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HOW CAN PHOTOPOLYMERIZERS AFFECT THE MICROHARDNESS OF COMPOSITE RESIN?

COMO OS FOTOPOLIMERIZADORES PODEM AFETAR A MICRODUREZA DA RESINA COMPOSTA?

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ABSTRACT

Inadequate photopolymerization of composite resins can cause restoration failures such as marginal microleakage, wear resistance and failures in the hardness of the restorative material. The microhardness of composite resins is extremely important as it affects the mechanical property and can cause premature loss of the restoration. Therefore, this literature review aims to identify the factors that affect the microhardness of composite resins during their polymerization, in order to avoid the failure of restorations. For this purpose, a bibliographic search was performed in the Google Scholar, PubMed and BVS - Virtual Health Library databases using the descriptors: composite resin, photopolymerizer, restoration, polymerization and microhardness. Thus, some factors are important to note, such as: aspects such as intensity and collimation of the light used and its wavelength, the material and technique chosen, the type and quantity of the photoinitiator present in the material and the characteristics of the photopolymerizer. To conclude, it is essential to know the light fixture selected and the properties of the restorative material, to optimize the results, prevent flaws in the material's hardness and thus provide longer-lasting restorations.

Keywords: Composite resin. Dental Restoration. Light curing. Microhardness. Polymerization.

RESUMO

A fotopolimerização inadequada das resinas compostas pode ocasionar falhas na restauração, como microinfiltração marginal, resistência ao desgaste e falhas na dureza do material restaurador. A microdureza das resinas compostas é de extrema importância, pois afeta a propriedade mecânica, podendo causar uma perda prematura da restauração. Diante disso, essa revisão de literatura tem como objetivo identificar os fatores que interferem na microdureza das resinas compostas durante a sua polimerização, para assim evitar a ocorrência do insucesso das restaurações. Para tanto, foi realizada uma busca bibliográfica nos bancos de dados Google Scholar, PubMed e Biblioteca Virtual em Saúde (BVS) com o emprego dos descritores: resina composta, fotopolimerizador, restauração, polimerização e microdureza. Alguns fatores importantes foram observados: aspectos como intensidade e colimação da luz usada e seu comprimento de onda, o material e a técnica escolhida, o tipo e a quantidade do fotoiniciador presente no material e as características do aparelho fotopolimerizador. Para concluir, é fundamental conhecer o aparelho de luz selecionado e as propriedades do material restaurador para otimizar seus resultados, prevenir falhas na dureza do material e assim proporcionar restaurações mais duradouras.

Palavras-chave: Fotopolimerizador. Microdureza. Polimerização. Resina Composta. Restauração dental.

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INTRODUCTION

The polymerization process changes the physical state of composite resins when monomers are converted into polymers, changing them from viscous to solid. The monomers most used in dental composites are dimethacrylates, such as BIS-GMA, which is responsible for increasing the viscosity of the material. However, they are less reactive due to their high molecular weight. Thus, there is a need for adding diluent monomers such as TEGDMA, which are more reactive and have a lower molecular weight (RUEGGEBERG *et al.*, 2017).

Initiating light-curing requires a certain amount of energy, known as activation energy. It is emitted by photons (irradiated energy units), which will activate the photoinitiator of the restorative material (MELO *et al*., 2020). The wavelength known as the light range that sensitizes the photoinitiator usually corresponds to the blue light range between 380 and 780 nm (VIEIRA *et al*., 1998). When photons react upon the photoinitiator, which becomes excited, the result is the production of free radicals, transforming monomers into polymers and ensuring complete material polymerization (MELO *et al*., 2020).

Photoinitiators are mostly classified as organic molecules presented in isolation or as two or more, and they may be classified into two systems: Norrish type I photoinitiators, which produce free radicals by dissociating from the photoinitiator in some parts, consequently producing two or more free radicals; and Norrish type II photoinitiators, which react with a co-initiator, producing one free radical that will start the polymerization reaction, such as camphorquinone and tertiary amine, considered the photoinitiators most present in resin materials (MELO *et al*., 2020). Device quality should be considered when aiming at clinical success because it may guarantee postoperative sensitivity control, marginal leakage, color maintenance, and resistance (CALDARELLI *et al*., 2011).

Light-curing devices with halogen lamps are still popular among professionals. They are composed of a tungsten filament lamp, filter, refrigeration system, and a light-conducting tip (CALDARELLI *et al*., 2011). These devices emit a broad visible light spectrum, producing a lot of heat, which may damage the pulp tissue, degrade the filter and bulb, reduce the quality of the light emitted, and restrict the service life of the device, which is around 50 hours (LUTZ *et al*., 1992; VIEIRA *et al*., 1998).

Recently, the most used technology is LED devices. The first devices launched in the dental market presented a cold light and narrow wavelength (468 nm), which corresponds to camphorquinone - the most used photoinitiator (FUJIBAYASHI *et al*., 1998; KURACHI *et al*., 2001; GODOY, 2008).

Currently, LED devices are classified into monowave and polywave. Monowave LEDs release wavelengths between 400 and 500 nm, which is ideal for the camphorquinone photoinitiator that has an absorption peak of 480 nm. However, clear or transparent restorative materials with other photoinitiators, such as BAPO, whose absorption peak is around 365 to 416 nm, require an LED device with a broader light spectrum. This device is known as polywave and can absorb wavelengths in the ultraviolet range without compromising the polymerization conversion rate (OLIVEIRA *et al*., 2015). This is possible due to the presence of chips with different wavelengths, thus allowing the polymerization of any photoinitiator in resin materials (Norrish type I or II) (MELO *et al.*, 2020).

Therefore, considering that several factors of the light device affect the quality of composite resin restorations, the present study aimed to review in the literature the main interferences of light-curing devices and photoinitiators in composite resin restorations.

METHODOLOGY

Search strategy and data selection

A systematic literature search was performed in the MEDLINE (PubMed) and Google Scholar databases and the gray literature, using the database of the Capes Journals. The search keywords included composite resin, light-curing device, restoration, polymerization, and microhardness. The studies were scanned based on titles and abstracts. After the identification, the studies found in duplicates were eliminated.

Assessment of methodological quality and data extracted

The data extracted included first author, year of publication, type of study, type of microhardness test, results, type of photoinitiator, clinical assessment of photoactivation devices, and material used.

Inclusion criteria

Only studies assessing the influence of light-curing on composite resin microhardness were selected, including only parallel clinical trials in English and published between 2000 and 2020.

Exclusion criteria

The exclusion criteria were duplicate studies, studies with assessment criteria not related to the research objectives, studies outside the assessment period, studies in Portuguese, review studies.

Data extraction from the studies

After selecting the studies, the risk of bias was assessed from the following criteria: blinding of outcome evaluators and incomplete result data. The data from the studies selected were grouped in study/author, type of study, type of microhardness test, results, type of photoinitiator, clinical assessment of photoactivation devices, and material used. Chart 1 shows the information of the studies included in the research.

DISCUSSION

Composite resins are extensively used in dentistry as a restorative material due to their esthetic characteristics, good adhesion to the dental structure, and easy handling. Despite the benefits of the material, shrinkage stress may occur during polymerization, causing a volume change, which may trigger the deformation of cavity walls, restoration fracture, microleakage, and postoperative hypersensitivity (TAUBÖCK *et al.*, 2010; MÜNCHOW *et al*., 2018). To prevent these problems, the light-curing process must be understood to ensure the emission of sufficient light and with the correct wavelength (ERNST *et al.*, 2018).

One of the tests most used to assess the quality of composite resin photoactivation is surface microhardness. This test shows that the higher the surface hardness, the better the photoactivation and wear resistance. The two tests most used to measure microhardness are Vickers and Knoop, and the latter is more used to measure small areas and fragile materials (SOUZA *et al.*, 2019). This agrees with the findings in Chart 1, which from the studies assessed in this review, three of them used the Knoop test and two used the Vickers test.

Another factor that strongly affects the quality of composite resin photoactivation is the composition of organic and inorganic matrices of the material, directly affecting its physical and mechanical properties. The load particles may aid light transmission inside the composite resin increment and increase mechanical properties such as modulus of elasticity, flexural strength, material hardness, among others (RODRIGUES *et al.*, 2017). To prevent complications regarding polymerization shrinkage, composite resins are inserted in the cavities in small increments of up to 2 mm of thickness to reduce polymerization shrinkage. Another option is using bulk-fill resins, which technique may present larger increments of 4 or 5 mm (BENETTI *et al.*, 2015; VICENZI; BENETTI, 2018).

Chart 1 - Data grouped according to the criteria for study extraction

Study	Author/ year	Type of microhardness test	Result	Photoinitiator	Light device	Composite resin
1. Polymerization shrinkage, microhardness and depth of cure of bulk fill resin composites	Rizzante *et al.* (2019)	Knoop	Low-viscosity composite resins presented lower KHN values than high-viscosity ones. The Z3XT presented the highest microhardness among the composite resins tested. The Z3XT and Z3F presented a lower DC than the bulk-fill resin composites	Not informed	- LED Blue Star - MONOWAVE Wavelength: 420 nm to 480 nm INTENSITY: 1550 Mw/cm^2	1. ADM 2. FBP 3. TBF 4. XF 5. Z3XT 6. FBF 7. SDR 8. XB 9. Z3F
2. Influence of light-curing units on surface microhardness and color change of composite resins after challenge	Souza *et al.* (2019)	Knoop	The LED with several wavelengths affected the microhardness of only one resin containing lucirin-TPO after AAA. The ΔE was more affected by the composite resin than the LED device.	- TPO with camphorquinone - Camphorquinone in isolation	- Radii-Cal, SDI - MONOWAVE Wavelength: 440-480 nm INTENSITY: 1200 mW/cm^2 Valo, Ultradent - POLYWAVE Wavelength: 395-480 nm INTENSITY: Not informed	1.TetricN-Ceram 2. Vit-l-escence 3.Filtek 350XT
3. Evaluation of microhardness, surface roughness, and wear behavior of different types of resin composites polymerized with two different light sources	Topcu *et al.* (2009)	Vickers	Microhardness was affected by the composition of composite resins and the type of light source used. The microhardness values on lower surfaces were lower than the upper surfaces for all materials.	Not informed	- QTH LCU - MONOWAVE Wavelength: 450-520 nm INTENSITY: 600 mW/cm^2 LEDLCU- MONOWAVE Wavelength: 450-490 nm INTENSITY: 950 mW/cm^2	1. Clearfil MajestyTM Posterior 2. FiltekTM 3.Supreme 4. Ceram-XTM 5. PremiseTM 6. FiltekTM Z250 7. Herculite1 XRV 8. ClearfilTM APX 9. QuixfilTM
4. Influence of light-curing intensity on color stability and microhardness of composite resins	Strazzi-Sahyon *et al.* (2019)	Knoop	The different light intensities and resin material colors affected composite resin microhardness, which was evidenced by the A3 composite resin light-cured with a Valo polywave presenting higher hardness values.	Not informed	- Valo -polywave Wavelength: 450-490 nm INTENSITY: 1.431 mW/cm^2 - EAC 450 - monowave Wavelength: 450-490 nm INTENSITY: 101 mW/cm^2	1. TPH color spectrum A3 and C3
5. Evaluation of curing light distance on resin composite microhardness and polymerization	Rode, Kawano and Turbino (2007)	Vickers	The results obtained conclude that greater tip distances decreased microhardness values and degree of conversion, while increasing resin thickness decreased microhardness values and degree of conversion.	Not informed	- Wavelength: 450-490 nm INTENSITY: 500 mW/cm^2 - LED Wavelength: 450-490 nm INTENSITY: 900 mW/cm^2 -Argon laser Wavelength: 450-490 nm INTENSITY: 892.85 mW/cm^2	1. Z350

Notes: PS - polymerization shrinkage; KNH - Knoop microhardness; DC - depth of cure; ΔE - color change; LED - light-emitting diode; AAA - artificial accelerated aging; QTH - quartz-tungsten-halogen; LCU - light-curing unit.
Source: the authors.

From the studies in Chart 1, only one compared the influence of photoactivation between conventional and bulk-fill resins. The study by Rizzante *et al.* (2019) showed that high-viscosity resins had higher microhardness values than low-viscosity ones, which can be explained by the composition of monomers and load particles of these resins (RODRIGUES *et al.,* 2017). Moreover, the bulk-fill resins tested behaved heterogeneously due to the organic matrix composition, modulus of elasticity, and different particles of each resin. For instance, the study showed a high-viscosity bulk-fill resin that presented a low microhardness value due to the composition of the Ormocer matrix based on organically modified ceramics instead of methacrylates.

The composition of the organic matrix of different composite resins available in the dental market is also highly important for adequate photoactivation. Camphorquinone is the main photoinitiator in composite resins and presents a wavelength between 400 nm and 500 nm, with an absorption peak around 470 nm. When absorbing visible light in the correct wavelength, camphorquinone reaches an excited state and combines with an organic matrix reducing agent, which produces the free radicals responsible for initiating the polymerization reaction. Hence, a co-initiator is added to resins, which may be tertiary amines. Its typical yellowish color has the disadvantage of limiting its use, especially in resin materials used for bleached teeth, and the need for a co-initiator. However, because of its yellow color, other photoinitiators with different wavelengths are used. This interferes directly with the quality of composite resin photoactivation. Most photoactivators can reach the wavelength of camphorquinone and are called monowave (BRANDT, 2007; SANTINI, 2010; MELO *et al*., 2020).

Composite resins of lighter color and effect indicated for bleached teeth use alternative photoinitiators, such as BAPO (bis-alkyl phosphine oxide), PPD (phenyl propanedione), and TPO (mono-alkyl phosphine oxide), which present lighter color, do not require a co-initiator, and involve light absorption with a lower wavelength than camphorquinone, around 364 to 416 nm. However, these lighter photoinitiators have a lower wavelength than camphorquinone and cannot be activated by monowave light devices, which may interfere negatively with the quality of photoactivation and consequently the physical and mechanical properties of the composite resin (NEUMANN *et al.,* 2006; BRANDT, 2007; SANTINI, 2010; MELO *et al.,* 2020).

In Chart 1, only one study informed the photoinitiators in the resins studied. This lack of information by the manufacturers is concerning because knowing the photoinitiator is essential for choosing the light device (SOUZA *et al.,* 2019). The studies assessed allowed identifying that polywave light devices presented superior results to monowave ones, potentially because of their wavelength amplitude (350 to 470 nm), which photoactivates a higher scope of photoinitiators.

Chart 1 also shows that the restorative material was more effective on ΔE than the LED device, again proving the relevance of the photoinitiator in the properties of the restorative material. Thus, it is verified the importance of dentists knowing the composition of composite resins to use a light-curing device that reaches the adequate wavelength and the need for the polywave light-curing device because it reaches several wavelengths.

The longevity of restorations with resin materials requires adequate polymerization because its deficiency will compromise the mechanical properties of the material, such as color stability, marginal sealing, and biocompatibility (STOLF, 2004). It may also decrease wear resistance, that is, the microhardness of the material (FAN *et al.,* 1987; BARATIERI, MONTEIRO JUNIOR; ANDRADA, 1995; BONA *et al*., 1997). Therefore, professionals must know the characteristics and properties of the materials used.

Chart 1 shows that Souza *et al*. (2019) and Strazzi-Sahyon *et al*. (2020) compared the effects of a monowave device with a polywave device to verify the differences in microhardness results. They concluded that the polywave device presented higher resistance values in resin materials, especially those with another photoinitiator besides camphorquinone (RIZZANTE *et al*., 2019).

Other important data is that different light intensities affect color stability and composite resin microhardness. Previous studies showed that the minimum intensity required to polymerize a 2-mm resin was 400 Mw, with a polymerization time of 40 seconds (RUEGGEBERG *et al*., 1994; ALKHUDHAIRY, 2017). From the studies assessing the light intensity of photoactivators and the distance from the device tip to the restoration, which also interferes with the light intensity reaching the material, it could be inferred that light devices with higher intensity promoted improved microhardness and degree of conversion (STRAZZI-SAHYON *et al*., 2020). In addition, the shortest distances between the device and the composite also promoted better results regardless of the type of light source (RODE *et al*., 2007).

CONCLUSION

The articles reviewed in the present study allow concluding that composite resins are still excellent restorative materials and, to fully reach their mechanical properties, adequate polymerization is required. The studies selected show that choosing the light device is crucial for the microhardness quality of composite resin surfaces. Thus, polywave light devices are indicated to photoactivate any composite resin in the dental market, while monowave devices are indicated for composite resins with camphorquinone as the only photoinitiator.

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