INTRODUCTION

Since the introduction on the market of photo-polymerized resin composites, the degree of conversion (DC) was recognized to be crucial for the clinical success of these materials. Indeed, photo-polymerized resin composites show limited penetration of visible light through their bulk, and as a result of reduced light irradiance passing through, these materials show a DC decreasing with increasing depth. The possible occurrence of insufficient polymerization may lead to poor physical/mechanical properties and adverse biological reactions owing to the leaching of the monomeric components of the unset resin composite. Therefore, when the cavity is large, incremental layering can be used, with approximately 2 mm thick increments. This technique is used both to avoid the limitation in the depth of cure and to decrease the effects of polymerization shrinkage. However, there are various disadvantages associated with incremental techniques, such as incorporation of voids or contamination between composite layers, failures in bonding between layers, placement difficulty owing to limited access in small cavities, and extended treatment time for placement of layers and their polymerization. To overcome these disadvantages “bulk fill” composites have been introduced. They have shown reduced cuspal deflection when compared with a conventional resin composite filled in an oblique incremental layering technique. Also, when marginal integrity was evaluated, bulk fill composites performed well.

In recent years, so-called polywave photo-curing units have been introduced, which are used with composites based on photo-initiator systems having absorption peak at different wavelength than standard Camphorquinone. Traditional single peak units have then been called monowave. Efficiency of bulk fill composite polymerization in combination with different types of photo-curing units have already been the topic of previous work. While there exist several factors affecting the efficiency of photo-curing dental restorative composites, the typical dental practitioner is usually not inclined to calibrate his device and control these factors, due to both the lack of technical resources and the need for fast clinical procedures. Thus, the question arises as to what would happen when a dentist takes a random choice of materials and irradiates them with a random choice of curing light devices, using a typical exposure time.

In this work we compared different bulk fill resins in terms of DC obtained when using different monowave or polywave LED units. We investigated three bulk fill composites (Mat1, Mat2, Mat3) cured by two polywave (Poly1, Poly2) and one monowave (Mono) lamps. We used infrared spectroscopy, nanoindentation and atomic force microscopy to assess degree of conversion (DC), stiffness, and roughness after polishing, respectively. Mat2 exhibited the highest DC with Poly1 and second highest with Mono, however was the less stiff. Both Mat1 and Mat3 showed highest DC with Poly2, while Poly1 scored better than Mono. Mat3 scored better than Mat1 and was the third highest when cured with Poly2. For each composite cured by different lamps the stiffness ranked same as the DC. However, roughness did not correlate with hardness. Absolute stiffness value depends on composite formulation. Polywave lamps work better than monowave but not in all cases, as Mat2 showed higher DC with Mono than with Poly2. However, all lamps guarantee a DC≥50% but Mono for Mat1.

Keywords: Bulk fill composites, Degree of conversion, Elastic modulus, Photo-curing unit, Surface roughness

MATERIALS AND METHODS

Specimen preparation

Three different bulk fill composite materials, all in shade A3, were examined, called Mat1 (Filtek Bulk...
Fill, 3M ESPE, St. Paul, MN, USA\textsuperscript{18}; Mat2 (Surefil SDR, Dentsply, York, PN, USA\textsuperscript{19}); and Mat3 (Tetric Evo Ceram Bulk Fill, Ivoclar Vivadent, Schaan, Liechtenstein\textsuperscript{20}). The information available from the manufacturers about the different materials are summarized in Table 1. The uncured composite paste was loaded in a stainless steel mold with slots of 7 mm diameter and 3 mm height. The slots were overfilled with the composite, and a Mylar strip was placed on top of the material with the top plate of the mold subsequently pressed into position and held together with a clamp. Then the excess material was scraped off and the mold was irradiated from the top side applying the light of the selected photo-curing unit through a Mylar strip for 20 s. Nine specimens for each composite were prepared and divided in three groups (N_{spec}=3). The groups were assigned to photo-curing by different LED lamps, one monowave called Mono (bluephase style M8, Ivoclar Vivadent)\textsuperscript{21} and two polywaves called Poly1 (bluephase style, Ivoclar Vivadent)\textsuperscript{21} and Poly2 (Valo, Ultradent, South Jordan, UT, USA\textsuperscript{22}). Thus we had nine samples, given by the combinations of three composites cured each with three different lamps. The information available from the manufacturers about the different photo-curing units are summarized in Table 2.

All specimens were stored at 37°C in water for 24 h prior to the characterization. The specimens were used for FTIR first (compared to uncured paste of same type),

### Table 1  Materials investigated in this study, with description of the known properties, in particular with respect to the filler size and loading and to the photoinitiator systems

| Composite brand name (company) | Composite short name | Resin matrix                                                                 | Photoinitiator system                                                                 | Filler materials                                                                 | Filler size range (µm) | Filler loading (vol.%) |
|--------------------------------|----------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------|------------------------|
| Filtek Bulk Fill\textsuperscript{18} (3M Espe) | Mat1                 | aromatic UDMA, UDMA and 1, 12-dodecane-DMA                                   | Camphorquinone-based (430–480 nm wavelength recommended)                             | silica, zirconia, ytterbium trifluoride                                        | 0.01–3.5               | 58.4                   |
| Surefil SDR\textsuperscript{19} (Dentsply)  | Mat2                 | proprietary modified ("polymerization modulator") UDMA, TEGDMA; polymerizable dimethacrylate and trimethacrylate | Camphorquinone with ethyl-4(dimethylamino) benzoate photoaccelerator                 | barium-aluminofluoroborosilicate glass, strontium alumino-fluorosilicate glass, fume silica, ytterbium fluoride | 0.002–25              | 47.3                   |
| Tetric Evo Ceram Bulk Fill\textsuperscript{20} (Ivoclar Vivadent) | Mat3                 | Bis-GMA, Bis-EMA and UDMA                                                    | Camphorquinone plus acyl phosphine oxide together with a proprietary dibenzoyl germanium derivative (Ivocerin) | barium aluminium silicate glass ("isofiller"), ytterbium fluoride, spherical mixed oxide | 0.16-0.7              | 61.0                   |

### Table 2  Photo-curing units (lamps) used in this study, with description of the known properties, in particular with respect to spectral peak intensity and nominal irradiance

| Lamp brand name (company) | Lamp type | Lamp short name | Nominal irradiance (W/cm\textsuperscript{2}) | Peak wavelength(s) (nm) | Apparent peak intensity ratio |
|---------------------------|-----------|-----------------|-----------------------------------------------|-------------------------|-------------------------------|
| Bluephase style M8 (Ivoclar Vivadent)\textsuperscript{21} | monowave | Mono            | 0.8                                           | 470                     | —                             |
| Bluephase style (Ivoclar Vivadent)\textsuperscript{21} | polywave | Poly1           | 1.2                                           | 470; 410*               | I_{470}/I_{410}≈2.3           |
| Valo (Ultradent)\textsuperscript{22} | polywave | Poly2           | 1.0\textsuperscript{4}                        | 470; 410\textsuperscript{9} | I_{470}/I_{410}≈1.7           |

* "halogen-like" broad spectrum, 380–515 nm\textsuperscript{10}.
\textsuperscript{1} in “standard power” mode.
\textsuperscript{2} 395–480 nm “effective” range\textsuperscript{20}.
then for nanoindentation, finally for AFM as the controls first, and then again for AFM after polishing according to a single standard system (Venus Supra, Heraeus Kulzer, Hanau, Germany), for details see\textsuperscript{23).

**FTIR spectrometry**

Fourier transformed infrared spectroscopy (FTIR) was performed by means of a spectrometer (Vertex 70, Bruker, Billerica, MA, USA). The measurements were carried out in ambient air at RT, both on the uncured composite pastes and on the specimens after polymerizing them with all different photo-curing units. The FTIR spectra were collected in attenuated total reflection mode, with an aperture diameter of 3 mm and a spectral resolution of 2 cm\(^{-1}\), in a spectral range of 400–5,000 cm\(^{-1}\). For optimal signal-to-noise ratio, 32 scans were averaged per sample spectrum. From the spectra a third order polynomial baseline was determined and removed. To assess the DC of the monomer paste into a polymerized resin, the peaks at 4,743 and 4,621 cm\(^{-1}\) were considered. The former peak (aliphatic=CH\(_2\)) is that one decreasing in intensity upon polymerization, whereas the latter peak (aromatic=CH\(_2\)) is used as internal reference (normalization) intensity. Thus, we used the following formula:

\[
DC=100\left[1-\frac{I_{4743}^{\text{pol}}}{I_{4621}^{\text{mon}}}\right]
\]  

where the indices ‘pol’ and ‘mon’ refer to the conditions of polymer and monomer, i.e. before and after photo-curing.

**Instrumented nanoindentation**

Mechanical properties were measured by an indenter (UNHT-CSM, Anton Paar, Graz, Austria). The specimens were tested with a standard Berkovich tip under a maximum load of 2 mN, with loading and unloading rates of 4 mN/min and a pause of 30 s at maximum load to saturate creep deformation. For each specimen of each sample (N\(_{\text{spec}}\)=3) four measurements were repeated (N=12). The Young’s modulus E and hardness H were calculated from the indentation curves by the standard method of Oliver and Pharr (see e.g.\textsuperscript{24}).

**Atomic force microscopy**

We used an AFM (MFP-3D, Asylum Research, Santa Barbara, CA, US), working in tapping mode in ambient air. The probes (PPP-NCHR, Nanosensors, Neuchâtel, Switzerland) had aluminum-coated silicon cantilever, and nominal resonance frequency and spring constant of \(\sim 330 \text{ kHz}\) and \(\sim 40 \text{ N/m}\). The nominal tip properties were as follows: length \(\geq 10 \mu\text{m}\), apex diameter \(< 20 \text{ nm}\). The images (collected at a scan rate of 0.2 Hz) had scan size of 50 \(\mu\text{m}\) and number of pixels per line of 256. For each specimen of each sample (N\(_{\text{spec}}\)=3) three different regions were analyzed (N=9). From each image, the 2D root mean square value of the height distribution \(S_h\) was extracted, assumed to best represent the surface roughness.

**Statistical analysis**

The results for both stiffness-related parameters (E and H, N=12) and the selected surface roughness parameter \(S_h\), N=9) for each material and curing unit were compared using both one-way and two-ways ANOVA, and Tukey’s post-hoc test (significance level \(\alpha=0.05\), by dedicated software (Origin 9, Originlab, Northampton, MA, USA).

**RESULTS**

In Fig. 1 the DC values obtained from the FTIR spectra after eq. (1) are plot as a bar chart. It appears that Mat2 exhibits the highest DC of all cases when cured with Poly1, but also the second highest when cured with Mono. Both Mat1 and Mat3 showed highest DC with lamp Poly2, while Poly1 scored better than Mono. Mat3 scored better in DC than Mat1, and was the third highest when cured with Poly2.

In Fig. 2 the results of nanoindentation measurements are graphically represented, for both elastic modulus E (Fig. 2a) and hardness H (Fig. 2b). Error bars extend one standard deviation above and below the mean levels. The values represented in Figs. 2a and b are listed in Tables 3 and 4, respectively, where the results of one-way ANOVA are also reported. In Fig. 2a one can see that for Mat1 and Mat3 composites, samples cured with the polywave lamps showed statistically higher E when compared to the samples cured with Mono (\(p<0.05\)). This was not the case for Mat2, which showed comparable E when cured with polywave lamps (even lower mean E for Poly2 versus Mono, yet without statistically significant difference). The trends for H, shown in Fig. 2b, are roughly the same as for the modulus in Fig. 2a, with the exception of lower average levels for Mat2. No significant differences in either E or H were found between the Mat1 and
Fig. 2 Nanoindentation results: a) elastic modulus E, b) hardness H.

Table 3 Means (±standard deviations) of elastic modulus E (GPa) for the three composites cured with the three lamps, according to different grouping

| Composite | Lamp | Mono  | Poly1 | Poly2 | Composite means |
|-----------|------|-------|-------|-------|-----------------|
| Mat1      | Mono | 6.4±1.9<sup>a</sup> | 11.5±0.9<sup>b</sup> | 12.6±1.3<sup>b</sup> | 10.4±3.0<sup>A</sup> |
| Mat2      | Mono | 8.5±0.7<sup>a</sup> | 9.2±1.0<sup>b</sup> | 7.1±0.9<sup>b</sup> | 8.3±1.2<sup>B</sup> |
| Mat3      | Mono | 9.5±0.8<sup>b</sup> | 13.1±0.9<sup>ii</sup> | 13.5±1.2<sup>c</sup> | 11.9±2.1<sup>C</sup> |
| lamp means| Mono | 8.3±1.7<sup>A</sup> | 11.1±1.9<sup>B</sup> | 11.2±3.1<sup>B</sup> | 10.1±2.6 |

The different characters of the same set (Greek letters, normal lowercase letters, and classes according to numbered list i, ii, iii) represent statistically different groups (p<0.05) according to repeated one-way ANOVA within the groups (top index: groups of lamps, bottom index: groups of composites). Uppercase letters represent two-way ANOVA between groups.

Table 4 Means (±standard deviations) of hardness H (MPa) for the three composites cured with the three lamps, according to different grouping

| Composite | Lamp | Mono  | Poly1 | Poly2 | Composite means |
|-----------|------|-------|-------|-------|-----------------|
| Mat1      | Mono | 224±56<sup>a</sup> | 473±49<sup>a</sup> | 575±92<sup>c</sup> | 433±160<sup>A</sup> |
| Mat2      | Mono | 255±25<sup>a</sup> | 276±43<sup>c</sup> | 203±28<sup>c</sup> | 246±44<sup>B</sup> |
| Mat3      | Mono | 328±48<sup>b</sup> | 557±61<sup>ii</sup> | 615±81<sup>i</sup> | 489±146<sup>C</sup> |
| lamp means| Mono | 273±60<sup>A</sup> | 423±128<sup>B</sup> | 469±201<sup>c</sup> | 384±163 |

The different characters of the same set (Greek letters, normal lowercase letters, and classes according to numbered list i,ii,iii) represent statistically different groups (p<0.05) according to repeated one-way ANOVA within the groups (top index: groups of lamps, bottom index: groups of composites). Uppercase letters represent two-way ANOVA between groups.

Mat3 when cured with the same lamp (either mono or polywave), whereas Mat2 cured with polywave lamps was always less stiff than both the other composites (and the difference was especially marked for H).

In Fig. 3 the plots of means are presented, where Figs. 3a, c are, for E and H respectively, the same as plot in a different way in Figs. 2a, b, respectively, from the point of view of the composite groups; Figs. 3b, d, again for E and H respectively, are instead the same data plot from the point of view of the lamp groups.

Representative AFM images of the specimens after polishing are shown in Fig. 4. Only the three different composites cured with one same lamp (Poly2 here) are shown, namely Mat1, Mat2 and Mat3 in Figs. 4a, b and c, respectively, as images of the composite surfaces polished after curing with the other lamps were qualitatively similar. It appears from Fig. 4 that largest fillers emerge in case of Mat3 (Fig. 4c), whereas Mat1 (Fig. 4a) has the surface structure with least amount of defects such as grooves and pits, which are more frequent instead in Mat2 (Fig. 4b).

However, from all the different nine samples (combinations of composites and lamps) we extracted and analyzed the values of $S_q$, used as a single most
significant descriptor selected for surface roughness, according to our previous experience\textsuperscript{25-28}. Again the data are presented in graphic form (Fig. 5) and listed in a Table for exact values and description of the ANOVA results (Table 5). The $S_q$ roughness of all composites (on the selected scan areas of $50^2 \mu m^2$) was always in the range of 100–350 nm. From Fig. 5 one can see that the higher mean values emerged for Mat1 in pre-polishing condition cured with all lamps, and for Mat3 pre-polishing cured with Poly1 and Poly2. Most combinations kept similar RMS after polishing and some decreased it (Mat1 with Mono and Poly1, and Mat3 with Poly2). For Mat2 cured with both polywave lamps, the RMS seemed instead to increase after polishing. Among all post, Mat1-Mono and Mat1-Poly1 appeared smoothest, and second smoothest Mat3-Poly2 and Mat3-Poly1; the roughest was instead Mat3 for Poly1 and Poly2. The statistical significance of the observed differences is commented in the DISCUSSION.

**DISCUSSION**

For evaluation of the DC from FTIR spectra, as compared to former works in our group\textsuperscript{29,30}, we used here different peaks in the NIR region instead of the MIR one. The reason is that we carried out the measurements in ambient air and the MIR region seems more sensitive to the water content\textsuperscript{31}, which may have changed among different measurement sessions. As a result, it should be noticed that the DC levels reported in Fig. 1 do not show error bars as the values were reproducible and consistent throughout different specimen regions and
Table 5  Means (+standard deviations) of roughness parameter $S_q$ (nm) for the different combinations of composites and lamps used to cure them

| Composite | Lamp  | Mono    | Poly1   | Poly2  |
|-----------|-------|---------|---------|--------|
| Mat1      | 329±168 $^c$ | 275±57 $^c$ | 337±176 $^c$ |
|           | 96±68 $^b$   | 84±45 $^b$   | 181±51 $^a$ |
| Mat2      | 245±142 $^{ac}$ | 241±41 $^{ac}$ | 203±94 $^{ac}$ |
|           | 185±99 $^{ac}$ | 318±58 $^{ac}$ | 306±129 $^{ac}$ |
| Mat3      | 265±48 $^{ac}$ | 249±67 $^{ac}$ | 253±155 $^{ac}$ |
|           | 235±49 $^{a}$ | 136±58 $^{ab}$ | 118±38 $^{b}$ |

Despite our presentation in column-row form, the variables are treated as a single factor of variable values pairs (see Fig. 5), so a single character set is considered, also including pre- and post-polishing condition. The upper rows values are for pre-polishing, the lower rows values are for post-polishing. Different letters represent statistically different groups ($p<0.05$) according to altogether one-way ANOVA.

Fig. 5  $S_q$ roughness of the different composites cured with the different lamps, before (magenta bars) and after (orange bars) polishing with a standard method.

different specimens, typically below ±4% variation, which makes most apparent differences probably significant.

From Fig. 1 it appears that practically, when changing from Mono to Poly1 and Poly2, the material that shows the highest increase in DC for both polywave lamps is Mat1, while this increase is less prominent for Mat3. Mat2 shows for Poly2 even lower DC than for Mono, and only slightly higher DC than Mono for Poly1. The good performance of Mat3 with lamps Poly1 and especially Poly2, better than Mat1, is consistent with the company claim that they engineered optimized photo-initiator system (containing both camphorquinone and Ivocerin, the latter with peak absorbance ~420 nm wavelength) for their polywave photo-curing system Poly2. Unfortunately, the limited knowledge of material composition both in fillers and in photo-initiator systems, which is a protected know-how of the manufacturers, makes a more detailed discussion of DC impracticable.

Overall, from Fig. 2 for a given material a general consistence of E and H ranking with DC ranking from Fig. 1 appears. However, this is accompanied by the absence of absolute correlation with the ranking of E and H values among different composites. For example, while having on average the highest DC, Mat2 has on average both the lowest E and H of all sample combinations, which means that the elastic properties can be ascribed more to the composite formulation rather than to incomplete curing (i.e. lower DC). Obviously, a critical role in the composite performance is to be ascribed to its contents, mainly in terms of filler type, size distribution and above all loading level. Actually, from the accessible company data it appears that the loading levels (in vol%) are 61.0 for Mat3, 58.4 for Mat1, and 47.3 for Mat2.

As previously mentioned, from Tables 3 and 4 it appears that, according to the stiffness parameters E and H respectively, several composite pairs (within each lamp group) are significantly different (according to one-way ANOVA), which is not surprising, being the formulations different; however, what should not be the case for best clinical performance, it appears also that the same composite behaves sometimes differently, when cured with a different lamp. To make this more clear, in Fig. 3 the plots of means are presented, pointing to stress the main effect of either composite (Figs. 3a, b) and lamp (Figs. 3c, d) factors, when assumed to be independent. In both cases (and for both E and H), a clear difference is observed in these line plots of group means for Mono as compared to Poly1 and Poly2, which are instead much more similar to each other. This points out the different behavior of the monowave lamp, and suggests some interaction between the composite and lamp factors. Indeed, when we carried out two-ways ANOVA, a significant interaction was observed ($p<0.01$), for both E and H datasets.
Because of the partial inconsistency between DC and stiffness parameters, and in order to provide additional insight in the mechanical consequences of the different composite formulations, we tried to characterize the materials cured under different conditions also according to the polishing behavior. During polishing the surface roughness is expected to decrease, after the abrasive action of the method. Since composite H should correlate to its wear resistance, polishing should be more effective (and thus resulting roughness lower) in materials with lower H, when differential erosion of matrix and fillers is avoided, in which case the opposite could hold33).

In Fig. 4a single case of photo-curing lamp (Poly2) used for all different composites (Mat1, Mat2 and Mat3 in Figs.4a, b and c, respectively) is presented, for post-polishing condition. As mentioned, the specimens of the same materials cured with different lamps looked very similar, for any given material, which occurs because the surface morphology of the specimens is obviously dominated by the composite formulation, and especially by the filler size and loading, rather than by the effects of the different lamps.

Next we will discuss the statistical significance of the difference among the means of S_q for all samples, in both conditions of pre-polishing (control roughness) and post-polishing (see Fig. 5). Because two-ways ANOVA confirmed the interaction between composite and lamp factors for the results of E and H, for the analysis of S_q results we did not distinguish the two factors further, and treated their pairs as a single combined factor, ‘composite-lamp’, as reported in the x axis to Fig. 5.

We first compare the effect on S_q of the different lamps, for a given composite under same polishing condition. In pre-polishing condition, for all composites no significant difference in S_q has been observed among the different lamps, as expected. In post-polishing condition, for Mat1, curing with Poly2 resulted in significantly higher S_q than both Mono and Poly1; for Mat2, curing with Mono resulted in significantly lower S_q than both Poly1 and Poly2; for Mat3, curing with Mono resulted in significantly higher S_q than both Poly1 and Poly2. Thus, interesting significant differences in S_q post-polishing emerge, which, together with the different elastic properties, can be correlated with the DC. Mat3, engineered for a polywave lamp, is better polished after curing by Poly1 and Poly2 than by Mono. But also the other materials showed significant differences: Mat2, on the contrary, was smoother after curing with monowave Mono; Mat1 was smooth with Poly1 and Mono and rough with Poly2.

Then, we compare the different polishing conditions, for a given composite under same lamp. It is observed that most cases show significant difference (all but Mat2 with Mono and Poly2, and Mat3 with Mono). The changes corresponding to statistically significant differences are mostly in the direction of a decrease of S_q on polishing (see Mat1 with all lamps), except one anomalous case (Mat2 with Poly1), where the S_q increases instead after polishing.

Finally, we compare among different composites, for a given lamp and polishing condition. It emerges that for lamp Mono, in pre-polishing condition no significant differences emerge among all composites; in post-polishing condition, instead, Mat1 has significantly lower S_q than both Mat2 and Mat3. For Poly1 lamp, in pre-polishing condition no significant differences emerge among all composites; in post-polishing condition, Mat2 has significantly higher S_q than both Mat1 and Mat3. For Poly2 lamp, in pre-polishing condition, no significant differences appear among all composites; in post-polishing condition, Mat2 has significantly higher S_q than both Mat1 and Mat3.

When trying to compare S_q post-polishing to H, overall it seems that no correlation is generally emerging, except a negative one (i.e. lower H associated with higher post-polishing S_q) in the case of Mat2 (the less hard composite and the rougher after polishing, at least when cured with polywave lamps). In fact, in that case differential erosion with occasional removal of fillers from the surface may have occurred, as apparent in Fig. 4c (dark pits at likely sites of previously embedded microfillers). However, it can be speculated that additional correlations may play a role, such as the nominal size of the fillers. Indeed, nominal values suggest that the largest fillers should be included in Mat2, presenting hybrid formulation with broad range of 0.002–25 µm filler diameters, while for both Mat3 (0.16–0.7 µm) and Mat1 (0.01–3.5 µm) smaller upper limit of the filler diameters is expected. Nevertheless, a detailed investigation of the composite formulation effects is beyond the scope of this work.

**CONCLUSIONS**

All the three lamps investigated here guaranteed a DC≥50% for all materials except Mono for Mat1. The null hypothesis i), that the different lamps do not affect the composite stiffness, was rejected. The use of polywave LED significantly increased the DC of the tested materials for all cases except Mat2 polymerized with Poly2. However, high DC does not necessarily mean high stiffness, as this depends mainly on the material formulation (i.e. filler loading and possibly also size distribution). The null hypothesis ii), that the different lamps do not affect the composite roughness after polishing, was confirmed. Indeed, the roughness after polishing with a standard method, resulting from atomic force microscopy measurements did not show correlation with H except for Mat2 (negative correlation); this has been tentatively ascribed to the removal of some large fillers (nominal diameter ≥10 µm) in low volume loading composite (nominal 44 vol% for Mat2).

While the scenario of curing lamps and resin materials in the dental offices is so diverse that any selection of combinations is incomplete and arbitrary, even the small subset of combinations chosen can add potentially useful information and provide a useful warning to the practitioners. Within the limitations of the present work, It is confirmed from this analysis that the choice of material–lamp combination has to be made
according to clinical experience and specific case. The mechanical properties are not correlated with DC alone. Additionally, stronger educational efforts and more detailed products instructions, including the used photoinitiator system, are required to improve the quality of dental composite restorations.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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