

Effect of irradiance from curing units on the microhardness of composite – a systematic review

Neenu Francis,*¹ Rakesh R. Rajan,¹ S. Vijay Kumar,² Anju Varughese,¹ Vineetha Karuveetil² and C. M. Sapna¹

Key points

- Proper functioning and adequate irradiance of light curing are essential for the longevity and satisfactory physical, chemical and mechanical properties of resin materials.
- Based on the studies, light irradiance is a relevant factor in the microhardness and polymerisation of composite resin material.
- From the data obtained from the reported and selected studies, it is evident that most of the included studies showed favourable results for higher irradiance of light than the lower irradiance of light on microhardness of composite; these results are based on articles.

Abstract

Purpose The systematic review aims to evaluate the effect of light irradiance from light-curing units on microhardness of composite.

Materials and methods The protocol was registered in PROSPERO following which primary search was carried out via MedLine, Scopus and Cochrane Library. A customised tool was used to assess the risk of bias. Among the 303 records retrieved from the databases, only ten articles qualified for qualitative synthesis after meeting all the requirements of the eligibility criteria. Covidence software was used to record the decisions. The studies published until 31 March 2021 were taken up for the review. The articles showed a low-to-moderate risk of bias.

Results From a total of 303 articles, ten articles were reviewed for full text. Ten *in vitro* studies were included for qualitative analysis. There was heterogeneity in sample size, curing time and outcome measured. Therefore, meta-analysis was not performed. Out of ten studies, seven studies reported higher microhardness value for higher intensity than lower intensity of light.

Conclusion Despite the fact that the findings of the evaluated studies are quite variable, significant scientific evidence revealed that high light intensity can enhance the hardness of resin composites.

Introduction

Resin-based composites (RBCs) have been widely utilised as a restorative material for both posterior and anterior teeth since their inception in the 1960s.¹ RBCs were either chemically cured two-component compounds or photo-initiated materials. They initially began with ultraviolet (UV) initiators and then switched to visible light initiators, such as camphorquinone which was developed in 1978.²

Light-cured composites are cured by radical photopolymerisation. In the presence of activators, photoinitiators absorb light photons and produce free radicals. The polymerisation reaction would be triggered by the free radicals, resulting in polymerisation.³

Camphorquinone (CQ) is one of the most extensively used photoinitiators and has a peak wavelength near 470 nm in the visible light spectrum. Acyl phosphine oxide (APO), Ivocerin and phenyl propanedione (PPD) are the other photoinitiators. PPD absorbs light in a UV wavelength range to around 490 nm and has an absorbance peak at 398 nm and effectively tails off after 460 nm,⁴ while APO, such as Lucirin TPO (2,4,6-trimethylbenzoyldiphenyl phosphine oxide) absorbs light primarily in the UV range. APO has a peak of about 370 nm, which is significantly lower than CQ's. Ivocerin is a newly designed germanium

photoinitiator with a sensitivity peak of around 420 nm and absorbs light across a wider wavelength spectrum than APO.⁵

As a result, monowave light-emitting diode (LED) light-curing units (LCUs) that produce light predominantly in the 445–480 nm spectral region would be inefficient in activating these photoinitiators.^{6,7,8,9,10,11} A third-generation curing light, polywave blue-violet LED-based LCUs,^{9,12} has been introduced to address this restriction, claiming to polymerise all resin composite restorations. These blue-violet LCUs combine up to three different colours. LED chips of various 'colours', with spectral emissions peaking between 440–460 nm (blue) and 400–410 nm (violet). It can obtain irradiances of up to 3,200 mW/cm² and polymerisation in as little as six seconds, depending on the mode selected.¹²

Many variables affect the amount of light energy received on the top and bottom

¹Department of Conservative Dentistry and Endodontics, Amrita School of Dentistry, Amrita Vishwa Vidyapeetham, Kochi 682041, India; ²Department of Public Health Dentistry, Amrita School of Dentistry, Amrita Vishwa Vidyapeetham, Kochi 682041, India.
*Correspondence to: Neenu Francis
Email address: neenufrancis@yahoo.com

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surfaces of a composite resin restoration, such as the design and size of the light guide, distance of the light guide tip from the composite resin, power density, exposure duration, shade and opacity of the composite resin, increment thickness, and material composition.^{13,14,15} The degree of monomer to polymer conversion is a defining factor for physical and mechanical characteristics of composite, and it is directly connected to irradiance.^{16,17} Spectral radiant power is the radiant power per wavelength.¹⁸ To adequately cure a photoactivated resin, the spectral output from the LCU must match the wavelength-dependent photosensitivity of the photoinitiator used in the resin.¹⁹ Insufficient radiant exposure (J/cm^2), due to poor curing procedures, may trigger a snowball effect driving to shorten the long-term lifetime service of composites.²⁰ Incomplete conversion of the polymer matrix, significant release of materials to the oral environment, high degradation upon oral fluids, increase of water sorption and increased roughness is the potential pathway of detrimental events leading to the increase of biofilm accumulation and, consequently, the risk of development of caries lesions around restorations (CARS) due to inappropriate curing procedures of the material.²¹

Researchers recommend for an effective polymerisation of maximum thickness of 2 mm increment of composite,⁸ a minimum irradiance of $300\text{ mW}/cm^2$ should be ensured.^{16,17}

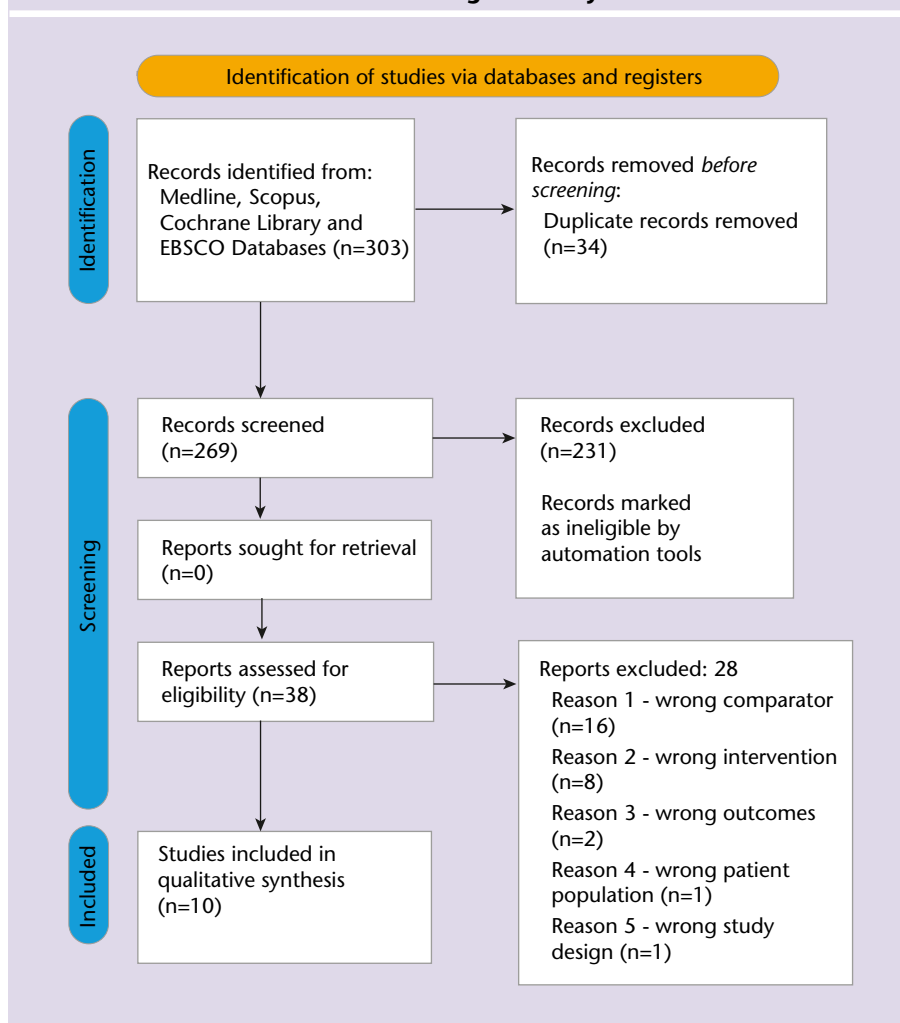
Lights with outputs more than $800\text{ mW}/cm^2$ are available and require only shorter exposure time. Shorter irradiation periods, on the other hand, may result in inadequate composite resin conversion, particularly towards the bottom of the restoration.^{22,23,24} Furthermore, the use of high irradiance in the initial phase of curing should result in a greater number of growth centres and higher crosslink density.²⁵

One of the most significant mechanical properties of dental composites is surface hardness. It is proportional to the rate of polymerisation conversion, which is affected by polymerisation time, distance of polymerisation light,²⁶ irradiation²⁷ and the type of material at the energy source's tip.²⁸ Microhardness testing has long been recognised as a feasible approach for evaluating composite curing and the efficiency of the light source.^{29,30} The degree

Table 1 Search strategy used in PubMed

Search No.	Search strategy
6	Search No.1 AND No.2 AND No.3 AND No.4 AND No.5
5	Search (composite)OR (resin composite)OR (composite restorative)
4	Search (microhardness)OR (knoop hardness)OR (Vickers microhardness)OR(surface microhardness)
3	Search (light intensity) OR (light curing lamps)
2	Search (light curing units) OR (light curing lamps)
1	Search (LED)OR (light emitting diode)

Fig. 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only



of conversion, or the percentage change in monomer double bonds to a single polymeric bond, is determined by polymerisation. The degree of conversion is a crucial indicator of how well the monomers used to make resins are polymerised and crosslinked.

Dental practitioners should be aware of the distinctions in LCUs such as irradiance and exposure time, and the effects these variances can have on the RBC as there are so many different types of LCUs available.

The key question addressed by this systemic review was: does variation in light irradiance from LED curing units influence the microhardness of the composite?

Materials and methods

This systematic review was piloted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) reporting guidelines. The systematic review has been registered

in the PROSPERO international database (CRD42021248471). The review aims to answer the guiding question: ‘Does variation in irradiance from LED curing units influence microhardness of the composite?’

Inclusion criteria

- Studies carried out until 31 March 2021
- *In vitro* studies carried out on artificial molds
- Comparative studies evaluating the microhardness of composite when cured with low irradiance (300–750 mW/cm²) and high irradiance (900–1300 mW/cm²) LED lights.

Exclusion criteria

- Review articles in languages other than English
- *Ex vivo* studies carried out on extracted teeth
- Studies not following the inclusion criteria.

Literature search

Sources for the systematic review included Medline, Scopus, and the Cochrane Library. The articles were selected until 31 March 2021. Searches were re-run before extraction and analysis.

The search aimed to identify both published and unpublished studies. To acquire articles on the topic, a broad search of Medline, Scopus, the Cochrane library and EBSCO was undertaken to identify articles on the topic and hand searching was done on the first ten pages of Google Scholar. A comprehensive search method for Medline and Scopus was implemented using text words found in the titles and abstracts of relevant articles, as well as the index keywords used to describe the articles. Each database and/or information source was given its search strategy, which incorporated all of the specified keywords and index terms. Additional studies were evaluated from the reference list of all relevant sources of evidence (Table 1).

Study selection

After the literature search, the results were exported to Covidence software. Title and abstract screening of the articles was performed by two independent reviewers (NF and VK). This was followed by full-text screening which was also carried out by two independent reviewers. A third subject

expert (RR) was invited to resolve conflicts of agreement. Covidence software was used for recording the decisions (Fig. 1).

Data collection process

After discussion with the team, a data extraction template was formulated and two independent reviewers (NF and VK) performed the extraction process. A third subject expert (RR) was invited to resolve conflicts of agreement. The data were extracted using a standardised form in Covidence software. The data extracted included demographic data (year, author, country) and characteristics of the study (aim, study design, sample size). Details of the microhardness test performed included the type of composite used and sample characters, which were recorded. Intervention (higher irradiance of 900–1300 mW/cm²) and control (lower irradiance 300–750 Mw/cm²) were defined and curing time was noted. The definition and measurement of the main outcome (microhardness) were noted. Data was collected for assessing the primary outcome that is microhardness, which was evaluated using Vickers and Knoop hardness test and expressed in Vickers Hardness Number (VHN) and Knoop Hardness Number (KHN).

Quality assessment

The risk of bias was examined independently by two reviewers (NF and VK). There was no standardised tool available for assessing the risk of bias for *in vitro* studies. Previous studies have used customised tools. The present study also used a customised tool adapted from the study AlShwaimi *et al.*³¹ The following parameters were assessed and graded for calculating the risk of bias:

1. Presence of control group
2. Description of sample size calculation
3. Light-curing procedure performed by a single operator
4. Use of irradiance of light-curing units according to manufacturer's instructions
5. Incubation performed before outcome assessment
6. Using Vickers or Knoop test to determine hardness (assessment of top and bottom surfaces).

The risk of bias was recorded as low, unclear or high for each of these parameters. For the overall risk of bias, the articles that cited 1–2 items were categorised as having low risk of

bias, 3–4 as moderate risk, and 5–6 as high risk.

Results

Descriptive analysis

All the ten studies selected were comparative *in vitro* studies carried out on various artificial models to support the restorations. The various molds used for the studies were spilt brass mold, aluminium rings, polyvinyl siloxane mold, Teflon mold, metallic matrices and cylindrical stainless steel mold. The specimen thickness ranged from 2–4 mm and the diameter ranged from 3–10 mm. For assessing the microhardness of composite, bulkfill composite,^{5,32,33,34} microhybrid composite,^{35,36} conventional and bulkfill composite,³⁷ low shrink posterior composite and microhybrid,³⁸ bulkfill and nanocomposite,³⁹ microfilled and microhybrid⁴⁰ were used.

Furthermore, most of the reviewed articles were published recently and the year of publication of studies ranged from 2005 to 2020. To evaluate microhardness, all of the reviewed studies (100%) employed either the Knoop or Vickers hardness tests as the primary testing method.^{5,32,33,34,35,36,37,38,39,40} In five of the studies, the outcome was measured using the Knoop hardness test^{5,36,37,38,40} and in the other five studies, it was the Vickers hardness test.^{32,33,34,35,39} The curing time in two of the studies was 20 seconds.^{32,37} In one of the studies, the curing time was 60 seconds³⁵ and in another study it was 40 seconds.³⁸ In some studies, they used multiple curing times: 5 seconds, 20 seconds and 80 seconds;³⁶ 10 seconds, 20 seconds and 40 seconds;³³ and 20 seconds, 60 seconds, 80 seconds and 100 seconds.⁴⁰ Three of the studies used different curing times for higher irradiance and lower irradiance^{5,34,39} (Table 2).

It can be concluded from Table 3 that in most of the studies,^{32,33,34,35,38,39,40} higher irradiance of light showed significantly higher hardness value compared to the lower irradiance of light. However, the results of the studies by Haenel *et al.* in 2015, Gan *et al.* in 2018 and Soto Montero *et al.* in 2020 showed that lower irradiance of light has significantly higher hardness value^{5,36,37} (Table 3).

Quality assessment

As per the parameters, four articles out of ten were graded as low risk^{5,35,37,40} and

Table 2 Demographic and study design of included study

Study ID	Country	Study design	Intervention	Control	Outcome
Alkudhairy <i>et al.</i> 2017 ³²	Saudi Arabia	Comparative <i>in vitro</i> study	H-1200 (Bluephase N; Ivoclar Vivadent, Schaan, Liechtenstein)	L-650 (Bluephase meter; Ivoclar Viva dent, Schaan, Liechtenstein)	Vickers-300 g force loaded for 15 sec
Haenel <i>et al.</i> 2015 ³⁶	Germany	Comparative <i>in vitro</i> study	H-1264 (Celalux 2 [Voco, Cuxhaven, Germany])	L-666 [Bluephase 20i (Ivoclar Vivadent, Schaan, Liechtenstein)]	Knoop-490.3 mN applied for 8 sec
Soto Montero <i>et al.</i> 2020 ³⁷	Brazil	Comparative <i>in vitro</i> study	H-935 (Bluephase Style, Ivoclar Vivadent AG, Schaan, Liechtenstein)	L-750 (Bluephase Style, Ivoclar Vivadent AG, Schaan, Liechtenstein)	Knoop-50 g(0.49N) for 5 secs
Gan <i>et al.</i> 2018 ⁵	Singapore	Comparative <i>in vitro</i> study	H-1200 (Bluephase N Polywave high power)	L-650 (Bluephase N Polywave low power)	Knoop-10 g load was applied with a dwell time for 15 secs
Prince <i>et al.</i> 2010 ³³	Belgium	Comparative <i>in vitro</i> study	H-1166 (G-Light)	L-644 (Freelight)	Vickers-200 g for 30 secs
Park <i>et al.</i> 2005 ³⁵	South Korea	Comparative <i>in vitro</i> study	H-980 (Elipar FreeLight 2)	L-330 (Elipar FreeLight)	Vickers
Cardia <i>et al.</i> 2015 ³⁸	Brazil	Comparative <i>in vitro</i> study	H-1000 (Blue Star 3, Microdont, São Paulo, SP, Brazil)	L-600 (Blue Star 3, Microdont, São Paulo, SP, Brazil)	Knoop-50 g for 30 secs
Conte <i>et al.</i> 2017 ³⁴	Italy	Comparative <i>in vitro</i> study	H-1224 (Valo, Multipeak)	L-712 (Smartlite iQ, Single peak)	Vickers -50 g load for 45 secs
Gritsch <i>et al.</i> 2008 ³⁹	France	Comparative <i>in vitro</i> study	H-1000 (Bluephase, Ivoclar Vivadent, Schaan, Liechtenstein)	L-400 (Bluephase ,Ivoclar Vivadent, Schaan, Liechtenstein)	Vickers-100 g for 30 secs
Cavalcante <i>et al.</i> 2009 ⁴⁰	United Kingdom	Comparative <i>in vitro</i> study	H-900 (Utralume5-ultradent)	L-750 (Radii-SDI)	Knoop-25 g for 20 secs

six articles were graded as moderate risk.^{32,33,34,36,38,39} None of the articles reported details on sample size estimation. Details of procedural and outcome measurement whether performed or recorded by a single operator were not reported in the ten articles (Table 4).

Discussion

Systematic reviews benefit clinical practitioners by generating precise evidence-based explanations to critical questions about the best available scientific knowledge. In addition, thorough reviews can lead to the development of new standardised research methods and procedures.

With the implementation of photopolymerisable composites, the intensity of the curing light is significant, and complete curing is difficult to achieve in practice. Bulk-fill composites have good mechanical qualities and little polymerisation shrinkage which can be cured in thick layers.⁴¹ LED curing light of the irradiance 400–500 mW/cm² is required for adequate polymerisation. A light irradiance of 200–600 mW/cm² with proper exposure duration is deemed sufficient to induce consistent polymerisation of RBCs.⁴² Improved LEDs with a higher irradiance

range (500–1400 mW/cm²) offer a wider range of the visible blue light spectrum.⁴³ Despite the fact that single-peak and multi-peak lights can create identical overall power output (watts) and supply the same power density (mW/cm²) to the restoration, spectral output discrepancies can have a substantial impact on the photoinitiating system.⁴⁴ Microhardness is one of the most important physical features of dental materials,⁶ and investigating it can make you understand the setting characteristics and depth of cure resin-based restorative materials.⁴⁵

Our systematic review indicated that the irradiance of light-curing units and the composition of the material has an influence on the microhardness of composite. There were a total of ten studies and the majority of them demonstrated that higher irradiance contributes to higher microhardness values. Only three included studies reported that lower irradiance of light produced higher microhardness value.^{5,36,37}

Soto Montero *et al.*³⁷ and Gan *et al.*⁵ in their studies compared the lower and higher irradiance of polywave light. The delivered irradiance for higher intensity was found between 935 and 1,200 mW/cm² and lower irradiance was between 650 and 750 mW/cm² in both studies. However, Haenel *et al.*³⁶

compared the irradiance of polywave and monowave light; in this study, mean upper surface hardness of the polywave light of lower irradiance was greater than monowave light. The variations in polymerisation were reported by Miletic *et al.* to be attributable to variances in emitted wavelengths for distinct LCUs.⁴⁶ The monowave light has a wavelength of 450 nm in distinction to the lower irradiance of polywave light with 463 nm, and this wavelength adapts better for CQ (470 nm).⁹ Park *et al.* reported that the additional wavelength range of polywave LCUs in the lesser range has an additional effect on the curing process.⁴⁷ As a result, the improved condition of curing of the lower irradiance polywave light, which has a wavelength range of 390–435 nm, could be explained. To summarise, the variations in peak maxima and extra wavelength range explain why the higher irradiance of monowave light and the lower irradiance of polywave light have distinct curing effectiveness.

The higher microhardness values are attained when the emission spectra and the photoinitiator absorption spectra are related.

Composite resin restorations should preferably be cured evenly throughout. A 4 mm-thick bulkfill specimen's bottom-to-top

Table 3 Material specification and measurement of outcome						
Study ID	Curing time (seconds)	Sample size	Sample character	Top/ bottom	Brand name of composite	Main conclusions
Alkudhairy <i>et al.</i> 2017 ³²	20	12	A two-part brass mold with a diameter of 5 mm and a thickness of 4 mm	Top	Tetric N ceram Filtek Sonicfill	Hardness value of composite was greater with high intensity of light
Haenel <i>et al.</i> 2015 ³⁶	5,20,80	5	1 mm thick circular aluminium rings	Top	Arabesk-microhybrid	Low intensity used polywave light High intensity used monowave light Low intensity shows higher hardness number than higher intensity in all exposure times Higher hardness number was seen when exposure time was increased
Soto Montero <i>et al.</i> 2020 ³⁷	20	10	Disc specimen (10 mm and 2 mm thick), mold-polyvinyl siloxane-4 mm	Top and bottom	Conventional HER-Herulite ultra TEC-Tetric evo ceram Bulkfill SOF-SONICFILL TBF-Tetric EvoCeram Bulk Fill	Hardness number was slightly high for low intensity, top surface > high intensity top surface > high intensity bottom surface > low intensity bottom surface Conventional (HER,TEC) and SOF (bulkfill), TBF (bulkfill) – higher intensity, top surface > lower intensity, top surface > higher intensity, bottom surface > lower intensity, bottom surface
Gan <i>et al.</i> 2018 ⁵	H-10 L-18.5	6	Black polyvinyl molds with cylindrical recesses of 4 mm ht and 3 mm diameter	Top and bottom	Tetric N-ceram bulk fill	Polywave light was used for low intensity (NL) and high intensity (NH) Hardness value in the order NL(TOP) > NH(TOP) > NL(BOTTOM) > NL(BOTTOM) Lower intensity favours higher hardness value
Prince <i>et al.</i> 2010 ³³	10,20,40	5	Brass mold 3 mm in diameter and 2 mm in depth	Top and 2 mm depth	Tetric evo ceram-A2 and BleachXL	High intensity (G-3rd generation) Lower intensity (F2-2nd generation) A2 TOP G(20s) > G(40s) > G(10s) > F2(40s) > F2(20s) > F2(10s) A2 BOTTOM G(40S) > F2(40S) > G(20S) > F2(20S) > G(10S) > F2(10S) BLEACH XL-TOP-G(40s) > G(10s) > G(20s) > F2(40s) > F2(20s) > F2(10s) BLEACH XL BOTTOM-G(40s) > G(20s) > F2(40s) > G(10s) > F2(20s) > F2(10s) Higher intensity shows higher hardness value of composite
Park <i>et al.</i> 2005 ³⁵	60	10	A 6 mm diameter hole was made in a 2 mm thick Teflon plate	Top and bottom	z250	Higher intensity (G2) Lower intensity(G4) Higher intensity of light favours higher hardness value TOP-G2 > G4 LOW-G2 > G4
Cardia <i>et al.</i> 2015 ³⁸	40	10	Metallic matrices 1 mm thick and 5 mm diameter	Top and bottom	Methacrylate based microhybrid Silorane-based microhybrid composite	Z250 > P90 KHN values increases with increased irradiance
Conte <i>et al.</i> 2017 ³⁴	H-14 L-22	5	Cylindrical SS mold (8 mm diameter and 2 mm thick)	Top and bottom	Tetric evoceram shades – translucent,A2,A4	Higher intensity of light (VA-mutipeak) shows higher hardness value than lower intensity of light (SQ-single peak)
Gritsch <i>et al.</i> 2008 ³⁹	H-16 L-40	10	The samples were prepared in Teflon moulds of 10 mm long by 4 mm wide and 3 mm deep	Top and bottom	Tetric evoceram – A3 ceram X-A3	Higher intensity of light shows higher hardness value
Cavalcante <i>et al.</i> 2009 ⁴⁰	20,40,60, 80,100	5	Metallic molds with cylindrical cavities 4 mm in diameter and 2 mm deep	Top and bottom	Microfilled heliomolar Microhybrid herculitexrv	Higher intensity of light shows higher hardness value

Table 4 Risk of bias assessment

Authors	Presence of control group	Description of sample size calculation	Light curing procedure performed by a single operator	Use of light intensities of light-curing units according to manufacturer's instruction	Incubation period performed prior to outcome assessment	Using Vickers or Knoop test to determine hardness, assessment of top and bottom surfaces	Risk of bias
Alkudhairy <i>et al.</i> 2017 ³²	Yes	No	No	No	Yes	No	Medium
Haenel <i>et al.</i> 2015 ³⁶	Yes	No	No	Yes	Yes	No	Medium
Soto Montero <i>et al.</i> 2020 ³⁷	Yes	No	No	Yes	Yes	Yes	Low
Gan <i>et al.</i> 2018 ⁵	Yes	No	No	Yes	Yes	Yes	Low
Prince <i>et al.</i> 2010 ³³	Yes	No	No	Yes	No	Yes	Medium
Park <i>et al.</i> 2005 ³⁵	Yes	No	No	Yes	Yes	Yes	Low
Cardia <i>et al.</i> 2015 ³⁸	Yes	No	No	No	Yes	Yes	Medium
Conte <i>et al.</i> 2017 ³⁴	Yes	No	No	No	No	Yes	Medium
Gritsch <i>et al.</i> 2008 ³⁹	Yes	No	No	No	Yes	Yes	Medium
Cavalcante <i>et al.</i> 2009 ⁴⁰	Yes	No	No	No	Yes	Yes	Low

hardness ratio should be close to or equal to 1 (100%). Due to light-curing and material constraints, several studies have chosen a hardness ratio of 0.8 or 80% as the criterion for a successful cure.⁴⁸

The use of photoinitiators in resin composite formulations is an important factor affecting the material's depth of cure.⁴⁹ New initiation systems based on benzoylgermanium derivatives have been synthesised and demonstrated to be efficient visible light photoinitiators.^{50,51,52,53} Similar to phosphine oxides, the benzoylgermanium initiators undergo photodecomposition to form radicals without the need for a co-initiator. The benzoylgermanium initiators exhibit strong absorption up to 450 nm, which is advantageous for improved initiation efficiency in dental materials. The novel initiators were demonstrated to exhibit improved UV stability, comparable shelf stability, improved bleaching, and increased cure depths and polymerisation rates relative to those of the CQ/amine systems.⁵⁴ Also, Meenes *et al.* found no significant difference in cure depth of the bulk-fill resin-based composites Tetric Evoceram Bulk Fill (containing CQ and Ivocerin) and Filtek Bulk Fill Posterior (containing

CQ) when cured with a monowave (Elipar S10) or a polywave (Bluephase G2). They conclude that there was some overlap between the absorbance of Ivocerin and the spectral output of the monowave S10 LCU, which may have allowed initiation of the Ivocerin in Tetric Evoceram Bulk Fill.⁵⁵

Chemical variables have a significant impact on the polymerisation performance of composite resin. Filler size was raised in some commercially available bulk-fill resin-based composites, lowering overall particle volume percentage. As a result, the light scattering and filler matrix are reduced, allowing light to penetrate deeper zones.⁵⁶ Furthermore, the viscosity of material appears to be a significant component in bulk-fill resin-based composite curing effectiveness, as several studies found that flowable materials had a greater depth of cure than materials with a higher viscosity.

The second generation single-peak LED LCUs emit a narrow spectrum of light that has a peak range of wavelength (450 nm to 470 nm), which matches CQ's absorbance wavelength.⁵⁷ On the other hand, alternative photoinitiators (for example, 2,4,6-trimethylbenzoyldiphenylphosphine oxide [Lucirin TPO] and 1-phenyl-1,2-propanedione [PPD]), which are more

sensitive to shorter wavelengths (<420 nm), have been introduced in some RBCs.⁵⁸ The use to mix diverse photoinitiators leads to an improvement of DC and better aesthetic qualities⁵⁹ and reduces the rate of stress.⁶⁰ The presence of these photoinitiators may reduce photoactivation effectiveness when a single-peak LED light (450–470 nm) is used.⁶¹ Third-generation multi-peak or polywave LED LCUs, provided with additional light output in the 400–415 nm range of wavelengths, are supposed to overcome that problem.⁶²

Nevertheless, when the LED LCUs were used to cure the composite with two photoinitiators at an energy density of 16 J/cm², the increasing power density was demonstrated to increase the microhardness.³⁹

Microhardness assessment is an indirect means of determining the degree of conversion.⁶³ For assessing the hardness of composite resins, three primary hardness tests have been recommended in the past (Barcol, Knoop and Vickers). The Vickers and Knoop hardness tests were used in the current systematic study.⁶⁴

The higher microhardness value achieved at the upper surface of the specimens compared to their lower surface can be

described by the light attenuation (due to absorption, reflection and dispersion) as it passes through the resin. Henceforth, at 2 mm depth, the attenuation of light may lessen the irradiance to nearly 75% of the irradiance that reaches the top surface.¹⁷

For all protocols, the microhardness values found after microhardness testing revealed that silorane-based resin showed statistically lower values than methacrylate-based resins. The chemical changes in the monomer, as well as changes in the distribution and type of inorganic particles, may explain why silorane-based resin has a lower polymerisation depth than methacrylate-based resin. The number of double bonds between carbon molecules that remain after polymerisation is used to determine the degree of conversion of methacrylate-based resins.⁶⁵

According to Emami *et al.*, the hardness and degree of cure values increase as irradiance and photoactivation duration increase. As a result, a material with improved mechanical properties is possible to obtain.⁶⁶ However, Lovell *et al.* stated that a high irradiance paired with a short photoactivation period has been found to lower the degree of cure and the length of the kinetic chain.⁶⁷

Long irradiation times are definitely of importance based on the microhardness data, as they resulted in improved microhardness on the bottom surface. However, Torno *et al.* believe that part of the favourable effect is due to the material being heated with light.⁶⁸ According to Zach and Cohen, the temperature at which permanent pulpal lesions might occur is 5.5 °C, but this value is arguable.⁶⁹ According to Baldissara *et al.*, short exposure to temperature rises ranging from 8.9 °C to 14.7 °C did not appear to be a major negative factor for healthy dental pulps.⁷⁰ In any event, it appears prudent to limit pulpal temperature variations to a minimum. Furthermore, due to many variables such as dentin thickness, preparation depth, output intensity and exposure period, predicting temperature rise in any given tooth is quite challenging.⁷¹ According to Peutzfeldt and Asmussen, temperature rise increases as power density increases.⁷²

Extensive electronic searches in various databases, as well as other supplementary analyses, gave a wide overview of the obtained data, which might be regarded as the research's major strength. To adequately examine the selected works, stringent and

methodical techniques were used during data extraction, in addition to a posterior risk of bias evaluation. Despite this, the main limitation identified was a high prevalence of low-to-medium risk of bias. To conclude, selected studies presented with significant methodological heterogeneity, specifically in terms of materials tested, assessment methods, exposure times and outcomes measured, which made it impossible to conduct a meta-analysis.

Conclusion

The irradiance of light is a relevant factor in the polymerisation of composite, influencing the hardness of the composite. To maintain the longevity and the quality of the restoration, it is essential to monitor the light irradiance of the light-curing units with a radiometer. Other factors could affect the power density and the resin-based material properties, including possible contamination and several sterilisations of the light guide, composition of composite and distance from the light guide to the restoration.

From the data obtained from the reported and selected studies, it is evident that most of the included studies showed favourable results for higher irradiance of light than lower irradiance of light on microhardness of composite – these results are based on articles. This systematic review highlighted the need for further studies with irradiance more than 1,300 mW/cm² which consistently prove they provide a complete polymerisation of composite.

After considering other essential elements such as purchasing prices, chairside time considerations and longevity, the choice of curing light system should be made based on clinical preferences.

Ethics declaration

The authors declare none.

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None.

Author contributions

Dr Neenu Francis, Dr Rakesh R. Rajan, Dr S.Vijay Kumar: conceptualisation and article screening.

Dr Neenu Francis, Dr Vineetha Karuveetil: methodology and statistical analysis. Dr Neenu Francis, Dr Rakesh R. Rajan, Dr Anju Varughese, Dr C. M. Sapna: writing – original draft, writing – review and editing.

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