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Comparison between a plasma arc light source and conventional halogen curing units regarding flexural strength, modulus, and hardness of photoactivated resin composites

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Abstract The plasma arc curing light Apollo 95 E (DMDS) is compared to conventional curing lights of different radiation intensities (Vivalux, Vivadent, 250 mW/cm^2; Spectrum, DeTrey, 550 mW/cm^2; Translux CL, Kulzer, 950 mW/cm^2). For this purpose, photoactivated resin composites were irradiated using the respective curing lights and tested for flexural strength, modulus of elasticity (ISO 4049), and hardness (Vickers, Knoop) 24 h after curing. For the hybrid composites containing only camphoroquinone (CQ) as a photoinitiator (Herculite XRV, Kerr; Z100, 3 M), flexural strength, modulus of elasticity, and surface hardness after plasma curing with two cycles of 3 s or with the step-curing mode were not significantly lower than after 40 s of irradiation using the high energy (Translux CL) or medium energy conventional light (Spectrum). However, irradiation by only one cycle of 3 s failed to produce adequate mechanical properties. Similar results were observed for the surface hardness of the CQ containing microfilled composite (Silux Plus, 3 M), whereas flexural strength and modulus of elasticity after plasma curing only reached the level of the weak conventional light (Vivalux). For the hybrid composites containing both CQ and photoinitiators absorbing at shorter wavelengths (370–450 nm) (Solitaire, Kulzer; Definite, Degussa), plasma curing produced inferior properties mechanical than conventional curing; only the flexural strength of Solitaire and the Vickers hardness of Definite reached levels not significantly lower than those observed for the weak conventional light (Vivalux). The suitability of plasma arc curing for different resin composites depends on which photoinitiators they contain.

Key words Resin composite · Light · Radiation effects · Hardness · Elasticity

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Introduction

The increasing use of resin composites has focussed scientific interest on polymerization. The degree of cure controls hardness [1, 10, 33], wear resistance [13], water sorption [27], residual monomer [27], and biocompatibility [4] of the dental restoration. For most of the currently available composites, polymerization is initiated by visible light. If camphoroquinone (CQ) is used as a photoinitiator, the most effective frequency band lies between 460 nm and 480 nm [21], with an optimum at 468 nm [38]. Experimental studies using monochromatic lasers [43] have shown that the 454.5 nm and 495.5 nm wavelengths are less effective than 476.5 nm but still contribute considerably to polymerization. In contrast, the 501.7 nm wavelength showed almost no effect. However, additional photoinitiators have been introduced requiring irradiation at shorter wavelengths (e.g., between 370 nm and 450 nm). Light absorption and dispersion within the resin composite limit the depth of cure. As resin composites have become increasingly popular, even for restoring posterior teeth, larger volumes of resinous materials have to be cured in deeper cavities. The degree of cure correlates to the product of the logarithms of light intensity and curing time [8, 26, 34]. Therefore, within certain limits, improving light intensity may allow shorter irradiation times while maintaining the same degree of cure. For these reasons, more powerful light sources would be desirable.

Halogen bulbs used in conventional curing units are referred to as incandescent lights. Their spectrum of radiation is continuous over the visible range, with radiation intensity increasing considerably toward the red end of the spectrum. Due to the selective absorption characteristics of the commonly used photoinitiator, 98% of this radiation does not contribute to polymerization and must be filtered to avoid heating the irradiated objects and/or blinding the operator [18]. Limitations of the filter technique and thermal problems render the further improvement of conventional curing lights difficult.

In contrast, laser sources emit light at a few distinct frequencies within the desired region, thus completely eliminating the need for filtering undesired wavelengths as compared to conventional light sources. Resin composites cured with continuous or pulsed argon lasers showed equivalent or superior Knoop hardness [41], flexural strength [6], conversion of double bonds [23, 39], degree of polymerization [3], and bond strength to enamel and dentine [15, 17, 30, 36, 42]. Laser curing required shorter irradiation time and reduced the increase of pulpal temperature [31].

In contrast to lasers, plasma arc light sources do not emit distinct frequencies but continuous frequency bands. However, these bands are much narrower than those of incandescent lights. Therefore, less radiation of undesired frequencies must be filtered. The plasma curing light Apollo 95 E (DMDS, Marburg, Germany) emits light at frequencies between 440 nm and 500 nm, with peaks at 470 nm and 485 nm and an intensity of 1320 mW/cm^2. Due to the high intensity, the manufacturer claims that 1 s to 3 s of plasma irradiation cures many resin composites to a hardness similar to that achieved after 40 s with conventional curing lights.

The purpose of the present study was to test the hypothesis that, for curing resin composites, exposure to a plasma arc curing light for 3 s or 6 s is equivalent to 40 s of irradiation using conventional halogen curing lights. Therefore, photoactivated resin composites were cured using the respective lights and tested for flexural strength, modulus of elasticity, and surface hardness 24 h after irradiation. In the present study, both Vickers and Knoop hardness were measured to evaluate the hypothesis that these methods are equally suitable.

Materials and methods

The arc curing light Apollo 95 E plasma evaluated in the present study provides curing modes with full energy for 1, 2, or 3 seconds (1 s, 2 s, and 3 s modes) and a step-curing mode with half energy for 2 s followed by full energy for 3.5 s (SC mode). The 3 s and SC modes (Apollo 3 s and Apollo SC) were selected for this study. In addition, specimens were also irradiated using two curing cycles of 3 seconds (Apollo 2×3 s). For comparison, specimens were cured using the conventional curing lights Vivalux (Vivadent, Schaan, Liechtenstein), Spectrum (DentSply DeTrey, Konstanz, Germany), and Translux CL (Kulzer, Wehrheim, Germany), each for 40 s. The performance of the curing lights was monitored daily using a handheld radiometer (Curing Radiometer, Demetron, Danbury, CT, USA) and was 250 mW/cm^2 (Vivalux), 550mW/cm^2 (Spectrum), and 950mW/cm^2 (Translux CL) for the conventional curing lights. The light intensity of the plasma arc curing light is reported by the manufacturer to be 1320 mW/cm^2 and would have exceeded the scale of the radiometer. To reduce its output to a level that could be handled by the radiometer, an aperture 3 mm in diameter was inserted between the light tip and the measuring window of the radiometer. This procedure produced a reading of 350 mW/cm^2. These results do not allow a ranking of the plasma curing light in comparison to the conventional lights, but instead served to monitor consistency of performance. The spectral radiometric output of the curing lights was determined at a resolution of 0.5 nm using an optical multichannel analyzer consisting of an imaging dual grating monochromator/spectrograph equipped with a 300-line grid (SpectraPro-150, Acton Research Corp., Acton, MA, USA) and a CCD camera (ITE/CCD – 1024 – NG, Princeton Instruments, Trenton, NJ, USA).

The restorative materials selected for the study were the fine hybrid composites Z100, Herculite XRV and Solitaire, microfilled composite Silux Plus, and the organically modified ceramics Definite. The manufacturers, shades, batch numbers, filler contents, and types of photoinitiators of these materials are specified in Table 1. Herculite XRV has been on the market for a long time and is well-documented in the literature. It may be considered representative of many other available fine hybrid resin composites. Z100 stands out for its high modulus of elasticity and fast curing characteristics. In contrast, Solitaire features a lower modulus of elasticity compared to most other hybrid composites and a slow curing mechanism that is claimed by the manufacturer to act as a built-in soft-start polymerization. Definite was selected to represent the new type of materials incorporating inorganic components into the matrix, viz., cross-linked polysiloxanes. Silux Plus was included to represent microfilled resin composites, which have been found to be more sensitive regarding depth of cure than hybrid composites [28, 35].

Flexural strength and modulus of elasticity were evaluated according to ISO 4049 [5]. Specimens of 2×2×25 mm were prepared using a stainless steel split mold placed on a microscope slide. To ease separation of the specimens from the slide, a transparent matrix band was inserted between the mold and the slide. The restorative material was packed into the mold with slight excess and covered by a second matrix band and a microscope slide. Slides and mold were clamped together to keep them aligned. The tip of the light guide was placed over the center of the mold and the curing light was activated for the designated period. Subsequently, the adjacent sections on either side were irradiated until the full length of the specimen was polymerized. The cured specimens were stored in demineralized water at 37 °C for 15 min, removed from the mold, and put back into the water bath. Before testing, excess material was cut off with a scalpel, and the height and width of the specimens were measured to an accuracy of 0.01 mm using a micrometer (55721, Mahr, Esslingen, Germany). The specimens were positioned in a three-point bending apparatus on two parallel supports separated by 20 mm and loaded until fracture at a crosshead speed of 0.75 mm/min in a universal testing machine (1445, Zwick, Ulm, Germany). Testing was performed 24 h after the start of polymerization. The flexural strength σ and modulus of elasticity E were calculated using the formulae:

$$\sigma = \frac{3 * F_{max} * l}{2 * w * h^2},$$

$$E = \frac{\Delta F}{\Delta d} * \frac{l^3}{4 * w * h^3},$$

where F_{max} was the force at fracture, l the distance between the parallel supports, and w and h the width and height of the specimen. The ratio ΔF/Δd corresponds to the slope of the linear part of the force vs. deflection curve and was determined from the corresponding diagram using the computer program Origin (Microcal Software Inc., Northampton, MA, USA).

To evaluate surface hardness, specimens about 5 mm in diameter were cured between microscope slides using a silicon mold with a height of 1.5 mm. The specimens were stored in demineralized water at 37 °C until testing. Prior to testing, a 0.1 mm layer was removed by wet grinding at the side from which the specimen had been irradiated. Vickers and Knoop hardness were measured 24 h after polymerization using a hardness tester (3212, Zwick, Ulm, Germany) with the respective indenters applying a load of 4.905 N (0.5 kp) for 30 s, with one evaluation of each specimen. Vickers and Knoop hardness were tested on the same specimens for Z100, Herculite XRV, and Solitaire and on separate specimens for Silux Plus and Definite.

Ten specimens were prepared for every combination of curing mode and restoration material, and mean values and standard deviations were calculated for these treatment groups. Differences between mean values were analyzed for statistical significance for each material separately using multiple paired U-tests (*Mann-Whitney*) with α-error adjustment according to *Bonferroni-Holm*. The level of statistical significance was set at $P<0.05$. The correlations between mean values of Vickers and Knoop hardness in the treatment groups were tested for statistical significance using *Spearman's* rank correlation coefficient ρ.

Results

The spectral radiometric output of the different curing lights is graphically presented in Fig. 1. The radiation spectrum emitted by the plasma curing light is considerably more narrow (i.e., 440–490 nm) as compared to the halogen lights. The output of the low intensity halogen light vivalux starts around 410 nm, whereas the spectra of the medium and high intensity halogen units (Spectrum, Translux CL) extend down to 390 nm.

Mean values and standard deviations of flexural strength in the different treatment groups are graphically presented in Fig. 2. Brackets connect groups not statistically different at a significance level of $P<0.05$. The differences between restorative materials were more pronounced than between curing modes within the same material. The highest flexural strength was observed for Z100 and Herculite XRV and the lowest values for Solitaire and Silux Plus, with Definite lying between. All

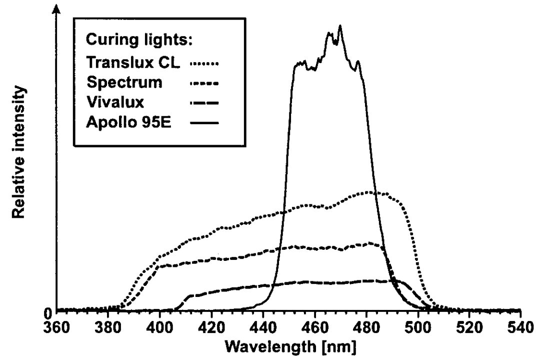

Fig. 1 Spectral radiometric outputs of the different curing lights

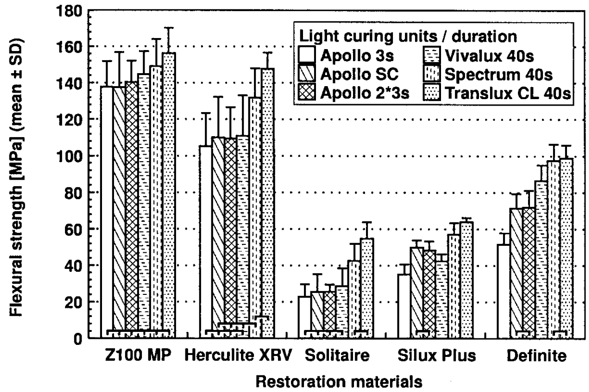

Fig. 2 Flexural strength (mean±SD, *n*=10) for the different combinations of restorative materials and curing modes/devices (*brackets* connect groups not different at a significance level of $P<0.05$)

materials featured the highest flexural strength when cured for 40 s using the Translux CL, i.e., the conventional light with the highest intensity, followed by Spectrum 40 s (conventional light, medium intensity), and, except for Silux Plus, Vivalux 40 s (conventional light, low intensity). Plasma irradiation with one step-curing cycle (Apollo SC) or two cycles of 3 seconds (Apollo 2×3 s) cured the materials to very similar flexural strengths ranging at or slightly below the level of the low intensity conventional light. Only for Silux Plus, curing with Apollo SC and Apollo 2×3 s, produced flexural strengths ranging between those with Vivalux 40 s and Spectrum 40 s. The lowest values for all materials were observed following plasma curing with one curing cycle of 3 seconds. Statistical analysis revealed that the influence of curing mode was more pronounced for Silux Plus, Definite, and Solitaire as compared to Herculite XRV and Z100. The flexural strength of Definite was significantly lower ($P<0.05$) when plasma-cured than after conventional irradiation, even with the weakest halogen light. Solitaire and Silux Plus featured better flexural strength ($P<0.05$) after conventional curing with medium or high intensity as compared to plasma curing. In the case of Herculite XRV, flexural strength resulting from

Table 1 Restorative materials used in the study

Name	Type	Manufacturer	Country of manufacture	Shade	Batch	Filler load (% w/w)	Filler load (% vol./vol.)	Content of photoinitiators with maximum absorption within the following wavelength ranges[c]:		
								450–500 nm	410–450 nm	<410 nm
Z100	Fast-curing, high-modulus, fine hybrid resin composite	3 M Medica, Borken, Germany	USA	A2 Dentin	19980114[a] 19980422[b]	84.5[c]	66[c]	Yes[f]	No	No
Herculite XRV	Fine hybrid resin composite	Kerr GmbH, Karlsruhe, Germany	USA	A2 Dentin	710013	87.1[c]/75[d]	59[c]	Yes[f]	No	No
Solitaire	Slow-curing, low-modulus, hybrid resin composite	Heraeus Kulzer, Wehrheim, Germany	Germany	A20	2001–04 28	64.4[c]	–[e]	Yes[f]	No	Yes
Silux Plus	Micro-filled resin composite	3 M Medica, Borken, Germany	USA	UO	7BC[a]8BD[b]	85[c]/57[d]	38[c]	Yes[f]	No	No
Definite	Polysiloxane-containing, fine hybrid composite	Degussa AG, Hanau, Germany	Germany	A2	205	75[c]	62[c]	Yes[f]	Yes	No

[a] Flexural strength and modulus of elasticity
[b] Hardness
[c] Manufacturer's specification
[d] After incineration [16]
[e] Not available
[f] Camphoroquinone

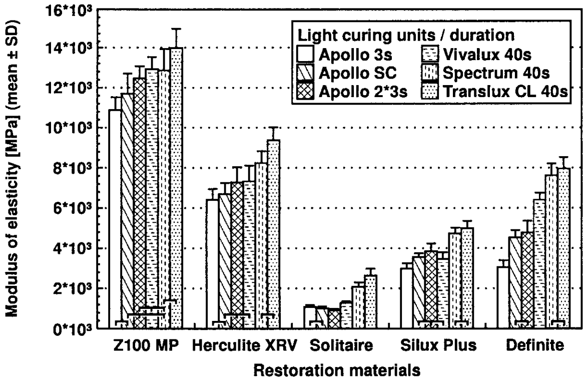

Fig. 3 Modulus of elasticity (mean±SD, *n*=10) for the different combinations of restorative materials and curing modes/devices (*brackets* connect groups not different at a significance level of *P*<0.05)

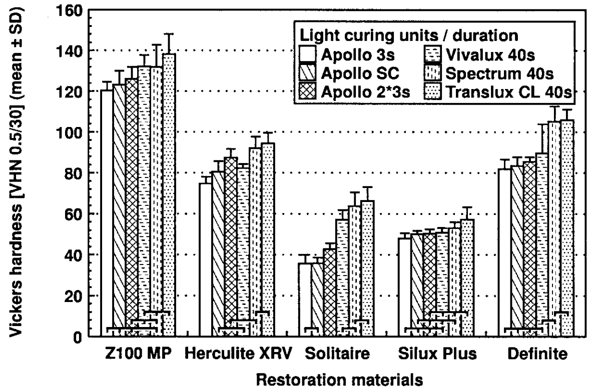

Fig. 4 Vickers hardness (mean±SD, *n*=10) for the different combinations of restorative materials and curing modes/devices as measured approximately 100 µm below the irradiated surface (*brackets* connect groups not different at a significance level of *P*<0.05)

plasma curing was not significantly inferior to conventional curing at low intensity. Indeed, using the step-curing mode or two cycles of 3 seconds yielded strength values not significantly lower than those obtained with medium intensity conventional curing. The flexural strength of Z100 was not significantly different, irrespective of which curing mode was used.

The general trends described for flexural strength were observed for modulus of elasticity as well (Fig. 3). All materials showed a significantly lower modulus of elasticity when irradiated with one plasma curing cycle of 3 seconds than after conventional curing (*P*<0.05). Again, the largest differences were found for Definite and Solitaire. All plasma curing modes produced an even lower modulus of elasticity than the low intensity conventional curing (*P*<0.05). After Apollo SC or Apollo 2×3 s curing, Herculite XRV and Silux Plus featured an elasticity modulus not significantly inferior to that effected by low intensity conventional curing. For Z100, only conventional curing at high intensity resulted in a significantly higher modulus of elasticity (*P*<0.05) than the Apollo SC and Apollo 2×3 s modes.

Mean values and standard deviations of Vickers hardness are presented in Fig. 4. The highest surface hardness was observed for Z100, followed by Definite and Herculite XRV. Silux Plus and Solitaire featured the lowest Vickers hardness. The largest variation due to curing mode was found in Solitaire. Here, plasma curing produced significantly lower Vickers hardness (*P*<0.05) than any of the conventional curing modes. For Definite, plasma curing resulted in surface hardness values not statistically lower than conventional curing at low intensity. In the case of Herculite XRV, Apollo SC was not significantly inferior to Vivalux 40s. The same was true for Apollo 2×3 s compared to Spectrum 40s. The Vickers hardness of Z100 with any plasma curing mode was exceeded only by high intensity conventional curing (*P*<0.05). The smallest differences between curing modes were observed for Silux Plus. All plasma curing modes reached at least the level of the weakest intensity

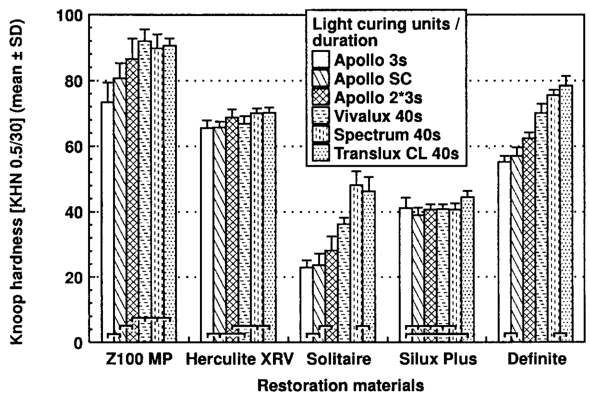

Fig. 5 Knoop hardness (mean±SD, *n*=10) for the different combinations of restorative materials and curing modes/devices as measured approximately 100 µm below the irradiated surface (*brackets* connect groups not different at a significance level of *P*<0.05)

curing light, Apollo SC and 2×3 s reached the level of the medium intensity light, and Apollo 2×3 s reached that of the high intensity conventional light.

Similar results were observed for Knoop hardness (Fig. 5). Again, all plasma-cured Solitaire and Definite specimens exhibited lower Knoop hardness values (*P*<0.05) than the conventionally cured ones. For Z100, Herculite XRV, and Silux Plus, one or several plasma curing modes produced surface hardness values not significantly lower than medium or even high intensity conventional irradiation.

In Fig. 6, mean values and standard deviations for Vickers and Knoop hardness in the different treatment groups are plotted against each other. For Herculite XRV, the Vickers hardness shows larger variations between curing modes than does Knoop hardness. The opposite is true for Z100 and Definite. *Spearman's* rank correlation coefficient (ρ=0.976) indicates a significant linear correlation between the two parameters (*P*<0.001). These data do not indicate that either method of hardness measurement is superior.

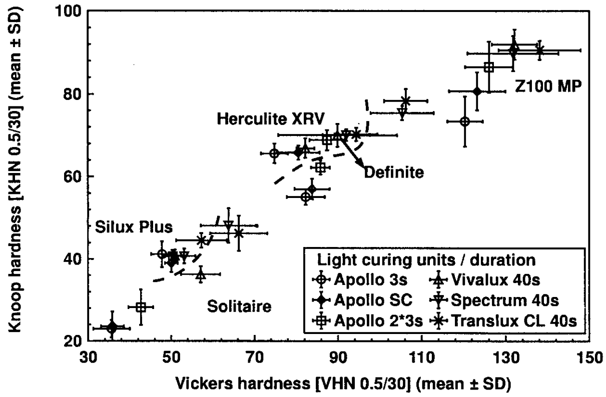

Fig. 6 Scatter plot of the mean values and standard deviations (n=10) of Vickers vs. Knoop hardness for the different combinations of restorative materials and curing modes/devices

Discussion

The results presented above do not support the hypothesis that 3 s of plasma arc curing is equivalent to 40 s of conventional halogen irradiation. However, they demonstrate that 6 s of plasma arc irradiation produces mechanical properties similar to those from 40 s of conventional halogen curing, provided that the resin composite contains only camphoroquinone as a photoinitiator.

The mechanical properties of resin composites are influenced by type and composition of the resin matrix, filler type, filler load, and mode of polymerization. The filler particles incorporated into the matrix provide much better mechanical properties than the matrix itself. Therefore, up to a certain limit, a higher filler load may be expected to improve mechanical properties. A correlation between volumetric filler content and hardness was demonstrated by *Pilo* and *Cardash* [28]. The differences between the restorative materials included in the present study can be explained by their different filler contents. Featuring the highest filler load, Z100 also ranked highest for flexural strength, modulus of elasticity, and surface hardness. On the other hand, Silux Plus and Solitaire, with the lowest filler load, also have the lowest mechanical properties in the study. These differences are inherent in the materials and cannot be compensated for in the curing mode.

The output intensity of light-curing units in clinical use was reported to vary between 25 and 825 mW/cm^2 [29] as measured by the curing radiometer (Demetron) or between 28 and 1368 W/m^2 [25] when a more narrow spectrum was recorded. According to the manufacturer of the curing radiometer, 200 mW/cm^2 is the lowest clinically acceptable intensity and, between 200 and 300 mW/cm^2, curing time should be increased. The conventional curing lights selected for the present study provide intensities of 250, 550, and 950 mW/cm^2, covering the range from clinically acceptable to excellent curing lights.

The importance of degree of cure of resin composites has been stated above. However, the direct measurement of conversion of double bonds is not easily achieved. Therefore, mechanical properties were evaluated in the present study to serve as indirect indicators of the degree of cure. Hardness [1, 9, 10, 11, 33], flexural strength, and modulus of elasticity [11] were found to correlate with conversion of double bonds. Others have argued that flexural strength reflects rate of polymerization rather than degree of cure, since curing at high intensity may produce more starter radicals and shorter polymer chains than low intensity curing [22].

Hardness is usually tested on surfaces created in contact with matrix bands or on longitudinal sections. *Reinhardt* [32] has demonstrated that the percentage of unreacted double bonds is up to twice as high at the interface to the matrix band as compared to the bulk of the material, even when the specimens are prepared in an argon atmosphere. This phenomenon can be explained by the fact that, in the bulk of the material, a free radical is surrounded 3-dimensionally by possible reaction partners, while a radical located at the interface can find possible reaction partners only on one side of a hypothetical sphere centered at the free radical. Therefore, hardness is lower at the surface than 80–100 µm deeper. To account for this interface effect, the surface layer was removed in the present study by wet grinding.

In the literature, both the Vickers and the Knoop methods have been used to evaluate the hardness of resin composites. Concerns have been raised that, for polymers, relaxation of the materials distorts the Vickers indentation, whereas the long diagonal of the Knoop indentation is not affected. Therefore, Knoop hardness is claimed to be more suitable. However, there are neither scientific data supporting this view nor international standards or specifications favoring one of these two types of measurement. The results of the present study revealed a significant linear correlation between Vickers and Knoop hardness, and both may be equally suitable for studying resin composites.

The mechanical properties of Z100 and Herculite XRV were not significantly lower when plasma-cured using the step-curing mode or two cycles of 3 seconds as compared to conventional curing at medium or even high (Knoop hardness; flexural strength of Z100) intensity. These materials appear to be rather insensitive to different light-curing procedures. Comparable observations have been reported in the literature. Compressive strength and stiffness of Herculite were not affected by irradiation times varying between 20 s and 120 s [2], and the hardness of Z100 was not influenced by curing at different light intensities [19, 40]. Flexural, compressive, and diametral tensile strength of Herculite were not different following 10 s of irradiation with an argon laser (1000 mW/cm^2) as compared to 40 s of conventional curing (354 mW/cm^2) [6]. Both materials featured similar flexural strength and modulus of elasticity when cured using different combinations of irradiation time and light intensity [24]. On the whole, both Z100 and Herculite XRV appear to be suitable candidates for curing at high light intensity and reduced irradiation time.

In the case of Silux Plus, medium or high intensity conventional curing produced superior flexural strength and moduli of elasticity than did any of the plasma curing modes evaluated in the present study. No significant differences were observed for surface hardness, at least when plasma curing consisted of two 3 s cycles. So far, no data are available comparing the effects of different curing procedures on the flexural strength or modulus of elasticity of Silux. Knoop hardness at varying depths of Silux following 30 s of argon laser (1000 mW/cm^2) as compared to 40 s of conventional curing (354 mW/cm^2) were found to be equivalent [41]. Wallace hardness at the surface of Silux Plus was found to be independent of the intensity of the curing light, as well [14]. Light attenuation within resin composites is commonly attributed to scattering by filler particles and thought to be most effective when the particle size is close to half the wavelength of the respective light [35]. However, the typical size of fumed silica particles is 40 nm. Therefore, a size of 235 nm (i.e., half of 470 nm, the most efficient frequency for activation of camphoroquinone) is only reached when one assumes an agglomeration of primary filler particles [28]. Only then can light attenuation be expected to be more pronounced in microfilled composites as compared to hybrid resin composites. The present results may be better explained by the lower concentration of the photoinitiator found in the Silux Plus matrix as compared to hybrid resin composites [37, 38]. High concentrations of the photoinitiator cause a yellowish discoloration of the resulting resin and compromise the color match to human teeth. This discoloration may be more easily concealed by the high filler load typically used in hybrid resins, whereas the higher proportion of resin in microfilled composites may limit the concentration of the photoinitiator. In fact, the depth of cure was found to be smaller in microfilled composites than in hybrid resin composites [12, 20]. These considerations may explain the observation in the present study that Vickers and Knoop hardness of Silux Plus measured 100 µm below the irradiated surface were similar for the various curing devices and procedures, whereas flexural strength and modulus of elasticity with conventional curing at medium or high intensity, evaluated using 2 mm specimens, revealed its superiority over plasma curing.

In Solitaire and Definite, plasma curing produced inferior mechanical properties to those with conventional curing. Only the flexural strength of Solitaire and the Vickers hardness of Definite reached levels not significantly lower than those of conventional curing at low intensity. No comparable data are available in the literature for these materials. According to the manufacturer's specifications, the filler type and load of Definite appear to be similar to those of Herculite XRV or Z100. In contrast, Solitaire's filler particles are porous and larger (8 µm) than those contained in most hybrid resin composites (ca. 1 µm). However, larger particles have been shown to have a positive effect on depth of cure [43]. The rate of polymerization also depends on the concentration of the initiator and type and concentration of the coinitiator [8, 43]. These parameters are usually not specified by manufacturers but were found to vary between commercially available resin composites [7, 37, 38] and may be responsible for the different curing behaviors. The spectral radiometric output of the plasma curing light Apollo 95 E is limited to the range between 440 and 490 nm, which is optimally suited for activating camphoroquinone (maximum absorption 468 nm). However, in addition to CQ, both Definite and Solitaire contain photoinitiators absorbing at shorter wavelengths. These initiators can be activated by conventional halogen curing lights but not by the plasma light source. This may explain the observation that plasma curing of Definite and Solitaire produces inferior mechanical properties as compared to irradiation using conventional halogen lights.

The range between 410 and 490 nm is covered by all of the three halogen sources used in the present study. For this reason, their potential for curing resin composites containing only CQ (i.e., Herculite XRV, Z100, and Silux Plus in the present study) or CQ and an initiator absorbing between 410 and 450 (i.e., Definite) depends on their output intensity level rather than their spectral radiometric output. However, in the present study the range between 380 and 410 nm is covered by the medium and high intensity but not by the weak conventional curing light. This limitation may further reduce the potential of the weak conventional source to cure resin composites containing photoinitiators absorbing at wavelengths shorter than 410 nm (i.e., Solitaire in the present study).

A reduction of irradiation time would save considerable time and be of great advantage in clinical practice. Especially in deep cavities, more layers of resin composite could be applied and cured in less time, which might help to avoid the negative consequences of polymerization shrinkage. Since plasma curing lights may become more popular in the future, manufacturers of resin composites should specify which spectral radiometric output is required for photoactivating their materials. Based on this information, the dentist can decide for himself whether plasma curing is appropriate or not. Further research is needed to determine whether rapid polymerization of resin composites with a plasma light compromises the marginal seal of the restorations.

Conclusions

The efficiency of the plasma light Apollo 95 E for curing resin composites strongly depends on which photoinitiators they contain. Herculite XRV and Z100, containing only camphoroquinone as a photoinitiator, appear to be suitable candidates for plasma curing. With these materials, two curing cycles of 3 s produce mechanical properties not significantly worse than with 40 s of conventional curing at medium or even high intensity. For Silux Plus containing CQ as well, the quality of plasma curing (two cycles of 3 s or one cycle of step-curing) ranges between low and medium intensity conventional curing. Both Solitaire and Definite contain CQ and additional initiators absorbing at shorter wavelengths. These restoration materials show inferior mechanical properties after plasma curing as compared to conventional curing. For the time being, plasma curing of these materials is not recommended.

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