 mass%). The numbers of the composite resins evaluated for this methodological study are listed in Table I. The samples were carefully rinsed and stored for at least another 7 days in 37 °C water prior to determination of wear.

Each sample was scanned with a contact profilometer (TalyScan 150, Taylor Hobson LTD, Leicester, UK) at 3 mm/s scanning rate with 5 µm intervals between the scanning lines. The profilometer stylus had a 2.0 µm tip radius and the force on the stylus was 0.98 mN. The specified vertical resolution of the inductive probe is 0.06 µm.

Then, the same specimen was scanned with a digital CCD microscope at 100-fold magnification (VHX1000 with VH-Z 100R lens, KEYENCE, Osaka, Japan) at 5 µm intervals along the z-axis. Samples were randomly first scanned with the contact or the non-contact device. With both methods, the specimens’ reference planes were adjusted using three points on the non-abraded site. Small ridge-like elevations seen next to the wear trace, probably due to plastic deformation under the action of the sliding ball, were disregarded for the software-produced calculation of maximum depth and volume loss of the wear trace by manually aligning the reference plane.

The bivariate data for maximum depth of wear and volume loss, determined with the two methods, were statistically treated by regression analysis using statistical software (SPSS Statistics ver.17, SAS, Cary, NC, USA).

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### Table I. Composite resins and number of specimens evaluated for 3-body wear.

<table>
<thead>
<tr>
<th>Material</th>
<th>Shade</th>
<th>Type</th>
<th>Manufacturer</th>
<th>Batch Code</th>
<th>Code</th>
<th>Number of specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durafill VS</td>
<td>A3</td>
<td>microfilled</td>
<td>Heraeus Kulzer, Hanau, Germany</td>
<td>010210</td>
<td>DUR</td>
<td>3</td>
</tr>
<tr>
<td>MI Flow</td>
<td>A3</td>
<td>nano-hybrid</td>
<td>GC Corp., Tokyo, Japan</td>
<td>0904132</td>
<td>MFL</td>
<td>5</td>
</tr>
<tr>
<td>Clearfil AP-X</td>
<td>A2</td>
<td>micro-hybrid</td>
<td>Kuraray Medical, Okayama, Japan</td>
<td>1078A</td>
<td>APX</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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Results

Regarding the contact profilometer measurement, scanning time for tracing the wear path of each specimen was approximately 3 hours, additionally 45 minutes were needed for wear quantification. In contrast, with the CCD microscope the scanning and quantification times for each specimen were 30 minutes and 30 minutes, respectively. Typical wear trace images obtained with the contact profilometer and the CCD microscope are shown in Fig. 1. Figure 2 shows the relationship between the maximum wear depths, recorded with the two scanning methods, respectively. Each bivariate point in the diagrams reflects wear of one composite resin specimen, abraded with one of the abrasive slurries. The maximum wear depths and volume loss values of DUR in poppy seed slurry and APX in PMMA beads suspension were relatively large, whereas those of APX and MFL in poppy seed slurry were relatively small. Linear regressions lines were fitted using the least square approach, and the 95% confidence intervals for mean response were drawn around the regression lines. The coefficients of determination, $r^2$, for both correlations were highly significant.

Discussion

This study aimed at comparing maximum depth and volume loss of wears traces, produced on composite resin surfaces using contact and non-contact profilometers. The research hypothesis that wear data determined with the two evaluation methods would not yield significantly different results is accepted. Thus, both methods seem to be equally suitable to quantify wear.
Interestingly, the amounts of wear recorded varied not only with the composite resin types but also with the third-body media used. Effects of different types of composite resins and third-body media on wear will be investigated and discussed in future studies.

A common problem encountered with both methods was the necessity for manual alignment of the flat reference plane, to define the wear trace margin by eliminating the marginal ridge, likely produced by plastic deformation of the resins.

The contact profilometer method has the disadvantage, that stylus tracking, depending on the stylus geometry and load, might deform the surface of the material. This is primarily important for materials with low rigidity. Although composites with very different moduli of elasticity, such as the microfilled brand on the one hand, and the micro-hybrid type on the other hand were used, this effect was apparently without practical significance, as shown by the stringent correlations with the CCD data. The disadvantage of the CCD method, where a light beam is used as the "stylus", is the transparency of the composite. Basically, the method requires an opaque diffuse reflecting surface. The shades of the composite specimens used in this trial were A3 and A2, according to the Vita scale. The stringent correlations with the contact profilometer readings show, that the materials were apparently sufficiently opaque.

Regarding the scanning and wear quantification times, contact profilometer measurements were more time consuming compared with the CCD microscope measurements. The scanning time was 6 times longer and wear quantification time was 1.5 times longer. Thus, non-contact CCD measurements were almost three hours faster.

The relative measuring error encountered with both methods becomes obviously larger with decreasing wear traces, as unequivocal definition of the trace margin is a challenge. Therefore, a sufficiently large number of loading cycles should be selected with in vitro evaluations. Future studies will have to reveal the effect of the changing contact areas between the antagonist cusp, here the zirconia ball, and the resulting stress exerted on the specimen surface.

Within the limitation of this in vitro trial, it is concluded that the contact profilometer method and the non-contact CCD method are both equally suitable for determination of depth of wear and volume loss of in vitro produced wear traces on composite resins. From a practical view, CCD microscopy is the preferred routine method, since measurements are contact-free, relatively easy and fast.

References